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MODERN TEACHING

VOL. 4



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THE SPARROW-HAWK

It must be confessed that this species, especially during the breeding season, does considerable harm among the Pheasant and Partridge "pops." Game, however, is a superfluous cornucopiousness, and the Sparrow Hawk's mission is to feed on the kitchen birds, i.e., Wood pigeons, Sparrows, and other seed-eating birds, and on small mammals such as Mole, Mice and Rats, of whom the agriculturist complains.

MODERN TEACHING

Practical Suggestions for Junior and Senior Schools

General Editor
ENID BLYTON

VOL 4
NATURE STUDY AND SCIENCE

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NATURE STUDY
AND
SCIENCE

FOREWORD

WITH great gladness one notices the ever-increasing trek of schools of all types towards the open air. Observation lessons, Sketching, School Journeys, Games and the like provide the objectives in a movement that promises immeasurable benefits for the Englishman of to-morrow. As civilised life becomes more complex, more responsible for the average man, and its noises and distractions more wearing to him, the greater he needs the soothing balm that only kindly Nature can provide. And this being true, if our claim is sincere that Education is the comprehensive preparation for manhood, a very plain duty is laid upon all of us who are charged with moulding the thoughts and habits of youth. The movement to the field, the river, the park, the hills, must be pressed to every reasonable length. Every child has the right to ask that those deputed to see him properly equipped before he crosses the threshold of manhood shall ensure him eyes that see, ears that hear, and a mind that understands and appreciates the glories and wonders that lie on the outskirts of even the most dismal man-made town. Yet, as with all our blessings, we must detect the dangers.

Those who undertake work of great potentiality must be worthy of the trust. The child whose lot is cast with a teacher to whom Nature Study is merely a *subject* is likely to lose a goodly heritage. The Nature Study that lives by books alone cannot endure beyond school-days; nor can it if its teacher is unlearned in its inner intricacies or sceptic of its profound delights.

To those not fully initiated, and yet willing to join the modern trek, this volume is offered. It seeks above all to generate interest. If the expert finds it simple, the Author has reached the goal he sought. He is a Schoolmaster who knows and loves his Nature, and who desires to increase his kingdom. If his labour of love finds favour in wide quarters, if school gardens become more and more the laboratories of the open road, and if a material number of his professional colleagues find help and inspiration in the book and its delightful sketches, then the writer will have earned the reward I think he has deserved.

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County Borough of Wolverhampton.

SECTION I

CHAPTER I

THE AIM OF NATURE STUDY AND SCIENCE

IN Nature Study and Science, teaching success depends entirely upon the attitude, outlook and interest of the teacher. He should be genuinely interested in the subject of his lessons and even if his knowledge is not extensive, it should be first-hand and accurate.

Frequently excellent work is done by teachers whose knowledge, when first attempting the subject, has been very limited, but who have not been afraid to learn with, and sometimes from, their pupils. The personal element is of vital importance in Nature Study. Unless the teacher shows enthusiasm and real interest in Nature, outside as well as inside the classroom, he cannot expect to stimulate his scholars or to endow his lessons with that glow of life and interest without which such lessons are of little value.

The main object of all Nature lessons should be to enlarge the interest of the child in living things in the world around him. To do this, full use should be made of the instinctive curiosity of the child, but it is essential that the teacher should be able to give guidance and advice as to what and how he is to observe.

Nature Study, therefore, can be considered as Nature, studied in its relations by the child, from the child's point of view, and by the teacher with the child.

Schemes of Work

Another point of great importance is the scheme of work. In this volume, certain schemes of work are given, not, however, with the idea of supplying teachers with ready-made articles. They are suggestions, and should be regarded as "tools" by the adaptation of which schemes in Nature Study and Science can be constructed to meet the needs of any particular school.

Excursions

No scheme is complete unless class excursions form an integral part. Nature Study must be first-hand. Four or five excursions each year are essential. In the lower classes the same ground should be covered on each occasion. As there is so much to see out of doors, it is necessary for the teacher to make up his mind beforehand as to the particular things to which attention is to be drawn. A too rigid adherence, however, to the planned excursion may tend to check original observation. The teacher must have a definite object in view, but actual observation by the scholars, apart from the planned scheme, should receive attention.

In Nature Study or Science, the aim of the work is to teach the children to see things for themselves. This power is one not highly developed in

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the majority of adults, and hence the innate curiosity of the scholars should not be curbed except within the limits of class discipline. Very little difficulty will be experienced, however, by the teacher who sets out on an excursion or Nature walk with a definite object in view—with a love of Nature in his heart and a real desire to help his scholars to develop the "seeing eye," "the hearing ear" and the "understanding heart."

The subjects studied under the general term, Nature Study, are many and varied. In Infant Schools the children should be made familiar with a large number of Nature objects, including, of course, plants and animals. This should be followed in the Senior Department by lessons on flowers and their names, fruits and seeds, buds and leaves, herbs and trees. Briefly stated, the child should be brought into intimate relationship with the living things in the world in which he lives, and should learn to love and care for some of the living things of field, hedgerow and garden.

In the higher classes of town and city schools the Nature-Study course should be extended by the introduction of electricity, physics and chemistry.

For country districts it is possible to apply the early knowledge gained to the study of the elements of Horticulture and Agriculture. In industrial areas some attempt should be made to introduce older children to the underlying features of the industries.

The aim of the Science course should be to investigate experimentally the properties of matter and later to discover the relationship of facts one with another. Gradually, if such a course is followed, the child begins to reason

and to imagine scientifically, to see for himself and to regard the things around him as a sacred trust. His outlook on life and appreciation of Nature and all her works develop into a deep love which cannot be expressed in words, and as the Duke says in "As You Like It," he "Finds tongues in trees, books in the running brooks, sermons in stones and good in everything."

Dislike of Nature Study

Unfortunately there are still teachers in the schools who do not take kindly to the teaching of Nature Study. This attitude may be the result of their early training. At one time Nature Study was treated in a haphazard manner. A lesson on flowers was, perhaps, followed by a lesson on Sago, to be succeeded by one on the Lion. Such lessons, which could not be associated, and for which actual examples were not available, simply became detached informative lessons which tended to become boring even to the best of pupils.

The study of Nature is not a series of disconnected lessons. Plants, flowers, insects, seeds and birds are inter-related, and in almost every case the objects dealt with can be seen and handled, other objects of study being those which can be constantly and easily observed. Sometimes, it is regrettable to state, the dislike of the subject is the result of bad teaching. The wrong point of view has been instilled, and Nature Study has become a subject to avoid rather than one to greet with the utmost pleasure.

Plant life in its broadest aspect means so much to mankind that it is the duty of those who train the future

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generation, to change as soon as possible the unkindly attitude towards the subject. Often the difficulty experienced in obtaining material is brought forward by teachers who say they "dislike Nature." Again this drawback can be removed. The wise teacher whose lessons have been well thought out experiences little or no difficulty; the pupils carry out the work and take a delight in doing it.

For instance, a teacher wishes to give a series of lessons on Twigs. If the class is told this on a Friday, often sufficient specimens will be forthcoming on Monday morning. Again, for lessons on Germination, the whole class will be candidates for the work of looking after the developing plants. The same applies to the aquarium and terrarium. Happy is the boy or girl who is told off to take care of the living inhabitants. The enthusiastic teacher also finds pleasure in obtaining specimens. In his spare time he

delights in being alone with Nature, watching her methods and observing the struggle for life which goes on incessantly in the plant world.

The personal element is the deciding factor in every instance. If the teacher is carrying out the study of Nature with his scholars, difficulties vanish. No teacher can be successful unless he is enthusiastic in his work and has the power to impart that enthusiasm to his pupils.

Sometimes the dislike of Nature Study is due to a lack of knowledge on the part of a teacher. Often a comprehensive view has not been taken, and on this account the opening part of this volume will contain a brief survey of the value of plant life to mankind.

When we consider how much we owe to the "Silent machinery in plant life," then an added interest is given to the study of "The grass that withereth and the flower that fadeth away."

CHAPTER II

A COMPREHENSIVE VIEW OF NATURAL SCIENCE

LEADING scientists agree that plants are the oldest living things on the earth. They cover the whole earth with beauty like a magic carpet, and certainly they are the foundation and mainstay of our existence. Man could not live without them, and, further, if it were not for the Vegetable Kingdom spread over the whole surface of the land, and along the surface and even the bottom of shallow

seas the whole Animal Kingdom would perish.

The world relies on plants for its food, and depends wholly on a secret which every plant possesses and which no man knows how to apply, for a plant is able to *take its food from air and water*. While we are looking at a plant it is taking in its supplies of nourishment, compounding its own food and, in most cases, reserving a supply

which may, at some future time, help in the building up of our own tissues.

The Dividing Line between Plant and Animal Kingdom

This is difficult to define. If all living things are represented by an ornamental Y-shaped tree with twigs on either fork, this can be considered the genealogical tree of life. To the right we could put the plants and on the left side the Animal Kingdom—this must be much longer than the right-hand side.

Animal life seems to have progressed through the ages at a much greater rate than the plants. One can admire the majestic beauty of the Beech tree, but one realises there is a great gulf between the tree and the Squirrel on its branches. This gulf is not so clear when we come to distinguish between a Mushroom and a Sponge.

Still more difficult is it to decide whether a living creature with a single cell is a plant or an animal, especially as some animals have, in some way, produced the green colouring matter called chlorophyll, which is the characteristic feature of practically all plants. Then again we must place at the bottom of our genealogical tree the Protists—single-celled creatures which both the botanists and zoologists claim. Whatever name is given does not really matter, but we can consider the Protists as the lowest form of plant life, and it is from such lowly positioned plants in the scale of life that all plants have, through the process of evolution, come into existence.

The Earliest Plants

Without considering deeply the evolutionary side of plant study, one might

assume that in the early days of the earth's history some lowly, single-celled creatures manufactured chlorophyll—surrounding themselves with a cell wall of cellulose (now sold in the shops as vegetable parchment paper)—and began to build up sugar, starch and other carbon compounds. Such might be considered as the earliest plants, and they probably lived freely on the surface of the sea, gradually becoming fixed to upstanding rocks or on the shore. The secret of their existence was their ability to feed at a low chemical level and to use the power of sunlight in the chemical operation of building up their tissue.

Such operations meant much for the future history of the world, for through this building up of tissue and the breaking down of carbon dioxide began the formation of an atmosphere of free oxygen.

The continual evolution of such plants and the increased formation of carbon compounds, not only for their own immediate use, but sufficient to reserve certain quantities, provided the basis for the evolution of the Animal Kingdom.

The Evolution of the Animal Kingdom

Animals had their simple beginnings, and the parting of the ways began when certain creatures—the first animals—gave up the habit of building up their own food on discovering the reserve food materials made by lowly plants. This breaking off from the habit of making their own food is the dividing line between plants and animals, and the discovery of a ready-made supply of essential food material was the deep secret of the animals. Further, the discovery meant the greater activity of the creatures who

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possessed the secret of living adventurously, for food, like fuel, is a supply of chemical energy.

Living on the food manufactured by plants gives a clue to the reason why members of the animal kingdom can dispense with green colouring matter, and why they are free from the clogging and embarrassing material—cellulose—of which the cell walls of plants in the early stages are made.

Further Divergence

Through the process of evolution the two sides of the Y-shaped tree have diverged further and further. It is not surprising, however, to discover that sometimes the plant has animal tendencies. The sun-dews and other similar plants depend partly on insects for their food. Many plants appear to seek sleep at night like animals, e.g. the Daisy, Clover and Crocus. Again one sees the sensitiveness to touch in the tendrils of the Pea or Convolvulus.

Plant tendencies can be seen in animals of a sluggish nature. For example—the Dormouse. This little animal fattens during the period of plenty, but during the time of scarcity—the winter—he passes his time in a dormant condition, using up his reserve of fat as a supply of energy to keep his organs in a living condition until warm weather returns. The Frog, who spends the winter hidden in the banks of pools, is another example of the plant lurking in the animal.

Diversity in Detail

So far as complexity of structure and life-history of plants are concerned—quite a study in themselves—the whole kingdom of many-celled plants comes

within comparatively small limits. The diversity in detail is enormous. There is great diversity between an Oak tree and the Moss on the mountain and the Heather on the hill side, compared with the fields of golden grain. What diversity exists between the flowers of the hedgerow and the Sea-weeds! Take a single class, the Ferns—a multitude of kinds, each having characteristics peculiar to itself. Or, consider the family to which the Rose belongs; all members have something in common, yet what a difference between the Rose of our garden, the Strawberry and the Apple! At first sight, who would think that the Buttercup, Monks-hood and Columbine belonged to the same family?

There is variety of form and habitation. Is there a plantless place, except in the depth of the sea? There are plants—Red Snow—found on floating icebergs, plants in hot springs and above the snow-line; doctors speak of the flora of the stomach.

What would life be worth without the beauty of the floral world? Is there anyone who cannot appreciate the beauty of the Hare-bells swinging by the wayside, the Snowdrop, or the delicate structure of the Orchid?

The Success of Plant Life

Now to turn to the other side of the picture; the Grass withers, the flower fades, yet Grass and members of this family are the most important and successful of all living things. They cover the whole earth with a green mantle. This power of successful growth is all very well when it is on man's side, but when it is possessed by injurious plants like Bracken in this country, or Prickly Pear in India,

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we realise the strength plant life possesses.

Again, consider the forest trees. They sustain enormous weights against gravity—every year adding to the burden and lifting it higher. One is apt to overlook the quiet strength of the roots of trees, which raise and twist the pavements or split up rocks on the hillside. We recognise the transformation of energy which goes on in engineering works, but do we realise the operations performed unceasingly throughout the summer day in the chemical and physical laboratory of every green leaf?—and all without the noise and smoke associated with the factories made by man.

The Cycle of Life

Consider the cycle of life as we know it to-day—birth, youth, reproduction and death: in plant life this is clear with annual or biennial plants, but not quite so obvious with perennials. Every plant is the intersection of numerous threads in the web of life. A few illustrations of the parts played by plants in the interaction of the Natural Kingdom will elucidate this point.

First there is the circulation of matter. We have seen that plants feed on air, water and salts, using the carbon dioxide as the basis for manufacturing the essentials of life known as starch, sugar and fats.

Some animals eat the plant or part of the plant and a second incarnation begins, e.g. the nectar the Bee collects is changed into honey; the nut the Squirrel cracks becomes part of the animal's body—it is incorporated with the living tissue of the animal.

During life animals exhale carbon

dioxide; this re-enters the atmosphere and may be absorbed by a green plant. Other forms of waste matter from the animal pass into the soil, and may form salts which the roots of plants absorb. Other waste products pass off as ammonia into the air to be washed down by the rain into the soil, to be captured later by the roots.

Again, when animals die and sink to the ground, bacteria (a very small, single-celled organism belonging to the Vegetable Kingdom) begin to work, and the body is said to rot. Its complex substances are broken down into simple substances such as water, carbon dioxide, ammonia and salts. Thus, from the dead body, bacteria make materials for plants to use as food. Certain bacteria, therefore, act as middle-men, making material from the dead fit food for the living and fit to enter again into the cycle of life. To sum up in a few words, the world is run on a plan such as this:

(1) Air, water and salts are absorbed by green plants.

(2) From the carbon dioxide of the air, carbon compounds such as starch, sugar, fats and proteids are built up.

(3) The reserves of carbon compounds and the plants themselves are eaten by the Animal Kingdom.

(4) When animals die, their bodies are broken down by bacteria into simple substances such as gases, water and salts.

(5) These salts and gases are again absorbed by green plants and the cycle of life begins afresh.

The Work of the Leaf

A plant is a laboratory of complex chemical substances; each cell has a

NATURE STUDY

particular work to do. The building up of tissue and the manufacture of food material could not go on without some outside help, and it is the green plant's secret to obtain this help from the orange-red rays of sunlight. The energy from the sun is used by plants to help in the manufacture of carbon compounds, which have chemical energy just as petrol has. What actually takes place in a green leaf is not yet fully known. What is known definitely is that nearly all plants are green and contain a material known as chlorophyll.

Plants, like all members of the Natural Kingdom, require oxygen for their existence and hence they, like ourselves, breathe in oxygen and breathe out carbonic acid gas or carbon dioxide. This respiratory process is unceasing. We find in all seeds and in all plants some accumulation of carbon compounds. Generally speaking, the carbons found in the soil are insoluble, and although there is a small quantity of carbon dioxide found in soil, this is exceedingly small when compared with the amount of carbon in combination found in plants. It is, therefore, a certainty that plants could not obtain their carbon from the soil. The only other possible source of carbon is the carbon dioxide of the air, and the power to use the carbon dioxide of the air is the main point for our consideration.

Carbon dioxide is, of course, carbon and oxygen combined, but it needs great power used at the right time and in the right way to separate them, but what is difficult to man is very simple to plants with their green leaves in sunlight.

The chlorophyll in plants has no power of itself, and hence, if the carbon dioxide of the air is to be used, some

power must be introduced. This the leaf is able to carry out, and it becomes "a trap to catch a sunbeam." Man can help himself to far more power than the green leaf, yet cannot apply it as the leaf does. The leaf beats the cleverest of men because of the green matter it contains. It is the green material that enables it to apply all the sunshine that it can to the business in hand, that is the splitting up of the carbon dioxide of the air—releasing the oxygen and retaining the carbon for its own use.

This process is carried on without the introduction of heat and without any waste. Such is the miracle performed every day, and on which our lives depend. We reap the benefit of this miracle, for not only do the plants take in the carbon necessary for their own existence, but accumulate reserves in the form of carbon compounds—these being used by the Animal Kingdom, including ourselves. Hence, not only do plants work for their own living, but for ours also, for it is due to their miserly habit of accumulating supplies that we are enabled to exist.

It is known that plants absorb carbonic acid gas or carbon dioxide from the atmosphere and return to the air the oxygen contained in it. The green parts act, therefore, as a reducing mechanism, and it follows that some organic compound must be formed at the expense of the carbon obtained. By an organic compound is meant a carbon-containing body which is capable of combining with oxygen.

Three Important Compounds

The first step in following the career of the absorbed carbon dioxide is to ascertain what organic compounds are

found in plants. There is no pure carbon found, for the carbon of the carbon dioxide unites with other substances. However, there are three universally present and important classes of organic compounds found in all plants. They are Proteids or Albuminoids, Carbohydrates, and Fats or Fatty Oils. These show their organic nature in being able to burn—that is, they are able to combine with the oxygen of the air and give off carbon dioxide.

The Proteids or Albuminoids are very complex carbon compounds containing Carbon, Oxygen, Hydrogen, Nitrogen, Sulphur and occasionally Phosphorus. The white of an egg is a typical example, and so is the lean of meat. There is one substance which is mainly composed of proteids, and which is of the utmost importance—it is the most important part of all living beings, Protoplasm. Continued growth means the increase in the amount of Protoplasm. Hence for growth one must have a constant supply of Carbon, Hydrogen, Oxygen, Nitrogen, Sulphur and Phosphorus—all necessary for the construction of Protoplasm, either in plants or animals.

Carbohydrates are simple compounds; they contain no nitrogen. Sugars are carbohydrates soluble in water. The sugar used for domestic purposes—cane sugar, $C_{12}H_{22}O_{11}$, occurs in many plants—Beet, Sugar Cane and Maple, etc. Grape Sugar, $C_6H_{12}O_6$, is found in most plants. Starch, $C_6H_{10}O_5$, is a solid carbohydrate insoluble in water. By the use of dilute acid or a ferment, starch can be converted into sugar.

Cellulose: the solid framework or skeleton of a plant is mainly constituted of cellulose or bodies allied to cellulose. This is a solid insoluble carbohydrate — colourless. When

treated with sulphuric acid it smells and forms a substance similar to starch paste; it will give the characteristic reaction to iodine. Further treatment with dilute acid will reduce the starch-like paste to a soluble sugar. Wood may be considered as a modified form of cellulose.

Thus the carbohydrates generally known are sugars or substances easily converted to sugars.

The last group, Fats and Fatty Oils, can be treated as one, for the oils are only liquid fats. These, again, are compounds of Carbon, Hydrogen and Oxygen, but contain no Nitrogen; they are poorer in Oxygen than the carbohydrates. They will not dissolve or mix with water, but, when acted upon by ferments, they change from an insoluble to a soluble condition.

The Food of Animals

The food supply of the Animal Kingdom consists of the reserve food material manufactured by plants, or of the plants themselves. Flesh used as food has its origin in the green plant and hence the phrase "All flesh is grass" has a true meaning.

Much more could be written about the work of plants, but such is not the aim of this book. If this brief survey of the Vegetable Kingdom stimulates teachers to look at Nature from a more extended point of view, then it will have served its purpose.

The information given in the preceding section is intended as an underlying aspect of Nature Study. In subsequent chapters much more detail will be given as to how far plant and animal life can be dealt with in schools.

CHAPTER III

THE PLANT—ORGANS AND FUNCTIONS

IN beginning the study of plants it is advisable to fix attention on some well-known plant and to consider the most striking features of its construction. Starting from the general knowledge possessed by all as the result of everyday observation, we may hope to gain a more accurate and systematic knowledge which is worthy of the name of Nature Study.

Take, for example, a well-known plant, the Wallflower or Gillyflower (Fig. 1), the parts of which are easily made out by even the most casual observer. There are the branched colourless parts called the roots, which are firmly fixed in the soil and from which arises the upright stem bearing the leaves. From the stem, branches arise, each from the angle between a leaf and the main stem. Branches also bear leaves, and resemble in all respects the stem which bears them. Flowers appear on the upper parts of the stem and branches; later these give rise to the fruits or seed cases. From the seeds themselves a new generation of plants can be obtained in the following year.

A plant of this description is a highly organised structure. The flower, leaf, stem or root is not simply a part of the plant, but a part having a definite work to do for the benefit of the whole. This division of labour is a principle carried out in a civilised community. Each part which has a definite duty to perform is called an "organ," and its work is termed its "function." Thus the root has a dual function. In the

first place it fixes the plant firmly in the soil, and secondly it takes up food therefrom.

The leaves have for their chief functions the absorption of food from the air, the carrying out of the process of respiration or breathing, and the getting rid of the excess water brought up by the roots from the soil.

The function of the stem is of a threefold value; it has to conduct the food which the roots and leaves absorb, to other parts of the plant, to support the leaves in a position where their function can best be performed and thirdly to bear the flowers.

The function of the flowers is of quite a different nature; their business is to produce seeds so as to provide future generations of flowers.

Briefly, therefore, plants bear two distinct types of organs. In the first case, the roots, stem and leaves work for the benefit of the parent plant to which they belong; these are termed Vegetative Organs. Flowers are concerned in the production of seeds and hence are called the Reproductive Organs.

MODIFIED ORGANS TO PERFORM SPECIAL FUNCTIONS

Root System and Modification of Roots

If the roots of the Wallflower are carefully washed to remove soil particles, certain main parts can be easily identified. In the first case (especially if a young plant is examined) the main

root or axis grows straight downwards and in the same line with the stem. A main root of this kind is called a primary root. From the primary root others arise which, instead of growing downwards, grow away from and almost at right angles to it. These lateral branches lengthen in the same way as the primary root, by growth near the tip, and are called secondary roots. They ultimately produce tertiary roots, which grow out obliquely from the secondary ones, and further branching may go on until a very extensive collection of roots is formed, the whole of which is called the Root System.

Tap Root

When the primary root, as in the case of the Wallflower, continues to grow, keeping distinctly larger than the lateral ones, it is called a tap root. This may remain slender and elongated or it may become much thickened and assume various characteristics. Very good examples are met with in the Carrot, Parsnip, Mangold, Turnip, Red Clover, Mustard, Shepherd's-purse, Poppy, etc., and most of the broad-leaved trees. Various terms are used to designate the thickened forms of roots. For example, the Carrot root is conical; the Radish is spindle-shaped or fusiform; the Turnip is described as napiform. Tap roots generally are food reserve storage organs.

Fibrous Roots

In some instances the primary root is not more clearly marked than the roots of later origin; it may even cease to grow altogether. Such plants, on being removed from the soil, exhibit a bunch of slender roots, the chief of

which are all much of the same diameter and length. Roots of this character are described as fibrous and are well exemplified in the common Groundsel and the Grasses.

Adventitious Roots

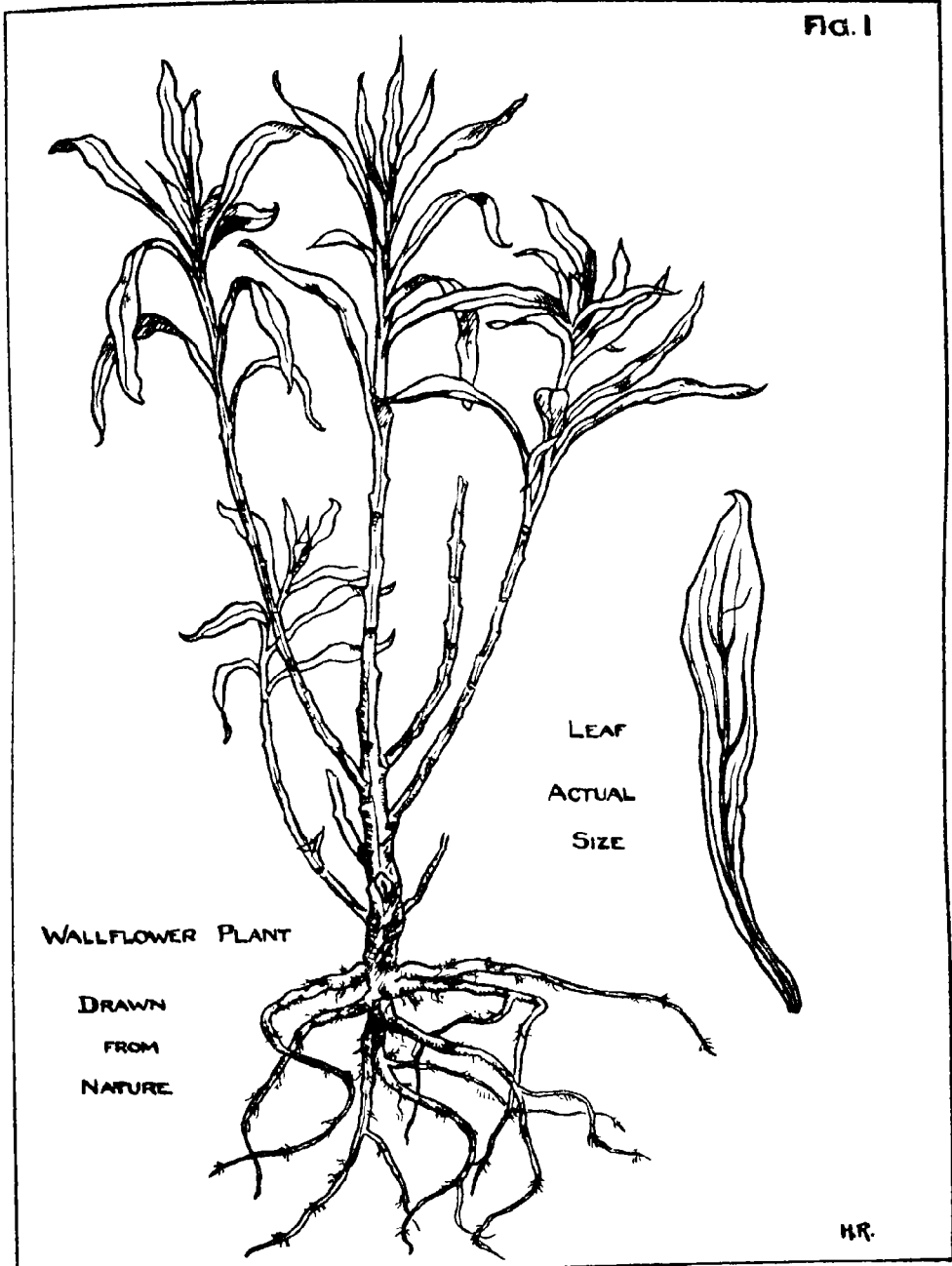
In some plants the roots differ very much from those previously mentioned. The single, primary root of the Onion, for example, lasts but a very short time and is succeeded by others which do not arise as branches of the primary one but spring from the very short stem of the plant. Roots which arise on the stem or leaves, or those which are not outgrowths of the primary root are described as adventitious.

Such roots are to be found on a great variety of plants, and may be considered as the main roots of all monocotyledonous plants. For example, in the Wheat, the embryo within the grain has three primary roots; the embryo of Barley has five or six. Such structures, however, are only temporary and only of use in the early stages of growth. Before the Wheat or Barley plant has unfolded a few leaves above ground the primary roots have withered away, being succeeded by adventitious roots which grow out from the lower joints of the stem near the surface of the soil. Excellent examples of adventitious roots are found on runners of the Strawberry, the stems of the Creeping Crowfoot and on the underground stems of the Mint, Potato and Hop.

Propagation by Cuttings

In this connection it is interesting to note that almost all parts of plants can be induced to produce adventitious roots. Generally speaking, they are

FIG. 1



THE VEGETATIVE ORGANS OF A PLANT.

The above drawing illustrates the root and shoot systems. Note the arrangement of the primary and secondary roots, and the position of the lateral branches. From the main stem, a number of leaves were removed in order to show the spiral arrangement.

produced at the joints or nodes, where leaves grow upon the stem; in other cases their development depends upon contact of the stem with water or damp soil. Pieces of stem cut off just below a leaf and placed in moist earth usually develop adventitious roots near the cut end. In this way the propagation of such plants as Gooseberries, Currants, Roses, Willows, and Geraniums is carried out.

Usually adventitious roots are thin and fibrous, but some of those of the Dahlia and Lesser Celandine act as organs for the storing of reserve food material. Such roots are spoken of as tuberous and are quite different in general characters from the tuber of the Potato, which is a modification of the stem.

Root System

The complete root systems of plants vary enormously in extent, but in all cases the total length of roots for any particular plant is much greater than is usually anticipated. A well-developed Oat plant, although its root system does not spread through more than two cubic yards of soil, has been found to reach over one hundred and fifty yards in length. The Wheat root system is much more elaborate than that of the Oat, and the roots penetrate much deeper into the soil.

If the rooting system of a tree that has been uprooted by the wind is examined, it will be noted that there are a number of stout roots similar to the thicker branches of the crown, and from these are given off a large number of a finer texture. The greater bulk, however, which the tree in its active state possessed, are left in the ground in the form of fine rootlets extending

outwards in all directions as far as, or farther than, the branches. Generally the roots do not penetrate to a depth of more than six or seven feet. Many of the largest trees send their main roots only a small distance down, but keep their root system nearer the surface, spreading out more horizontally in the ground. The Elm and Larch are typical of this kind of tree. Horticulturists take advantage of the shallow-rooting system of the Quince, and this is generally used as a stock on which to graft Pears. Similar surface-rooting habit is most marked in the Paradise Apple, on which stock Apples are grafted, and in the Wild Cherry (*Prunus malaleb*) upon which Cherries are often grafted.

Root systems generally are affected by the kinds of soil in which the plants are growing. In deep, open soils and loose, sandy soils the root system will be much larger than that of a similar plant grown in more compact or heavier soil. The richness of the upper layers of the soil is also a deciding factor, and this, to a certain extent, modifies the depth to which the larger roots penetrate.

Root-hairs

Just above the tip of the roots or root-cap of the Wallflower or of any plant is to be found a band of fine, white, silky hairs. On removing a plant from the soil, these delicate structures are destroyed, and hence it is necessary, in order to observe the silky hairs, to grow seeds on damp blotting paper or on flannel.

These delicate outgrowths, although almost invisible, are among the most important organs which plants possess. All the food constituents obtained from

the soil and from the various manures applied to the latter are taken in by the root-hairs. By means of these small structures, plants are kept constantly supplied with water. The process of transplanting, or any disturbance of the development and action, such as may be caused by excessive dryness of the soil, leads to a deficiency in water supply and causes wilting and the ultimate withering of the plant.

These root-hairs are never formed at the tip of the root, but arise at some distance from the growing point. As the root (either primary, secondary, etc.) elongates, the root-hairs on the older parts die off, but others are produced on the younger parts. No matter what length or size the root may be, these silky, delicate, transparent hairs are formed a short distance behind its tip.

Stems and their Modifications

Tubers

The functions of stem leaves and roots are modified in some plants. In the Potato, for example, there is an additional function performed by a modification of an organ. Potatoes are formed underground on parts which are often wrongly called roots. On examination of the branches on which Potatoes are formed, we find that they bear small, scaly leaves. Similar tiny leaves will be found on the Potato itself, surrounding the "eyes," and the "eyes" themselves grow into new stems when potatoes are planted. Occasionally one finds on the stems of the Potato, above-ground bodies which are intermediate between Potato tubers and the ordinary green stem. From the fact that scale or modified leaves

appear on the underground part of the Potato plant, and also because the young Potato tuber, when left in sunlight, turns green, scientists have agreed that certain shoots of the Potato plant have become so modified as to lose the more obvious characteristics of shoots and to bear a resemblance to roots. The tubers (Fig. 2) are a modification of the underground stem which have become adapted to serve as storehouses of food for the young plants which will grow from the eyes the following year.

From the above description of a Potato, therefore, it should be noted that a "tuber" is the term applied to a shoot with a short, thick, fleshy stem and minute scaly leaves, in whose axils are buds or eyes. Another example is to be found in the Jerusalem Artichoke.

Rhizomes

This modification of the shoot to perform a definite function is further indicated in such plants as the Couch Grass ("Scutch," "Twitch," "Squitch"). There are three grasses which come under the above name, Couch Grass (*Agrropyrum repens*), Black Twitch or the common Bent Grass (*Agrostis vulgaris*) and the Onion Twitch (*Arrhenatherum bulbosum*). The true Couch Grass (Fig. 3) has white, fleshy, underground stems the thickness of a stout knitting needle, at the joints or nodes of which buds are produced on the upper surface and from the underside of which small adventitious roots arise.

Generally such underground stems may be definite or indefinite in growth. In the latter case the true, or main, axis continues to grow at the tip, the

parts which come above the ground being secondary branches which arise in the axils of its scaly leaves. When underground stems are of definite growth, the main axis, after growing for a longer or shorter distance underground, comes above the ground and takes the form of a sub-aerial shoot while a lateral or secondary bud arises to carry on the growth of the underground stem.

Underground stems, that is, shoots, stout or slender, which grow more or less in a horizontal position under the surface, are known as rhizomes. Many examples of this modification can be found. Rhizomes of definite growth can be found in the Wood Anemones, Sedges and Reeds and in Solomon's Seal (Fig. 4). A good example of the indefinite growth of a rhizome is to be found in Couch Grass and Cuckoo Pint. Occasionally the underground stems grow in a more or less upright position; in such cases the rhizomic stems are termed root-stocks, as in the case of the Primrose. Other examples of rhizomes are to be found in Coltsfoot, Butterbur, Bracken and Convolvulus (Bindweed).

Corms

Another stem modification is to be found in the organ known as a corm. This is a short, thick, fleshy stem with a few thin, scaly leaves covering it and bearing at its apex one or more buds. A bud develops in spring into erect flowering shoots at the expense of the stored food material (Fig. 5A), while adventitious roots arise from the base of the bud and also from the condensed stem. At the end of the spring, the substance stored in the stem has been partially used up and become

shrivelled and dead-like (Fig. 5B). The green leaves, after developing, manufacture a considerable amount of food, and this descends from the leaves and is stored in the short stem (Fig. 5C), which thickens in consequence and becomes a new corm at the end of the season. The buds which are formed in the axils of the leaves of the new corm remain near its apex and carry on the production of new leaves, flowers and a corm the following year. Sometimes a corm, instead of possessing only one bud at its apex, has several buds, each of which may give rise to a new corm as described above. Examples of the corm are to be found in the Crocus, Gladiolus, Meadow Saffron, etc.

Bulbs

The bulb is another form of underground shoot or bud. This differs from the corm in the relatively smaller size of the stem. In the corm the stem portion is by far the most important and prominent part, the leaves being merely protective scales, but in the bulb the stem portion is relatively insignificant, small and bun-shaped, the greater bulk of the structure being formed by the basal portions of thick, fleshy leaves which contain large stores of reserve food. The leaves in this case, therefore, act as the storehouse for food in place of the stem.

In the bulbs of the Lilies, etc., the fleshy scale leaves, of which the bulk of the structure is composed, merely develop, each covering a small portion of the surface. The scales of the Onion, Hyacinth and Tulip each completely envelop the bulb. The outer ones are thin and membranous and protect the inner, fleshy, food-storing leaves. The

TUBER OF POTATO

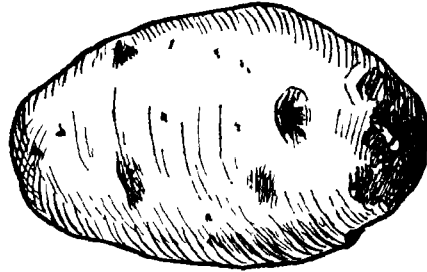


FIG. 2

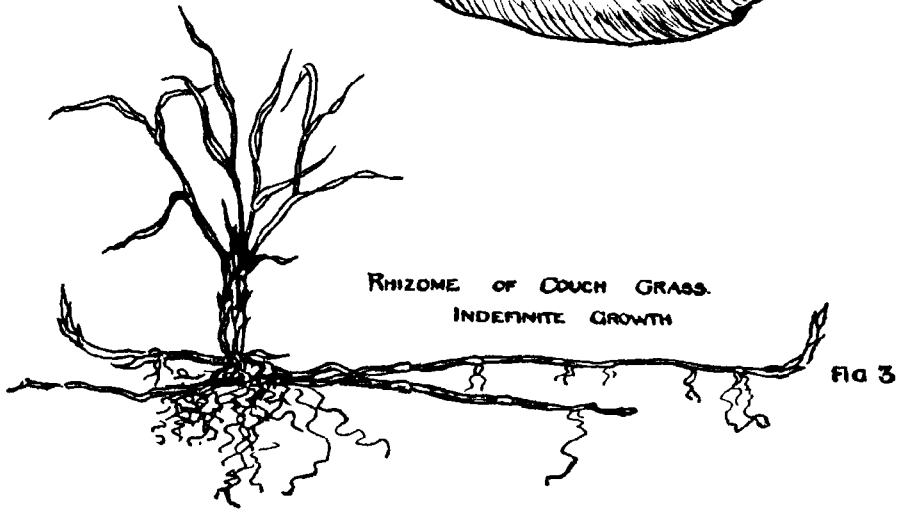


FIG. 3

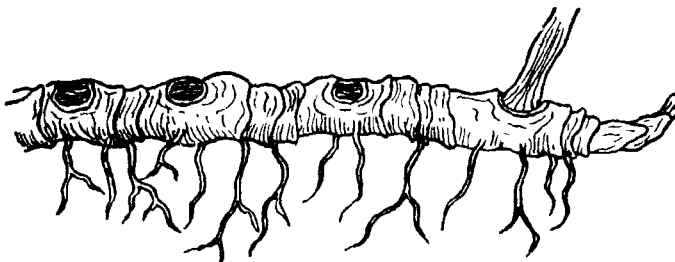


FIG. 4

RHIZOME OF SOLOMON'S SEAL.
DEFINITE GROWTH

H.R.

UNDERGROUND STEMS.

The potato is the swollen terminal portion of an underground stem. In the Couch Grass the terminal bud continues to grow in a horizontal position underground—lateral buds form the aerial portion. The terminal bud of the rhizome of Solomon's Seal forms the vegetative shoot each year

coloured membranous covering of such bulbs is formed by the shrivelled remains of the leaves of a previous season.

The bulb of the Hyacinth (*Hyacinthus orientalis*) (Fig. 6) consists of the enlarged, fleshy, persistent bases of foliage leaves and a number of scale leaves. A bud arises in the axil of the innermost leaf and the following spring will develop into a flowering axis surrounded by a number of foliage leaves, on the outside of which are scales or scaly leaves. The outermost scale leaves of the previous year's growth shrivel, the inner ones persist with the basal parts of the foliage leaves and, with an axillary bud, form the central portion of a new bulb. When two or more buds are formed in the axils of the innermost leaves a rupture ultimately occurs in the parent bulb as the developing buds form new bulbs.

The resting bulb of the Snowdrop (*Galanthus nivalis*) (Fig. 6) is composed of the fleshy bases of the two long, narrow leaves and of an outer sheathing leaf; the base of the flower stalk may persist. The whole is surrounded by the brown shrivelled bases of the previous year. In the axil of the upper foliage leaf a bud is formed; this produces its flowering axis the following season. Occasionally a bud develops in the axil of the sheathing leaf. On the growth of this bud a new bulb is formed, and when this takes place the growth of the bud ruptures the sheathing leaf and eventually becomes detached from the parent.

From seed, the development of the Snowdrop bulb is as follows. The seed gives rise to a very short stem and

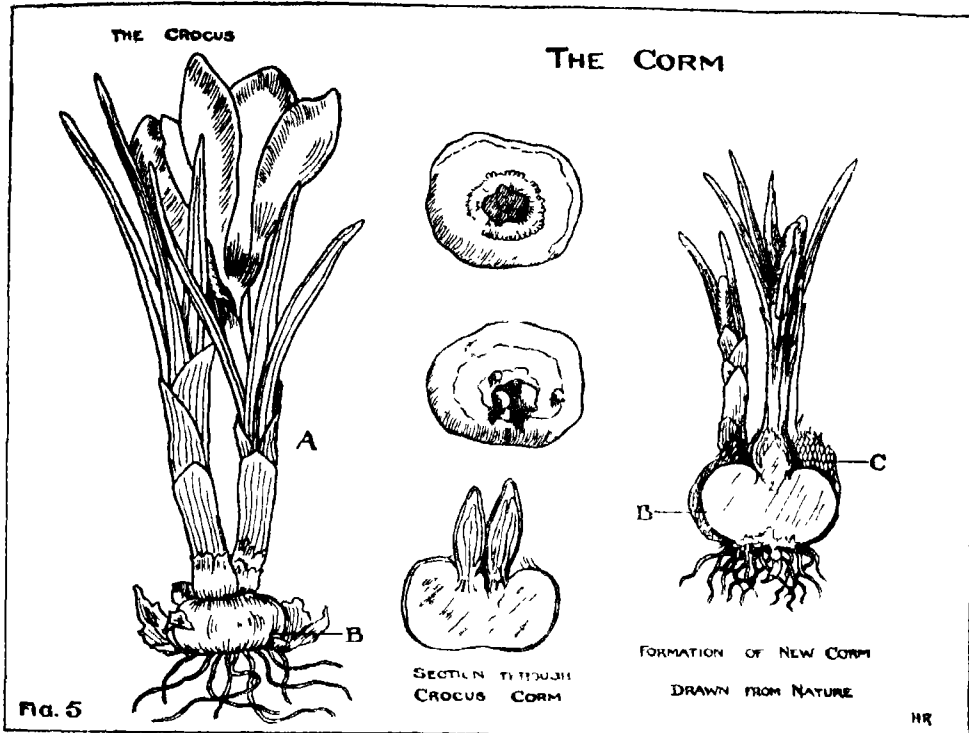
two long and narrow leaves which are surrounded by a sheathing scale leaf. During the growing season the food manufactured by the leaves is stored in their basal parts. Ultimately a bud arises in the axil of the uppermost leaf. The parts aboveground die off, leaving the food reserve in the underground basal part of the leaves. At the commencement of the following growing season the bud uses up some of the reserve material in forming the new season's leaves and the flowering axis. The same process is repeated each succeeding year. Food is stored in the underground parts of the leaves, situated on a very small stem; an axillary bud is formed in readiness for the next year; the parts of the leaves above-ground, together with the flowering axis, die off.

Bulbs, corms, rhizomes and tubers afford plants a means of vegetative reproduction. In many cases, the possession of such subterranean stems enables plants to compete successfully with others, better equipped in some respects, in the struggle for existence.

Aerial Stems and their Modifications

Herbaceous and Woody Stems

Stems which are soft, as in the case of the Sunflower and Nettle, and which last only for a short time, are termed herbaceous. Most stems which continue to grow for several seasons need a stronger material in their tissues and hence become, through the formation of wood, much harder and firmer in structure. Such stems are called woody stems. It is well, however, to remember that all stems produce woody tissue. In herbaceous stems this is only of a very thin nature,



MODIFIED STEM-STRUCTURE.

The corm is a modified stem. In this case the food necessary for the development of the dormant buds is stored in the underground portion of the stem.

forming strands of wood relatively small when compared with the remainder of the soft parts. When young, all stems are herbaceous. It is only in the later development that the distinction between woody and herbaceous stems is apparent. To return to the Wallflower, the upper parts are soft and herbaceous, but the older part of the stem is quite hard and woody. The same point of distinction may be noted in the Rose and many other plants.

Trees and shrubs have well-developed woody stems. The former shows a main stem or trunk which has no branches for some distance above the ground. In trees the branches never attain the same size as the trunk. A

shrub has no definite main stem, and its branches are very much the same size and spring from a point either on or close to the ground.

Runners

Many plants produce lateral branches which become highly specialised to perform certain definite functions. In the Strawberry plant a lateral branch grows horizontally along the surface of the soil which often attains a length of two to three feet. Along the length, at intervals of a few inches, small scale leaves are formed. In the axil of each scale leaf a bud arises, and from the bases of these buds adventitious roots arise. The buds produce foliage leaves and ultimately (after the connecting

portions of the runner or stolon have withered away) a flowering axis. The Creeping Crowfoot (*Ranunculus repens*) provides an excellent example of the formation of Runners. Another example is found in the House Leek. In the latter the Stolons are very short.

Creeping Stems

In some plants the main axis lies along the ground and takes root at the nodes. On the upper surface an axillary bud is formed which produces a new shoot. If the internodes are broken up so as to separate the parts, fresh plants are produced, each capable of further propagation by means of Creeping Stems. Creeping stems differ from Stolons in one respect only. In the latter the main axis forms a plant, while in the former the main axis is the prostrate stem, the plants being produced by axillary buds.

Suckers

A Sucker is distinguished from a Stolon or Runner because in this case the branch arises below the level of the ground. In the case of Roses, Poplars, Limes and Elms, the Suckers arise from the roots, but the growing apex soon becomes like that of a stem. The Suckers of the Mint are lateral branches arising from an underground stem.

Bulbils

Here, again, is a peculiar modification of an organ to perform a special function. Sometimes buds are formed in the position of flower buds which, however, do not contain any floral members. As they resemble very much the bud known as a bulb, they are known as bulbils. Occasionally bulbils

are formed on Lilies (Tiger Lilies, etc.), and on Onions. In Shepherd's Fescue (*Festuca ovina*), a well-known meadow grass, the scale leaves enclosing the flowers increase in size and form bulbils. These are stored with food material, and on separating from the parent are capable of developing into new plants. This often occurs in mountain pastures and may be considered as a special provision for carrying on the race or the adaptation of functions to the conditions of environment.

Climbing Stems

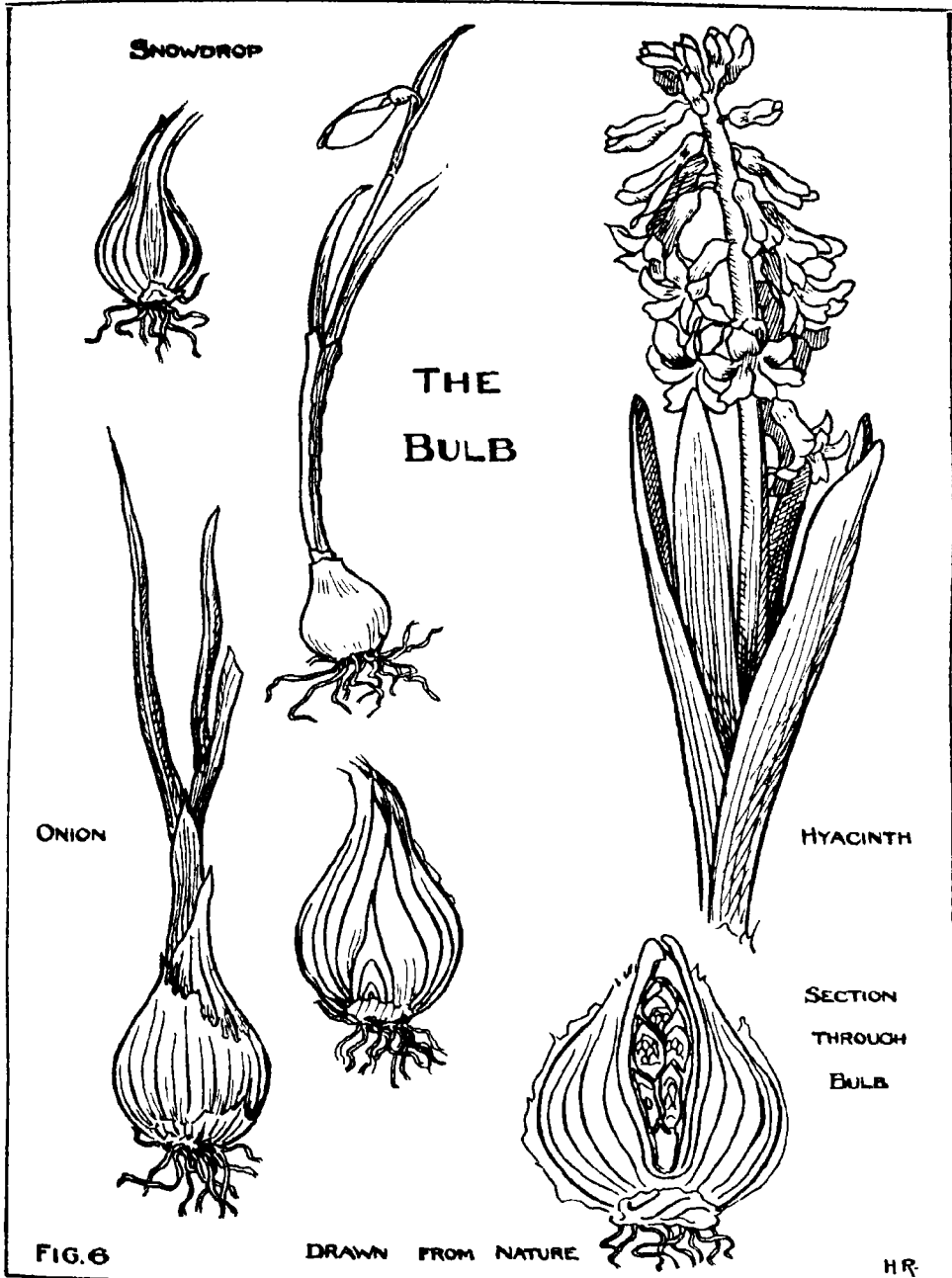
Many plants have stems which are too weak to maintain an erect position but are capable of using suitable objects near them as supports. Adaptations to secure the most favourable condition for growth, flowering and fruiting generally come under three types: (1) the whole stem turns round a support; (2) by special irritable organs known as tendrils; or (3) by the formation of specialised structures—aerial roots.

Aerial Roots

The Ivy is a typical example of a plant which climbs by adventitious aerial roots. The latter are formed along the shaded portion of the stem and also at the nodes.

Tendrils

Many plants climb by the modification of some part or other to form irritable organs or tendrils. These may be either stem structure or leaf structure. In the Vegetable Marrow and White Bryony, these special organs occupy the position of buds, that is, they arise in the axils of foliage leaves. The leaf-



MODIFICATION OF LEAVES.

Bulbs are the basal parts of leaves modified to perform a definite function. In the Snowdrop the basal parts of the leaves form the new bulb. The Onion and Hyacinth use the basal portions of their foliage leaves together with scale leaves for their reserve food-storage organs.

stalks of the Clematis (Travellers' Joy) and the Woody Nightshade act as tendrils. They coil round any slender support and increase in size and strength as the need for increased support arises. The specialised tendrils of the Virginian Creeper (*Ampelopsis*) produce disk-like suckers which attach the plant to any roughened surface.

Twining

In the first type mentioned the whole stem coils round some neighbouring object. Generally speaking the twine is in the opposite direction to the sun, as for example, the Convolvulus; The Hop and the Honeysuckle follow it; the Scarlet Runner Bean twines from right to left, the Black Bryony in the opposite direction, from left to right.

Spines and Thorns

In certain plants, such as the Hawthorn, Sloe, Buckthorn, Wild Pear and Wild Plum, some of the branches of the stems are modified and terminate in a hard sharp point instead of in a bud or soft growing point. That such thorns are modified branches is indicated by the fact that they take the place of buds, being formed in the axils of the foliage leaves.

Spines

These outgrowths are generally formed from a modification of the leaves. The Holly and the Spear-thistle give very good examples of this adaptation. As in the case of thorns the spines serve as a protection.

Prickles

On the Rose and Bramble stems are found various outgrowths called

prickles. These do not occupy any definite position, and by botanists are given the general term "Emergencies." The same term is also applied to hairs. Generally the formation of thorns, spines, prickles and hairs depends on external conditions. Plants grown on poor soil assume a more or less prickly nature, but when the ground is rich, or in a damp situation, plants assume a less aggressive nature. A typical example of this adaptation to conditions is found in the Restharrow (*Ononis arvensis*). On a poor dry soil the tips of the leaves and the branches end in hard, sharp points. When found in a good, cultivated soil, the spines do not develop.

The outgrowths, spines, thorns, etc., may be regarded as a means of protection from animals. When first formed, the young leaves of the Holly have no spines—especially noticeable is this at the top of the tree. Gorse grown in a cultivated garden for ornamental purposes loses its spiny nature to a certain degree.

Cladodes

Another modification of stems and branches takes place in countries where climatic changes are frequent. One example of this specialisation will suffice. The Butcher's-broom does not develop true branches. The assimilating surface is the vertically flattened branch, which becomes green and leaf-like. The flowers arise in the axil of a small scale leaf upon the cladode (or modified branch).

The Vegetative Shoot

Returning to the Wallflower as a starting point, it has been pointed out that arising from the ground was a

part known as the stem. In this case it is erect and much branched. The lower part, which is hard and woody, is covered with scales of pale-brown bark. The upper portions of the stem and the branches are much softer in texture, are covered with green and are to some extent hairy (see Fig. 1). On a close examination of the stem or a branch, it will be found that the surface is ridged lengthways. The fine ridges run vertically along the whole length of the stem and pass through the places where the leaves are attached.

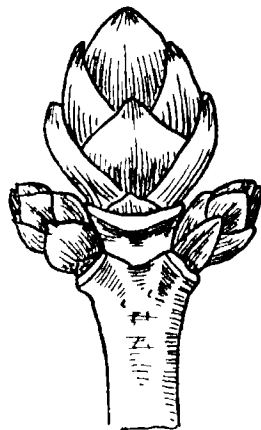
It is obvious that the lower parts of the stem are the older. For a certain distance from the ground there are no leaves, but the scars can be plainly seen. Higher up the leaves appear to be withering, and higher still they are green, fresh and of full size. As the tip is approached the leaves get smaller and smaller. Those at the tip cannot easily be seen. The extreme tip is known as the growing point; this point, with the young leaves surrounding it, is called the *leaf bud*.

The growing point, which is of a very delicate and tender nature, is protected by the young enfolding leaves, the latter arising as outgrowths from its external surface. The youngest leaves are always nearest the stem which bears them, the older ones being further removed from it in regular order—that is, in botanical terms, they arise in acropetal succession. Adventitious leaves are never met with.

Buds

The stems and leaves of all flowering plants arise from leaf buds, as indicated. Buds may, therefore, be regarded as embryonic or incipient shoots. It is by their growth that all trees, which

FIG. 7



BUD OF SYCAMORE



SECTION THROUGH BUD

THE BUD OF A SYCAMORE.

The illustration indicates the scale leaves which protect the delicate growing point. The section shows the folding of the leaves in the bud.

appear so bare in winter, become clothed in green leaves in the succeeding spring.

The relationship which buds bear to leaves and stems produced by them can best be observed in the development of the terminal bud of a Sycamore or Horse-chestnut. Buds which, when formed, do not grow out into young leaves must be protected during the winter. On the outside of the Sycamore bud will, therefore, be found a series of scaly leaves which overlap each other and protect and cover up the very delicate growing point.

A section through a terminal bud (Fig. 7) shows that within the protective scale leaves are ordinary leaves arranged on a short rudimentary stem. When growth commences, the inner scale leaves grow for a time, but soon die off, leaving scars where they were attached to the twig. The elongating stem, bearing the rudimentary leaves, forces the latter out from between the protective bud scales. After a week or so the stem attains a considerable length, the rudimentary leaves unfold and grow out flat, increasing in size as growth continues.

Generally the vegetative shoots of all plants end in terminal buds, and not only are buds present at the tips, but on either side as well. These side or lateral buds are formed where the leaf bases and the stem join each other. Such buds are termed axillary buds, and the angles of the leaf bases are called the axils. Usually only one bud is formed in an axil, but occasionally two may be present.

The first leaves of a bud, that is, those which are outermost or lowest on the stem, are generally rudimentary structures and differ in appearance from those which unfold later. In shrubs or trees this is quite apparent, but with the primary bud of a developing seed

(plumule) or the buds of herbaceous plants, this feature is not so prominent.

Scaly Buds

The term scale leaves has previously been mentioned as a protective agent to the bud of a Sycamore. Often such protective scale leaves or scales are more or less firm, tough structures and provide an efficient covering for the interior of the buds. The Ash, Sycamore and Horse-chestnut and the majority of trees show the development of scales quite clearly. Buds which are protected in this manner are called scaly buds.

Naked Buds

In some instances buds are without protective scales. In these cases the rudimentary leaves surrounding the growing point are packed very close together. Examples of naked buds are to be found in the Dog Wood and Mealy Guelder Rose.

Leaf Buds, Flower Buds, Etc.

Such buds as the terminal buds of the Wallflower and Sycamore previously described develop into shoots bearing foliage leaves. In the Wallflower and all herbaceous plants a bud which produces stems and leaves is called a leaf bud. In the Sycamore and trees or shrubs the same development takes place, but often the term *Wood Buds* is used, since, from such buds new woody twigs are formed. Many buds, however, on opening produce flowers only, such buds being termed *Flower Buds*. There are, however, buds which produce new stems and flowers; these are termed *Mixed Buds*. In the section on School Gardens this latter type of bud will receive more attention. Briefly

stated now, buds which produce stems and flowers are known as *Fruit Buds* and are very important from a horticultural point of view.

Branching of Stems

It will be noted in the Wallflower that the stem or primary shoot has arranged on it a series of appendages known as leaves, and the same applies to the lateral branches. The points on the stem where the leaves are attached are slightly thickened, and are called "nodes" or "joints," the lengths of stem between them being called "internodes."

In the early stages of growth in most plants the primary shoot or stem is single, and may continue to grow as a simple straight structure, with leaves only on it. Usually, however, the buds in the axils of some of the leaves produce secondary axes, and those borne by the latter, tertiary, etc. The total number of stems bearing leaves, therefore, may become very large on a single plant. This is especially noticeable in trees and shrubs.

Indefinite Growth

In some plants and trees the terminal bud of the primary axis continues to grow. Plants of this kind produce branches which never attain to the size of the main stem. This type of branching is termed *Racemose* and is typical of most trees.

Definite Growth and Cymose Branching

Often the terminal bud of a stem produces a flower. In this case the main axis ceases to elongate, and hence its growth is said to be *definite*. The lateral branches arising on a stem of

definite growth are usually few in number and soon attain the same size as (or exceed) the primary axis. Such branching is known as *Cymose* and is well indicated in the common Chickweed.

Sympodium

Frequently the growth of trees appears to be definitely of the type known as *Racemose*. Often the terminal bud of the primary axis is destroyed by wind, frost, insect attacks or other means, and further elongation is prevented. A lateral bud, however, carries on the upward growth. Similarly the terminal bud of this secondary axis may be destroyed, further growth taking place by means of a lateral bud. The whole shoot, however, although crooked at first, may, as growth increases, straighten out and ultimately appear as an axis of the first order, as a primary axis. The branches of the Elm, Hazel and many other trees appear straight and indefinite in growth, but are often, in reality, *Sympodia*, the terminal bud on each annual shoot having a false axis, being formed by the vigorous development of the highest lateral bud.

Further examples of *Sympodia* are to be found in the underground stems of the Couch Grass and Solomon's Seal (Figs. 3 and 4).

Dormant Buds

On examining trees and plants, it will be found that all buds formed do not develop into leaves or shoots. Some buds, which have been formed in regular order in the axils of leaves, remain in a dormant condition for years and may ultimately die. On the other hand, if through injury or

other reasons the parts above the dormant buds cease to function, they—the “dormant” or “resting” buds—may burst into activity. The pruning of fruit trees and Rose trees and the lopping of the trees in the streets cause the dormant buds to develop. In the fields the grazing and mowing of grasses promote the development of buds and a consequent increase in the leafy stems. The mowing of lawns and consequent increase in the thickness of the sward is another result of dormant bud activity.

Adventitious Buds

Under certain conditions buds may arise at any point on a plant, on the stem or even upon the roots and leaves; such buds are termed *Adventitious Buds*. When the stems of a Rose tree have been cut down, adventitious buds are produced on the roots, and these give rise to the new shoots. Further examples are met with on the roots of the Docks, Poplars, etc., when the upper bud-bearing stems have been removed.

In the classroom it is possible to produce new Hyacinth or other bulbs by planting the scales in soil. Adventitious buds are formed at the base of the scales, these ultimately becoming new bulbs.

Leaves

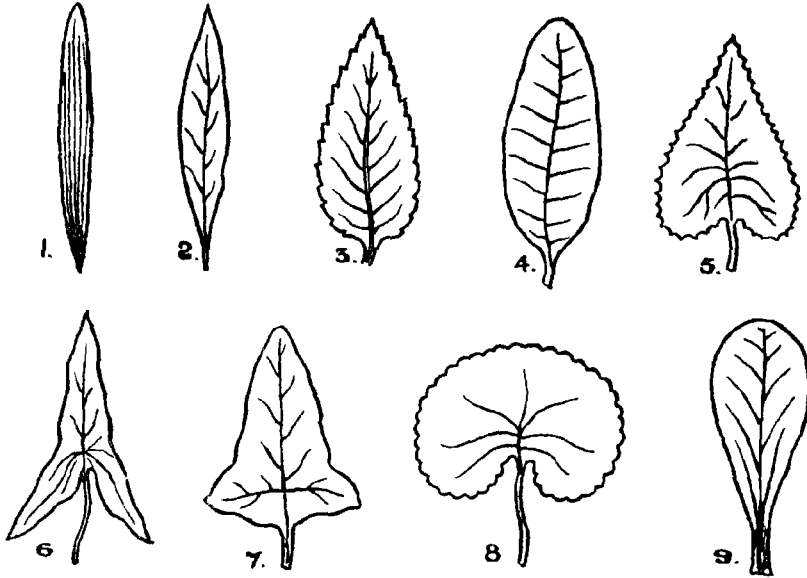
It has been previously pointed out that the lateral appendages of the stems are called leaves, and in all cases these arise from buds. In the Wallflower it will be noticed that no two leaves arise at the same level; each leaf is placed a little higher or a little below its neighbours. The leaves, therefore, in this case are said

to be alternate. With a more detailed examination it will be found that the leaves are arranged in a spiral. A line connecting the bases of the leaves will be found to ascend from right to left. If the leaves are counted carefully in an upward direction, not counting the one we start with, it will be found that the fifth leaf comes exactly above the uncounted one. In order to reach the fifth leaf it will be found that the spiral has passed exactly twice round the stem. (For a beginner it is best to insert pins in the bases of the leaves and find the spiral by means of cotton wound round each pin in turn.)

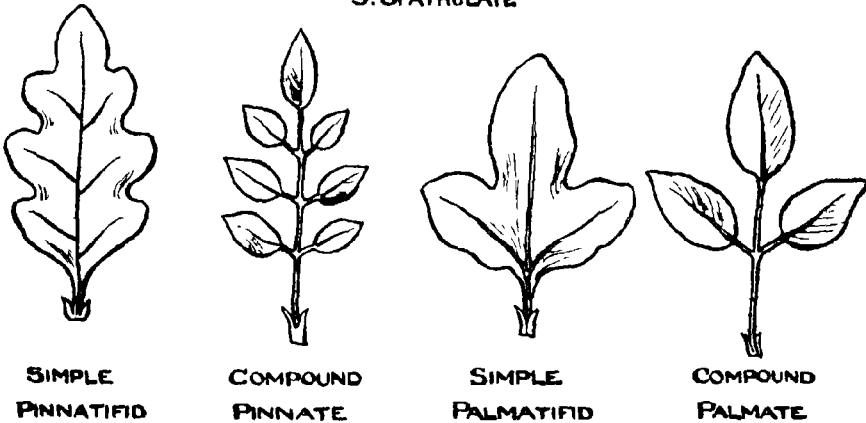
This arrangement is often expressed in the form of the fraction $\frac{1}{2}$. The denominator indicates the number of the leaf which comes directly above the starting point; the numerator denotes the number of times the spiral passes round the stem. In the Wallflower each leaf is attached to the stem at a node by a narrow base. There is no distinct stalk, but the body of the leaf narrows near the base, broadens out quite gradually for about two-thirds of the whole length and narrows again to a pointed end. The leaf, therefore, consists of two parts, the base and blade, or lamina. In the majority of leaves a third distinct part is present. This is formed between the base and the blade, being known as the leaf stalk or petiole. When the petiole is absent, as in the case of the Wallflower, the leaf is said to be *Sessile* (Fig. 1).

In some cases the base of the leaf is not clearly distinguished from the petiole; in other cases, for instance the Buttercup, Nasturtium, etc., it is well developed and forms a sheath,

FIG. 8



1. LINEAR 2. LANCEOLATE 3. OVATE SERRATE 4. ELLIPTICAL ENTIRE
 5. CORDATE DENTATE 6. SAGITTATE 7. HASTATE 8. RENIFORM CRENATE
 9. SPATHULATE



**SIMPLE
PINNATIFID**

**COMPOUND
PINNATE**

**SIMPLE
PALMATIFID**

**COMPOUND
PALMATE**

H.R.

THE SHAPE OF LEAVES.

The illustrations given show how leaves can be described. Numbers 3, 4, 5 and 8 give the terms used to denote the type of leaf margin. For example: "Ovate Serrate": the first term denotes that the leaf is oval in outline, the term "serrate" being applied to the saw-edged margin

In grasses the sheath often completely encircles the stem.

Leaves are generally flattened structures, and with the exception of those known as floral leaves, usually have buds in their axils. They differ from stems and roots, for after reaching a definite size their growth ceases. The lamina, in all cases, is the most conspicuous part of a foliage leaf, and there are several points of note in its general outline, margin, apex and venation.

Stipules

Frequently the sheath bears wing-like outgrowths. In the Rose, these outgrowths from the leaf-sheath are membranous. The Pansy shows outgrowths of a green leafy structure. In each case such structures are called Stipules. These outgrowths of the sheath are to be found also on the very young leaves of Apple, Lime and Beech. As the leaves unfold they fall off. In some types of Peas, especially *Lathyrus aphaca*, the stipules act as ordinary green leaves; the leaves proper are modified to form tendrils.

Venation

Net Venation

The substance of a leaf is transversed by a number of woody strands which are termed nerves or veins. (These differ in structure and function from the veins of animals.) The arrangement of the veins is an interesting point, and the venation of the leaf calls for keen observation. In some leaves, as, for example, the Wallflower, the veins form a network of strands within the leaf, and this arrangement is called Reticulate or Net Venation (Fig. 1).

Pinnate

In this type two divisions are to be found. Sometimes, as in the Wallflower, the leaves have a central strand, or mid-rib, which is much more prominent than those given off from it. Further examples of this type can be seen in the leaves of the Oak, Spanish Chestnut, Lime, Elm and Beech. Such leaves are said to be *Pinnate*.

Palmate

The other division is quite distinct. Each leaf has several strong strands which start from the base of the blade and spread across to its margins like the fingers of an outstretched hand. The Ivy, Sycamore, Vine and Currant leaves are typical examples of this type of venation, which is known as *Palmate*.

Parallel Venation

In grasses, and in the Hyacinth, Onion and Snowdrop, etc., the veins or chief strands run parallel to each other from the base of the leaf to the tip. This type of venation is known as Parallel Venation (Fig. 6).

Forms of the Lamina (Fig. 8)

The outline of the blade of the leaf may assume almost any geometrical figure. That of the Wallflower assumes the shape of a lance-head, and is known as *Lanceolate*. A leaf long and narrow, as in the case of grasses, is termed *Linear*. The Daisy is an example of a spoon-shaped leaf, to which the term *Spatulate* or *Spathulate* is given. Another shape, not so well known, is that of the Wild Arum or Cuckoo Pint (*Arum maculatum*). This is termed *Saggitate*. Another example of this type is to be found in the Arrowhead. The Ground Ivy is an example of a

kidney-shaped leaf, and is called *Reniform*.

When the Lamina is widest near its base and the projections are rounded on either side, as in the Dead Nettle, the term *Cordate* is applied. The Honeysuckle is an example of an *Ovate* leaf. The apex is somewhat pointed, but the base of the leaf is rounded. The leaves of the Nasturtium and Wall Pennywort are symmetrical and rounded. This type of leaf is termed *Orbicular* or *Circular*.

Edge of Lamina

The edge of the Lamina is a special feature. In the Wallflower and Privet it is *Entire*. Some leaves are indented with small or large incisions. Leaves having margins like the teeth of a saw are *Serrate*. Such indentations are seen in the leaves of the Rose, Willow, etc. When the small teeth stand at right angles to the edges, then the edge of the leaf is termed *Dentate*. In some leaves, the edges have semi-circular prominences: in these instances the term *Crenate* is applied. This type of indentation is well illustrated in the Geranium.

In certain leaves, the indentations run deeply into the leaf tissues. The leaves are then spoken of as *Lobed* (fid) or *Parted* (partite) or *Dissected* (sect) as the divisions reach about one half, three-quarters or nearly the whole way down towards the mid-rib. As the indentations generally follow the direction of the main vein of a leaf, there are two types of lobed—partite and dissected—leaves, those of pinnate leaves being described as pinnatifid, pinnatipartite and pinnatisect, and those of palmate leaves

as palmatifid, palmatipartite or palmatisect.

Compound Leaves

So long as the divisions of the Lamina do not reach to the mid-rib, the leaf is described as simple. When, however, the partitions are such that the leaf appears to consist of several distinct blades, it is then compound, and the separate parts are described as leaflets.

Compound leaves are met with in the Ash, Rose, Pea, etc., and in these are described as pinnately compound. Compound palmate leaves are met with in Clover, Horse-chestnut, Lupin, Meadow Cranebill, etc. A compound leaf can be readily distinguished from a stem bearing leaves if it is noticed that the blade or leaflets do not possess axillary buds. Such buds are formed only at the base of the whole leaf.

Leaves and their Modifications

Often structures are met with on the stems of plants which, although not possessing all the parts of a foliage leaf, may be regarded as modified leaves by reason of their origin and position and because they usually have buds in their axils. These modified leaves are given special names according to their position on the stem or according to their texture, colour or other peculiarities.

Cotyledons or Seed Leaves

In the seed are found structures which bear a superficial resemblance to leaves. They are outgrowths from the axis of the embryo plantlet contained in the seed. If two of these modified structures are found, the embryo is termed a *Dicotyledon*; if one only, the term *Monocotyledon* is applied. In the Bean and Pea the cotyledons merely act as storehouses for the food upon

which the seedling or embryo depends for its early growth. In other seeds, the cotyledons may come above the ground and function as absorbing organs, as in the case of the Castor Oil, Lupins, Sunflower, Mustard and Cress. Such leaves are always much more simple in form than ordinary foliage leaves. In the Scarlet Runner Bean the cotyledons remain underground and the first two foliage leaves are of a simple structure; the subsequent leaves, however, are compound.

In cereals and grasses generally the cotyledon acts as an absorbing organ, using up the endosperm or reserve food material of the seed and transferring it to the growing point of the young root and shoot.

Scales

Leaf-like structures, usually small sessile, generally coloured brown, white or yellow, are often met with. They possess no green colouring matter and hence take no part in the assimilatory process. On the stem above-ground, these scales, modified leaves, are present as a protection to the inner parts of the buds on trees and shrubs. Scales are always present on the underground stems of plants such as the Couch Grass and Potato. In this case they are small, colourless and of a membranous nature. The leaves of a resting bulb are large scales, some of which are thick and fleshy and stored with food.

Bracts

Leaves which occur upon the stem at points where the flower arises are termed *Bracts*. This term is most strictly applied to the leaf member which subtends a lateral axis, and is of great importance when the lateral axis is directly terminated by a flower.

In some plants they cannot be distinguished from the foliage leaf except by their position. The bracts surrounding the flowers of grasses are termed *Glumes*. In the Arum Lily, the Iris, Narcissus and Snowdrop a large bract encloses the whole flower or inflorescence (collection of flowers) and is termed a *Spathe*.

Prophylls

Each lateral shoot arises in close connection with a subtending leaf; that is, in the axil of a bract, the first two leaves come to lie more or less transversely so that they fill the space left vacant on the flanks. These two leaves are termed *Prophylls*, and on a vegetative shoot they are usually smaller than the subsequent ones. The two prophylls are usually the only vegetative leaves on the axis of a floral shoot, and are very conspicuous on the flower stalk of the Pansy.

Spines and Thorns

Sometimes leaves are modified to serve in a protective capacity. In this case they are modified into sharply pointed structures known as spines or thorns. This modification is well illustrated in the Barberry, the position of the spines clearly showing that they take the place of leaves on the stem. In Gorse the spines may be either modified leaves or branches.

Floral Leaves

Although the flower of a plant appears different in many respects from the ordinary stem and leaves of a plant, it is in reality a form of simple stem or a shoot with leaves upon it. The whole of the leaves, however, have been modified to serve the purpose of seed production.

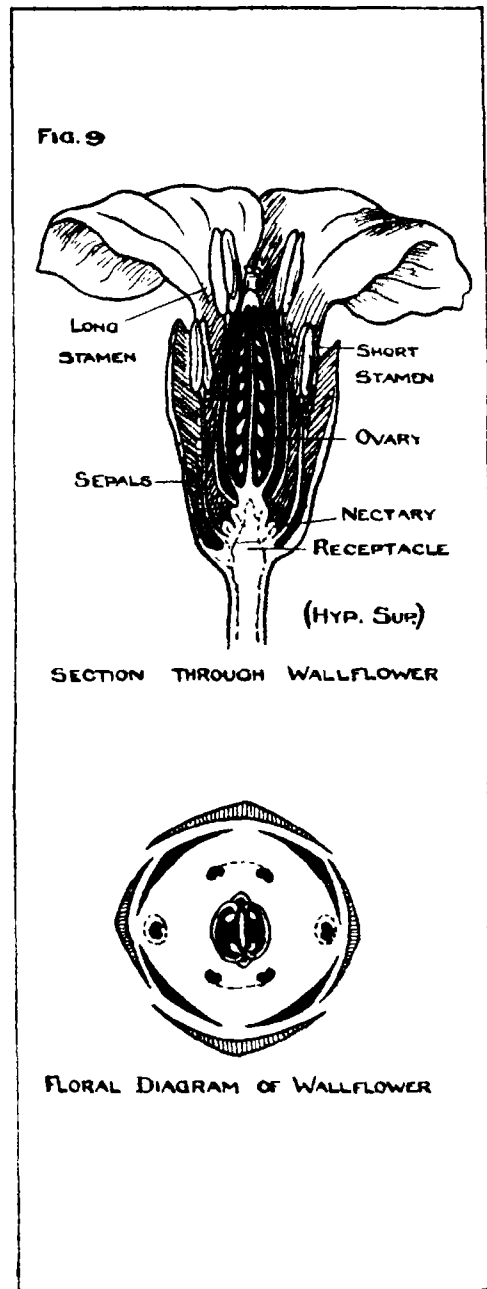
The leaf-like structure of the sepals and petals will be fairly obvious; a so-called double flower also gives the general idea of leafy structure. A flower is essentially equivalent to a shoot with very short internodes. It occupies the position of a shoot either at the apex of a stem or in the axil of a leaf. The various parts of a flower, the sepals, petals, stamens and carpels, occupy the position of leaves upon the axis of the flower. They are the lateral appendages of the axis or receptacle, and are termed floral leaves. This is a typical example of the modification of organs to perform a definite function.

The Flower

On the Wallflower the branches which bear the flower are exactly similar to the ordinary vegetative branches. They arise in the axils of leaves and for some time bear leaves themselves. The production of leaves, however, soon ceases, and from this time flowers only are formed. Hence each single flower may be regarded as a modified branch, the leaves of which differ greatly in arrangement, colour and structure from ordinary vegetative leaves. It will be noted from the above that in the Wallflower the flowers do not arise in the axils of leaves, for there are no leaves on the part of the plant which bears them. This variation is characteristic of the Cruciferae Family, to which the Wallflower belongs. In most plants, however, the flowers are borne, like other branches, in the axils of leaves.

Inflorescence

In the Wallflower the flowers are borne laterally on a main axis which terminates in a bud. From the bud new



THE FLOWER.

In the section, note that the ovary occupies the highest position on the receptacle. The position of the nectaries is of considerable importance (see text).

flowers are formed as long as growth continues. The youngest flowers,

therefore, are those nearest the top. The manner in which flowers are borne on a stem is termed the Inflorescence, hence an inflorescence of this kind is known as indefinite. The flowers are also found to be borne on short stalks, hence to describe the flowering axis of a Wallflower the term Raceme is used. A Raceme is an indefinite inflorescence with a single main elongated axis bearing stalked flowers.

Parts of a Flower

On dissecting a single flower, there are certain points worthy of note. The stalk (or pedicel) is quite bare, all the floral leaves being crowded together at the tip, the enlarged end of which is termed the receptacle or thalamus.

It will be found that the floral leaves are not arranged spirally, like the ordinary leaves of the stem, but two or more grow at the same level (see Fig. 9).

Sepals and Calyx

On the outside of the flower are four narrow leaves, forming an outer and an inner pair, placed at right angles to each other. These are not inserted at the same level, one pair being nearer to the centre of the axis than the other. Each leaf is called a Sepal, and together they form the part called by the botanist the Calyx. As the sepals are quite separate, the calyx is said to be polysepalous.

Petals and Corolla

Inside the calyx will be found four floral leaves, inserted at the same level and forming a ring, or whorl. These are the most conspicuous parts of the flower (the colour varies greatly, from a pale yellow to a blood red), and are

called the petals. They alternate with the sepals at their bases, the middle of each petal coming exactly opposite the space between two sepals. Each petal is narrowed at its base, tapering like a stalk, and at the upper part is broad and rounded. The petals collectively are called the Corolla, and since the petals are separate, like the sepals, they are termed polypetalous.

Both the sepals and petals are veined, but not in such a conspicuous manner as the leaves. Generally the venation is reticulate in character.

Perianth

In speaking of the outer envelope of the flower, which generally consists of the two series of leaves forming the calyx and corolla, the term perianth is often applied. These parts may be considered as the non-essential parts of the flower.

The Andræcium—Stamens—Filament and Anther

The organs of the flower so far considered bear obvious resemblances to the leaves. The next Whorl or ring of the Wallflower, however, is made up of bodies which, at first sight, are not at all leaf-like. Each one consists of an elongated thread-like portion—the filament—surmounted by a swollen, thicker part termed the Anther. The anther consists of two somewhat elongated halves or lobes which are usually situated on opposite sides of the upper part of the filament uniting the anther lobes. Briefly stated, the anther lobes may be considered as the two halves of a modified leaf, the mid-rib of which forms the filament and the connective, the part of the filament between or connecting the lobes.

Running lengthways in the interior of each lobe are generally two chambers named pollen-sacs, within which pollen is produced in the form of loose round or oval pollen grains. In the young state the pollen is completely enclosed in the anther lobes, but in a longer or shorter time after the opening of the flower, the partition between the pollen-sacs is ruptured and the anther lobes open by longitudinal slits along the line of union of the two sacs, the pollen grains being set free in the form of dust-like powder. The anther and filament form one complete organ, which is termed the Stamen. The collection of Stamens in a flower is called the *Andræcium*.

In the Wallflower the *Andræcium* consists of six stamens, four of which are longer than the other two. The two shorter stamens stand on either side of the flower, and each is placed just between two of the petals and immediately opposite the innermost sepals. The four longer stamens are slightly farther in, each pair (joined at the base of the filament) standing between two petals and just opposite the two outer sepals (see Floral Diagram, Fig. 9).

Nectaries

On the insides of the bases of the shorter stamens are two large green sacs called honey glands or nectaries. The filaments of these stamens are bent slightly outwards to make room for them. This bulging is shown in the lateral sepals, and can be easily observed.

Gynæceum or Pistil

The centre of the flower is occupied by a further modification of a vegeta-



THE DEAD NETTLE.

A zygomorphic flower. The fruit consists of four "nutlets."

tive leaf. This is merely a cylindrical hollow green body, tapering a little towards the top and surmounted by a forked outgrowth. The latter is called the stigma; the lower, thicker part, which is more than three-quarters of the whole length, is the ovary, and the short, tapering portion between the stigma and the ovary is the style.

The floral leaves of which the pistil is composed are termed carpels. The ovary is divided lengthwise into two compartments by a membrane called the septum. The two carpels are so placed as to be opposite the two inner sepals. Inside the ovary are the immature seeds or ovules. They are attached to the walls of the ovary adjoining the septum; the point of attachment is termed the placenta.

With careful study it will be noted

that a carpel may be considered as a leaf which has been folded along the mid-rib and united along its edges. The pod of a Pea or Bean is an example of a single carpel forming the ovary ; in the Wallflower the septum represents the fused walls of two carpels. In the Pea the line corresponding to the united edges of the leaf is known technically as the ventral suture, and it is along this line that the ovules are borne in a double row, one corresponding to each edge of the leaf. The line corresponding to the mid-rib of the carpellary leaf is called the dorsal suture. In the Wallflower, the carpels have fused, a dorsal of one with the ventral suture of the opposite carpel. Hence the ovules are attached in pairs on the opposite sides of the ovary.

Before the ovules develop into seeds, the pollen must be transferred from the anther to the stigma (not necessarily from the same flower). When

this has been done, the change known as fertilisation takes place. Pollination and fertilisation will be dealt with in a general manner later.

Arrangement, Symmetry and Number of Floral Leaves

Cyclic

In the Wallflower it has been pointed out that all the floral leaves are arranged in rings or whorls on the receptacle. In flowers of this type the arrangement of the floral leaves is spoken of as Cyclic.

Acyclic

In other instances the floral leaves are arranged in the form of a spiral, such arrangement being termed Acyclic, examples of which are to be found in the Water Lily and Christmas Rose (*Helleborus niger*).

Hemicyclic

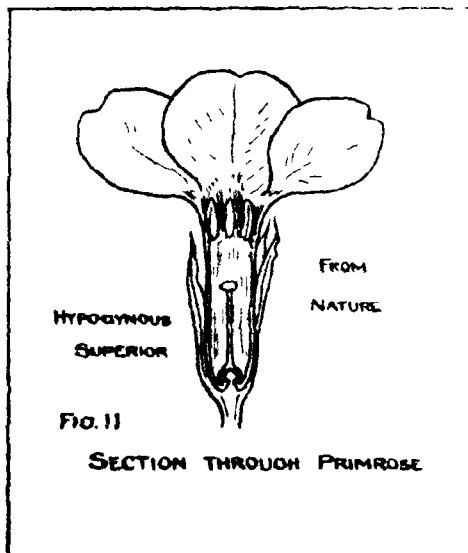
In the flowers of members of the Buttercup family (*Ranunculus*) the sepals and petals usually form whorls, but the stamens and carpels are arranged in a close spiral. Such flowers are spoken of as Hemicyclic.

Regular and Irregular

The members of each whorl in the cyclic flower of the Wallflower are alike in shape and size. Such a flower is regular, while those of the Pea, Violet, etc., where some of the petals are much larger than the rest, are spoken of as being irregular.

Actinomorphic

All flowers which can be divided into two equal and similar halves by a



THE THRUM-EYED PRIMROSE.

An example of a hypogynous flower. note the positions of the stamens and stigma.

plane passing through the axis of the receptacle are symmetrical. Regular flowers like the Wallflower can usually be divided into two halves by planes passing through the axis in several directions. Such flowers are designated actinomorphic flowers, and excellent examples are found in the Poppy, Chickweed and Primrose.

Zygomorphic

Flowers which can only be cut into halves in one direction are termed zygomorphic, and such examples are to be found in the Pea, Gorse, Dead Nettle and Foxglove (Fig. 10).

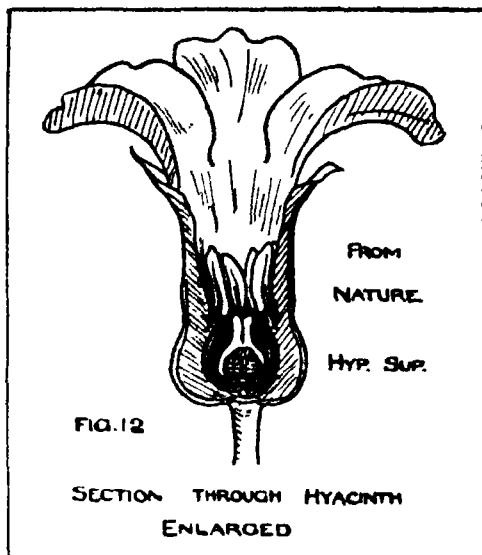
The Receptacle

Hypogynous—Superior

In the Wallflower the receptacle is a more or less conical-shaped axis, the whole of the floral leaves being arranged on it in successively higher levels, the gynæceum or pistil occupying the highest and the calyx the lowest respectively. Flowers which, like the Wallflower, have the corolla and andræcium inserted on the receptacle at a lower level than the gynæceum and free from the latter are termed *Hypogynous Flowers* and the ovary is said to be *superior*. Further examples of this arrangement are to be found in the Poppy, Primrose, Chickweed and Buttercup. (Figs. 9, 11 and 12.)

Perigynous—Superior

In some flowers the apex of the receptacle ceases to grow at an early stage, but the parts below grow up all round it, forming a hollow basin or urn-like structure on the edge of which the perianth and stamens are arranged.



THE HYACINTH.

All floral members are arranged in groups of three.
The ovary is tricarpeillary.

Flowers of this type, which are found in the Rose (*Rosa canina*), the Plum, Blackberry, Agrimony, etc., are described as perigynous. The gynæceum is still superior, for the bottom of the hollow receptacle is the apex of the floral axis. (Figs. 13, 14 and 15.)

Epigynous—Inferior

In the Apple, Pear, Snowdrop and Daffodil the receptacle appears to be hollowed out, as in perigynous flowers, but the carpels, instead of being free, are fused with the receptacle. In such flowers the sepals, stamens and anthers appear as if they were outgrowths of the upper gynæceum, although in reality they spring from the receptacle, which has become united with the carpels. In cases similar to the above the flowers are described as Epigynous and the ovary as *inferior*. (Figs. 16, 17 and 18.)

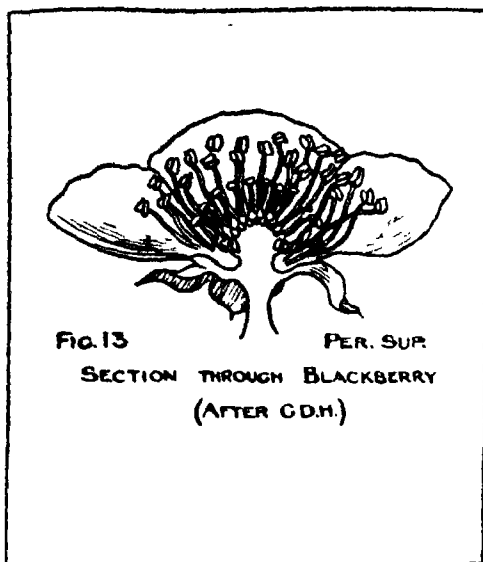


FIG. 13
SECTION THROUGH BLACKBERRY
(AFTER G.D.M.)

THE BLACKBERRY.

The fruit is a collection of drupelets: compare with the Raspberry and Loganberry.

Gynæceum

Apocarpous

The gynæceum may consist of separate carpels, as in the case of the Buttercup, Clematis and Larkspur. When the carpels are free they are said to be Apocarpous.

Syncarpous

Frequently, however, the carpels are fixed or completely united to form one ovary. In this case the styles are usually fused, but the stigmas remain free. Fused carpels form a syncarpous ovary. The ovary thus formed by the fusion of the carpels may contain only one cavity or loculus and is termed unilocular. When, however, the edges of the carpels meet in the middle of an ovary, the united parts forming partitions dividing up the common ovary into several cavities, such ovaries are

spoken of as multilocular, and each cavity corresponds to a single cavity.

Monoclinous and Diclinous Flowers

When the essential parts of a flower, that is the Andrœcium and Gynæceum, are present in the same flower, as in the Wallflower, Primrose, Buttercup, the flower is described as monoclinous; the terms hermaphrodite or perfect are sometimes used in this connection.

When, as in the flowers of the Hazel and Willow, one or other of the essential parts is missing, the flower is described as diclinous or imperfect. Sometimes those which have the anthers only are described as Male Flowers or Staminate Flowers, those bearing the Pistil being known as Pistillate, Female or Carpellary Flowers.

Monœcious and Diœcious

When both types of diclinous flowers are met with on the same plant, as in the Hazel, the plant is described as monœcious. In Willows and Poplars, however, the two kinds of diclinous flowers are found on separate individuals. In this case the plants are known as diœcious.

The Inflorescence

In many plants, as, for example, the Poppy, Buttercup and Tulip, the flowers are borne singly and terminally at the end of the main axis or singly and terminally on lateral axes in the axils of foliage leaves, as in the Scarlet Pimpernel and Speedwell. Such flowers are termed *solitary*. Generally, however, flowers are grouped more or less compactly together on a special shoot or axis, as in the Hyacinth, Foxglove or Wallflower. Such a flower-bearing axis is termed an Inflorescence.

The axis of the inflorescence is called the peduncle or rachis, the individual flower stalks, when present, as in the Wallflower and Hyacinth, being termed the pedicels; the leaf-like structure in the axils, on which the pedicels of some flowers are borne, are designated bracts. Occasionally other leaf-like structures appear on the pedicels, these being known as bracteoles or prophylls. There is a great variety of forms of inflorescence met with showing differences in the manner of branching, length and thickness of the axes, etc. The inflorescence, however, generally follows the mode of branching exhibited by the stem, whether this be monopodial (racemose) or sympodial (cymose), yet there are various other considerations which help to modify and complicate it.

Racemose Inflorescence

In the Wallflower, Foxglove and Antirrhinum the main axis or peduncle is elongated, so that there are well-defined internodes between the flowers, and each floret has a pedicel. Such an inflorescence is termed a *Raceme*.

Flowers which have no pedicels and are sessile on the peduncle are known as *Spikes*. This type of inflorescence is well represented in the Horse Mint, Spear Mint and the Plantain. A *Catkin* is a spike bearing unisexual flowers of one kind, as for example the Hazel and Willow.

Umbel

In some instances the peduncles are very short, so that the pedicels of the flowers are crowded together. When the peduncle or main axis is extremely short, the internodes also being short, this type of inflorescence is termed an

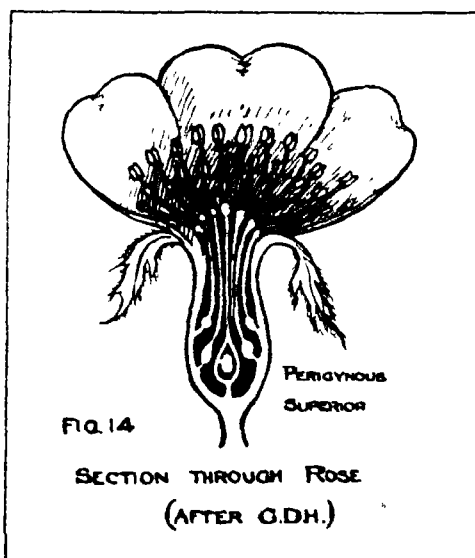
Umbel. This is well exemplified in the Cowslip.

Capitulum

When the peduncle is reduced, as in the umbel, and the florets are sessile (without pedicels), the term *Capitulum* is applied. Examples of this type of inflorescence are well known, the common Field Daisy, Dandelion, Groundsel, etc., being excellent representatives.

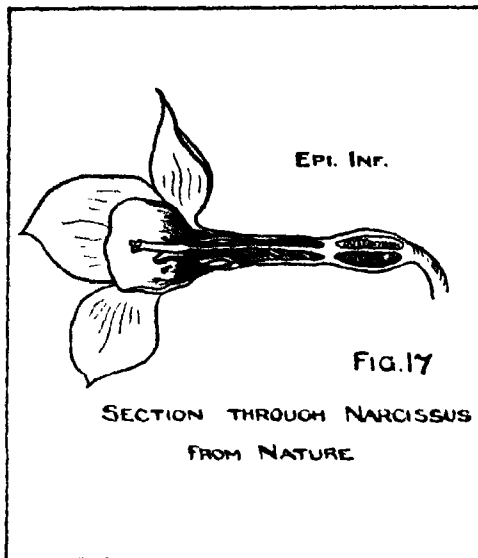
Cymose Inflorescence

In some flowers the main axis terminates in a single flower, and hence the growth of the peduncle ceases. If other flowers arise upon the axis, they must spring from lateral axillary buds below the apex. Usually each axis of this description bears one, two or a few branches only, which grow vigorously and soon overtop the main one. Such lateral branches may terminate in



THE DOG ROSE.

Note that the carpels are not fused with the receptacle. The fruit is called a "Hip."



THE NARCISSUS.

This flower, like the Daffodil, has a corona. The receptacle and ovary are fused, the ovary being inferior.

plants—Poplar, Willow, Hop, Dog's Mercury, etc.

Monoclinous Plants

The staminate and carpellary organs are borne on the same plant and on the same shoot as in the case of the Hazel, Ash and Oak. Although, however, monoclinous flowers may be in close proximity to each other, they frequently do not ripen together.

Protandrous Flowers

In this section two types of plants are met with. The anthers of many flowers ripen and shed their pollen some considerable time before the stigmas are in a suitable condition to receive it. Such flowers are spoken of as protandrous and are quite common. Examples are met with in the Daisy, Dandelion, Dead-nettle, Bean, Vetch, Parsley, Carrot, Fool's Parsley, Peas, and in fact practically all members

of the plant families Compositæ, Leguminosæ, Umbelliferæ, and Labiata.

Protogynous Flowers

Flowers whose stigmas ripen before the anthers scatter their pollen are less common. These are termed protogynous. Examples, however, are met with in the Apple, Pear, Plantain, and in several meadow Grasses, such as the Foxtail and Sweet Vernal Grass, Rushes and Figwort.

In the Wallflower a special adaptation is found. The two shorter stamens dehisce and scatter their pollen before the stigma is ready to receive the grains. A Bee visiting the flower in search of the nectar at the base of the two short stamens receives pollen on its head. When the Bee flies to another flower it is sure to deposit some of the pollen on the stigma as it enters the flower. When this happens, cross-pollination is effected, that is, the stigma of one flower receives the pollen of another; this may be between the flowers of the same plant or between the flowers of different plants. If this does not take place, however, the pollen from the long stamens, which ripen later and rise above the stigma, is sure to fall upon the stigmas when they are in a receptive condition.

In other monoclinous flowers, in which the anthers and stigmas ripen simultaneously, the distance apart and their relative position are often such that self-pollination is uncertain. Adaptations of this class are met with in the Thrum-eyed and Pin-eyed Primrose and in the Cowslip.

External Agencies in the Transference of Pollen

Pollen grains have no power of movement, hence for cross-pollination ex-

ternal agents are essential for the transference of pollen from flower to flower. The chief agencies in the work are the wind, insects (Moths, Butterflies, Bees, etc.) and occasionally water.

Wind Pollination

Plants which are pollinated by the wind exhibit several special characteristics, such as the absence of nectaries, abundance of pollen, small greenish, scentless flowers, large, exposed and much-branched hairy or feathery stigmas and freely exposed anthers hanging out of the flowers so that the wind can easily carry the pollen away. In these instances there is always a great waste of pollen; thousands of grains are produced, only one of which may fulfil its function. The Grasses, Poplars and the Hazel are typical examples of wind-pollinated flowers (hay fever is caused by the irritation set up by the pollen of Grasses on the mucous membrane of the nose and throat).

Water pollination is rare and need not be dealt with in schools.

Insect Pollination

Flowers which are insect pollinated do not all conform to rules. In certain cases, for example the Violet, Dandelion, Dead-nettle, Foxglove, Pansy and Wallflower, there are many common features. They are all scented and have large conspicuous perianths, the scent and colour evidently being important for insect attraction. In flowers of this type glands termed nectaries are present. These secrete a sweet juice—nectar—which insects use as food and which Bees change into honey. Generally flowers having nectaries produce only a relatively small

amount of pollen. However, some types, for example the Buttercup and Poppy, although possessing nectaries, also produce a large amount of pollen. Insects use the pollen from these flowers for food, and hence Nature has provided sufficient pollen to make up for that used as food.

Bees and insects are very methodical in their visits to flowers, and often confine their activities to a particular kind of flower for several hours at a time. In this connection it may be useful to refer to Bee-keeping and Honey. The honey collected during the early spring is of a light colour and is sometimes known as Lime Honey. That secured at a later time, when the Clover is in flower, is of a darker texture and is consequently known as Clover Honey.

It must not be supposed, however, that Bees are aware of their particular value to the types of flowers they visit. One might reasonably consider that on

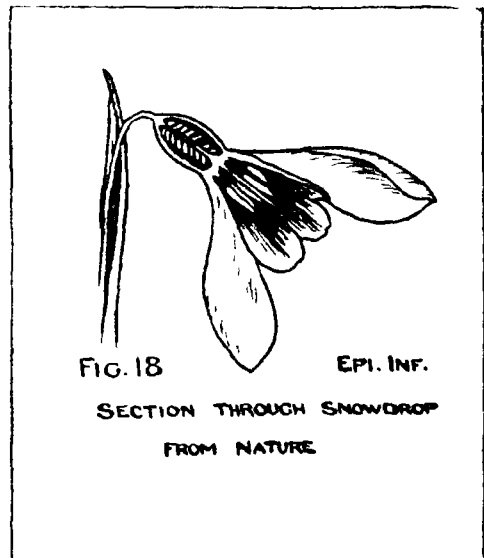


FIG. 18 EPI. INF.
SECTION THROUGH SNOWDROP
FROM NATURE

THE SNOWDROP.
The sepals are petaloid. Note the green tips of the
nectals. The ovary is inferior and tricarpeillary.

finding a particular type of flower with easily obtainable nectar, the insects, whose sense of smell and vision is highly organised, seek out similar types for their visits. This question is one which might be taken up as an intensive observational study by an interested teacher of Nature Study.

From the purely matter-of-fact point of view plants require the services of insects for the transference of pollen from the anthers to the stigmas, and in return for this service they sacrifice a certain amount of their nutrition in order to provide the nectar and pollen which insect visitors require as food.

Among the insect visitors Beetles, Bees, Flies, Wasps, Butterflies and Moths are included. Generally Butterflies and Moths have very long sucking organs or proboscides, 5 to 8 cm. or more in length. These insects, therefore, are able to obtain nectar from flowers having long tubes, such as are found in the gamopetalous flowers. Pinks, Carnations and Campions are visited by Butterflies, whose long length of proboscides enables them to secure the nectar from the base of the flower.

Beetles and Flies are not so highly organised in some respects as the Butterflies and Moths. These generally have much shorter proboscides or else short licking tongues. Open flowers, such as the Lesser Celandine, Buttercups, Poppies, Ivy, etc., whose nectaries are easily accessible to short-tongued insects, are visited and pollinated chiefly by this class of insect.

Wasps and the smaller Bees have short licking tongues, and hence can only obtain their food from flowers with exposed nectaries. Sometimes Wasps, with their strong jaws, bite

away the petal-tube in order to obtain the nectar.

The Hive Bees have long tongues which have developed into suctorial organs. These insects have retentive memories and show considerable intelligence in their search for nectar. The Humble-bee is probably the most valuable insect so far as the agriculturist is concerned; with its long proboscis it is able to search for honey in the flowers of the Clover. Its weight is an asset in this type of inflorescence, and it is mainly through the intervention of such Bees that Clover seeds are produced.

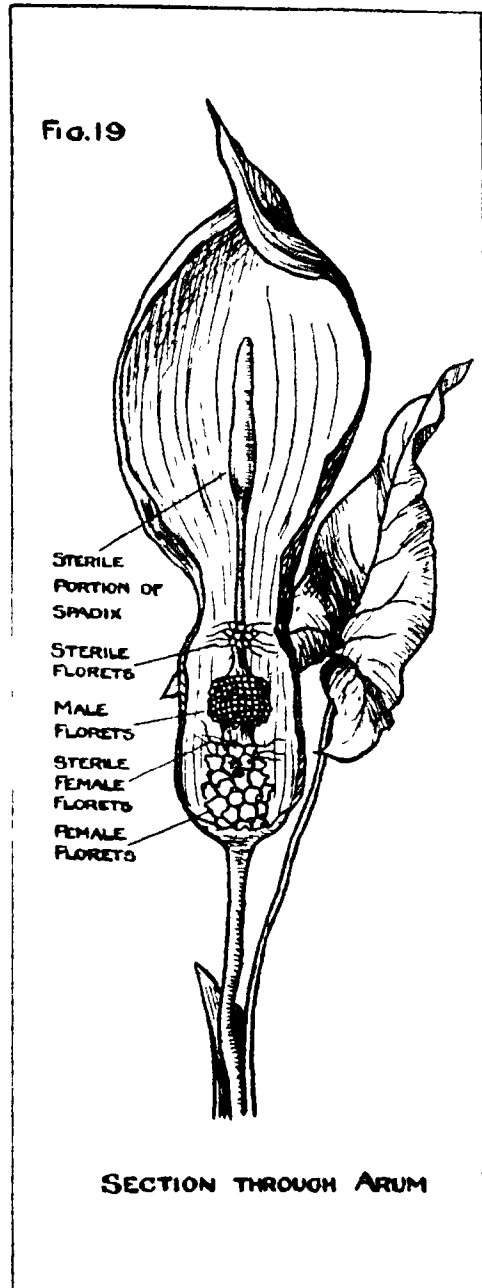
The Honeysuckle or Wild Woodbine is a flower needing an insect with a specialised proboscis. The night-flying Privet Hawk Moth visits the Honeysuckle for its food, and in return, carries out the work of pollination.

Many flowers, like the Honeysuckle, have become so highly specialised that they can only be pollinated by a certain type of insect visitor. This leaves such flowers open to the risk of never securing cross-pollination. The open flower, such as the Buttercup, can be either self- or cross-pollinated by almost any insect of moderate size, whereas highly specialised flowers and those adapted for the visits of Bees, Butterflies and Moths are generally constructed in such a manner that the nectar can only be obtained when the insect visits the flowers in a particular manner. In the Dead-nettle and Pea families one or more petals form a platform on which the insect must alight; the remaining petals enclose and protect the essential organs. The weight of the insect's body, if of the desired type, and its efforts to enter the flower may bring the anther or

stigma into contact with the visitor's body. In the flowers of the Pea and Scarlet Runner Bean, it is the under-surface of the insect which comes into contact with the anther and stigma, while in the Foxglove, Antirrhinum, Sage and Dead-nettle the back of the insect is the pollinating agent. This arrangement for specialisation in pollen transference certainly avoids unnecessary waste of pollen, and the delicate sexual organs are placed in a position of greater security from adverse climatic conditions.

As a rule creeping and crawling insects are unwelcome visitors to flowers. Certain types of flower, however, exhibit arrangements for the accommodation of such insects. The Arum (Lords and Ladies) shows this special adaptation. On the flowering axis inside the spathe are a number of hairs placed in a downward-oblique direction. Small creeping insects pass the hairs quite easily in their search for food, but their exit is prevented by the hairs. The anthers dehisce their pollen some time before the stigmas are ready. This falls on the entrapped insects. In their struggles to escape the insects transfer the pollen to the ripening stigmas, after which the hairs lose their stiffness. In this way the Arum and its allies secure auto-pollination or a type of self-pollination (Fig. 19).

Self-pollination is very common, especially in flowers whose anthers and stigmas mature at the same time. In other types, for example the Dandelion, provision is made for cross-pollination in the first place, and arrangements are made for self-pollination as a last resource. During development the sticky faces of the two-lobed stigma



THE ARUM.

The inflorescence is another example of organs modified to perform a definite function. The stigmas of the sterile florets imprison insects until pollination has been effected.

are closed. The anthers dehisce their pollen towards the style, which, in its growth upwards and towards the anthers, becomes coated with pollen. The stigma opens, exposing the two lobes for the reception of pollen. If this is not forthcoming the lobes curl over until their receptive sides come in contact with the pollen on the style. Hence self-pollination is effected (Fig. 20).

Fertilisation and the Fruit

The flowers of plants ultimately give place to the fruits. This is brought about by a physiological process known as fertilisation, the details of which cannot be appreciated by the children in our schools. The teacher, however, should know the details of this process, and such can be obtained from any good textbook on botany.

Briefly stated, the process of fertilisation is the union of a certain portion of the contents of a pollen grain with a minute structure called the egg-cell, which forms part of the interior of the ovule. From the union of these two parts an embryo or young plant develops within the ovule, the first leaves of which form the cotyledons or seed leaves. During the process of ripening, the cotyledons become packed with reserve food material, and in course of time the ovule becomes "a seed."

For the guidance of the young Nature-Study teacher a few of the details follow. The ovule is a small oval body attached to the carpel by a stalk called the funicle; in some cases it is sessile or has no stalk. It consists of a mass of thin-walled tissue termed the nucellus, surrounded by one or two coats called integuments. When young the nucellus is naked, but later

a pair of ring-like outgrowths arise from the funicle and grow up around the young ovule, leaving only a tiny pore of micropyle exposed at the apex of the nucellus. In the latter, quite near to the micropyle, is a clear oval space called the embryo sac which contains the female germ cell, together with other structures (Fig. 21).

The pollen grain is at first a single-celled body covered by a double cell wall. When ripe its contents divide into two, a small "reproductive cell" and a larger "vegetative cell" (Fig. 22). These cells, however, are not divided by a definite cell wall and are not well defined. When a ripe pollen grain falls on a suitable stigma it is said to germinate. The outer wall breaks and the inner wall grows out to form a tube which penetrates the tissues of the style until it reaches the ovary. In some wonderful manner the pollen tube is attracted by the micropyle of an ovule. Here it passes through the apex of the nucellus and comes into contact with the embryo sac. The living contents have, meanwhile, been slowly moving down the pollen tube, and eventually pass into the embryo sac. Here the reproductive cell fuses with the largest of three cells, which form the egg apparatus. This fusion of a single male cell with a single female cell is known as fertilisation.

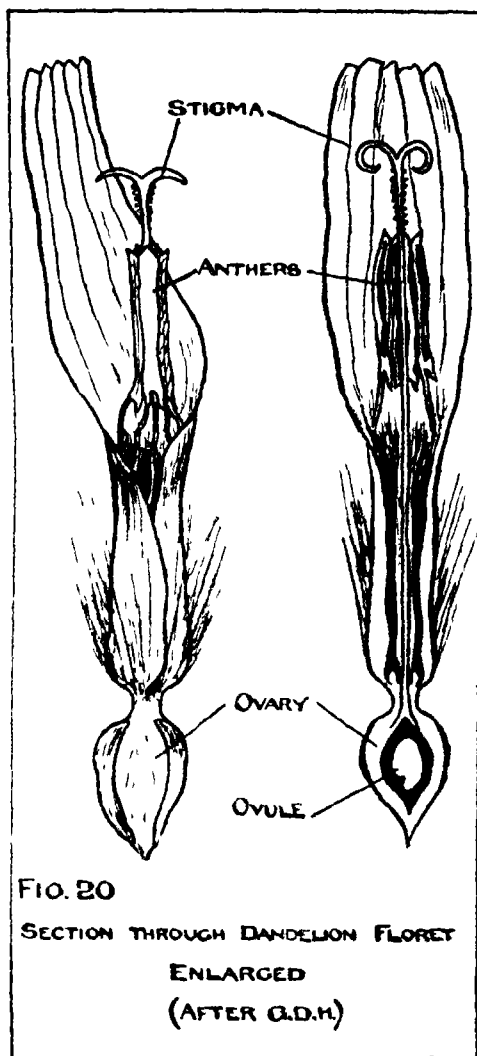
After this union rapid division takes place. The embryo is formed with its one or more cotyledons. What were the integuments of the ovule become the testa of the seed, which develops generally into a comparatively hard and resistant covering; the micropyle remains an opening into the seed; the stalk or funicle of the ovule develops into the stalk or funicle of the seed.

Formation of the Fruit

Immediately after this process has taken place the andrœcium and corolla usually wither up and drop off; in many cases the sepals fall also. The style and stigma also die off, but the ovary in all cases remains and grows rapidly to accommodate the developing seeds. When the ovary has reached its full development it is called the fruit of the plant; the carpel walls of the gynœceum enclosing and protecting the seeds form the pericarp of the fruit.

Unfortunately the term fruit is used in a very haphazard manner, and will be found a source of difficulty in Nature-Study work. It is used in popular language to describe a number of different parts of plants which have no connection with the ripe gynœceum of a flower. In the Apple, for example, the succulent part is the enlarged receptacle of the epigynous flower. (It will be remembered that in this case the receptacle and ovary walls are fused.) The true fruit of the Apple is the "Core." The Tomato, Cucumber and Vegetable Marrow are true fruits, that is, they are the ripened gynœceum; in popular language they are known as vegetables. The Strawberry is another example which will give trouble; the succulent edible part is the receptacle of the flower; the fruits are the small seed-like bodies studded over the receptacle.

True fruits may either be simple or formed of a collection of free carpels, as in the aggregate fruits of the Raspberry or Blackberry. A simple fruit may be formed by one free carpel, as in the Pea, Bean and Gorse, or by united carpels, as in the Wallflower and Hyacinth. The fruit of the Raspberry

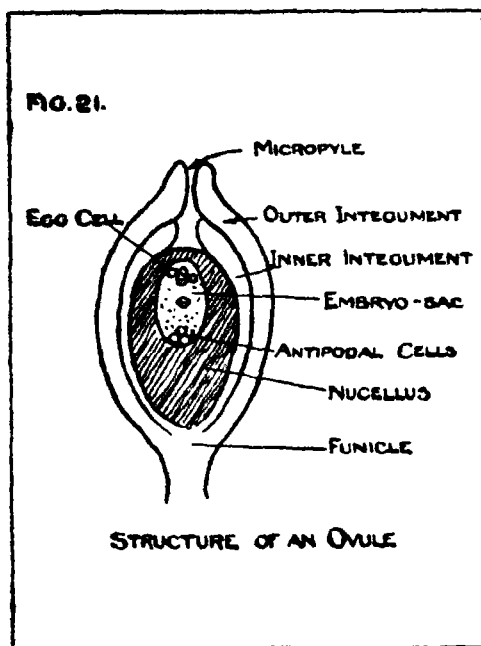


THE DANDELION.

This flower shows an arrangement for self pollination when cross pollination has not been effective. The divided stigma curls in order to reach the pollen on the style.

and Blackberry consists of an aggregate of ripened carpels inserted on the persistent receptacle.

In many cases the apparent fruit is not derived from a single flower, but from an inflorescence. The head or "Clock" of the Dandelion is a collection



STRUCTURE OF AN OVULE.

The pollen grain rests on the micropyle— the tube passes down to the nucellus

of simple fruits, each of which is formed from a single flower (Fig. 23).

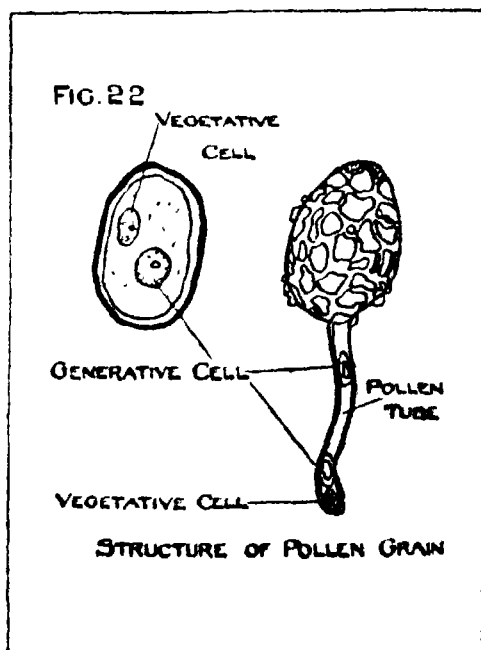
Fruits may be divided into four main groups in accordance with the texture of the pericarp (the outer wall of the ovary) and from the manner in which the seeds are set free. It will be realised that the purpose of the fruit is to secure the dispersal of the seed.

Generally, when a fruit contains more than one seed, the pericarp splits or dehisces in order that the seeds can escape. Sometimes the pericarp becomes hard and dry, or it may remain in a soft and fleshy condition.

I. Dry Indehiscent Fruits

One type of fruit met with is that which does not split up and whose pericarp becomes dry and hard. Such fruits are described as dry

indehiscent fruits. *The Nut* is a good example. In this case the pericarp becomes quite hard and woody. Examples are met with in the Hazel Nut, Beech Nut and Spanish or Eating Chestnut. Such fruits are derived from inferior syncarpous ovaries. The pericarp in all cases does not become hard, but forms a thin leathery covering. For such fruits the term *Achene* is used, examples of which are to be found in the Buttercup, Strawberry and the Rose. As a rule achenes are formed from superior apocarpous ovaries. When the seeds are united with the walls of the ovary or pericarp the fruit is described as a caryopses. Fruits resembling achenes have wing-like structures attached to the pericarp; such fruits are termed *Samaras*, excellent examples being met with in the



STRUCTURE OF A POLLEN GRAIN.

After the formation of the pollen tube, the vegetative cell is the first to pass down.

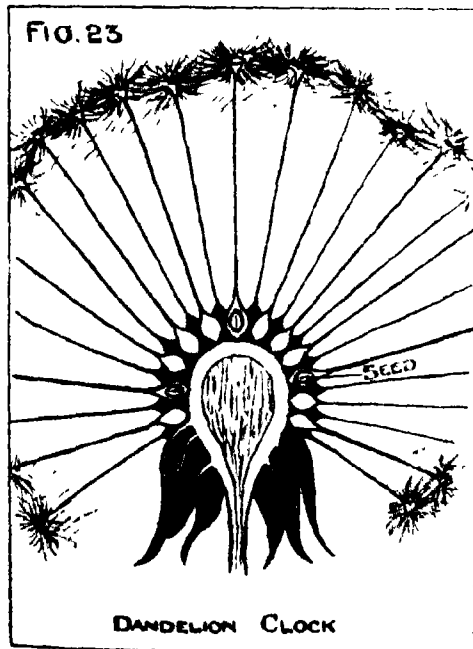
Ash, Elm and Sycamore (Double Samara).

2. *Schizocarps*

Some fruits composed of two or more one-seeded carpels split apart when ripe, thus separating into several "mericarps" or "nutlets." Good examples are found in the Dead-nettle Family, and in the wild Geranium, Cranebills, Mallow, etc. These splitting fruits are known as Schizocarps. The Sycamore is an example of a splitting Samara.

3. *Dehiscent Fruits*

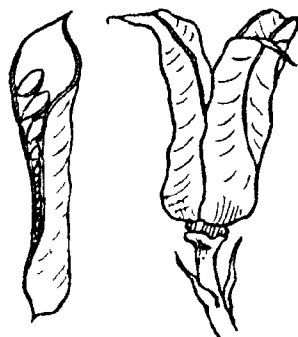
A fruit in which the pericarp splits or opens to release the seeds is known as a Dehiscent Fruit. Many types are met with, the most common being :



THE DANDELION CLOCK.

Each achene is provided with a hairy pappus which acts as a parachute—an aid to dispersal.

FIG 24.



A FOLLICLE

THE MONKSHOOD.

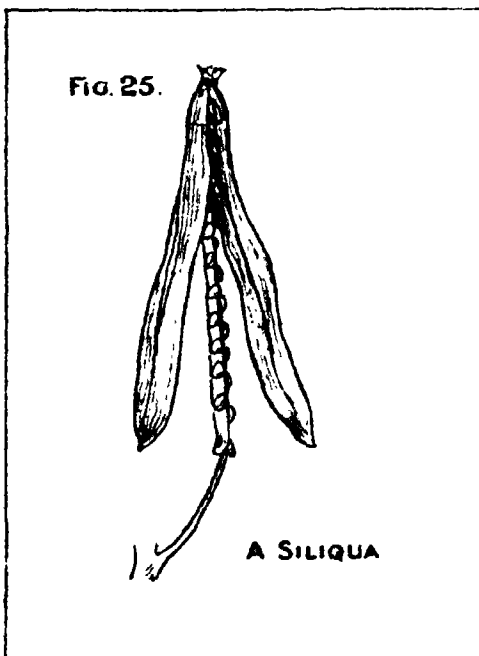
A follicle is a special form of capsule—one side of which opens.

(a) The Legume, a superior fruit consisting of one carpel, which splits along both sides (Sutures). Peas and Beans are examples.

(b) The Follicle is formed from a superior ovary, but splits along one suture only. The Columbine, Monkshood and Larkspur are examples of this kind of fruit (Fig. 24).

(c) The Siliqua. In the Wallflower the fruit is formed by a two-chambered ovary. When ripe, the two carpels dehisce from below upwards and leave the seeds attached to the placenta. This type of fruit is termed a Siliqua, and examples are met with in the Hedge Mustard, Turnip, Cabbage, etc. In the Shepherd's-purse the fruit is quite short and broad at the top. The name Silicula is applied to this fruit (Fig. 25).

(d) The Capsule. This term is usually applied to practically all forms of dry dehiscent fruits except those previously mentioned. They may be formed from either superior or inferior ovaries, and generally are many-seeded. The manner in which the split occurs is varied; most frequently it is longitudinally (Fig. 26). In the Chickweed and Stitchwort the capsule opens by means of "teeth" at the top. That of the Willow, Foxglove, Tulip, Willow Herb, etc., opens by valves separating from above downwards. The Poppy Capsule dehisces its seeds through pores under the stigmas (Fig. 26A). Another interesting dehiscence is that of the Scarlet Pimpernel and Plantain and the Red Clover. The capsule separates horizontally and the upper part falls off in the form of a cap or lid.



THE FRUIT OF THE WALLFLOWER.

The carpels open from below upwards—leaving the seeds exposed.

4. Succulent Fruits

In the fleshy or succulent fruits the pericarp is more or less soft and juicy. The most common types are the following:

(a) The Drupe is an indehiscent superior fruit consisting of a single carpel. The ripe pericarp shows three distinct layers, the skin or epicarp, the fleshy part or mesocarp and a hard, bony layer which forms the "stone" of the fruit, called the endocarp. The seed is quite separate from the stone. Examples of this kind of fruit are seen in the Cherry, Plum, Apricot, etc., and in the Raspberry, Blackberry, etc. In the latter the separate carpels are single drupes or drupels; the whole fruit, being a compound one, consists of a collection of drupels. The so-called berries of the Holly, Elder and Hawthorn are compound drupes. These fruits are formed from syncarpous ovaries, each chamber of which may form a distinct stone or drupe.

(b) The Berry. The Gooseberry is an example of another type of fruit. In this case the endocarp does not form a stone, but remains, like the mesocarp, soft and fleshy. The seeds are embedded in this succulent part. Currants, Cucumbers, Tomatos, Grapes, Bananas, Oranges, etc., are further examples. Dates are berries, the seed of which should not be confused with the stone of the drupe.

(c) The Pome is an indehiscent "false" fruit. Good examples are found in the Apple and Pear; the true fruit is the "core," the succulent part being the fleshy, swollen receptacle.

Dispersal of Fruits and Seeds

The purpose of the fruit is to secure the dispersal of the seeds, hence many

means are adopted to secure the performance of this function. In some instances the fruits have explosive or mechanical devices to shoot their seeds some distance from the parent plant.

Explosive Fruits

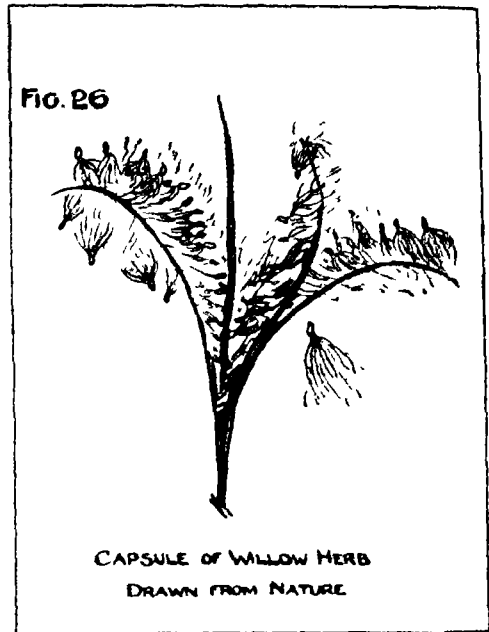
The Violet and Pansy are splendid fruits to observe in the classroom. The Capsules, when ripe, split into three curved pieces. As these dry they roll together and, squeezing on the polished ends of the seeds, force them to jump away. The Gorse fruits, when ripe and when the sun is shining on them, split suddenly open and shoot out their seeds some considerable distance. In other cases the valves of the pods, after opening, twist or curl up suddenly; the contraction of the valves forces the seeds away. The Bird's-foot Trefoil and Laburnum are excellent examples. The Balsam also is a good example. Its swollen, succulent capsules when ripe will, on the slightest touch, split open with such suddenness that its seeds are thrown several feet away.

Mechanical Devices

Mechanical devices for dispersal are found in the fruits of the bitter cresses, and many species of the Cranebill and Geranium. The Meadow Cranebill, found wild in the south of the country and often in cultivated gardens farther north, is an excellent type for school purposes. The fruits are large and the catapult arrangement can be induced to act in a warm room.

Dispersal by Wind

The wind is perhaps the most powerful and most obvious agency at work in the distribution of fruits and seeds. The number of modifications



THE CAPSULE OF THE WILLOW HERB.

This capsule is a beautiful object of study. Each seed is provided with a silky pappus—an aid to dispersal.

among plants to secure dispersal by this means is enormous. In some instances this dispersal is facilitated by the minuteness of the fruits or seeds and by the presence of a tuft of hairs or wing-like membranes, which increase the surface exposed to the wind without the addition of any great weight. Some seeds are smooth and round and easily roll along the ground.

In many plants, such as the Dandelion (see Fig. 23), Thistles and Groundsel, the calyx of the flower becomes a tuft of long delicate hairs which, acting as a parachute, prevents the rapid fall of the fruit when once the latter is taken up by the wind. In a moderate breeze the fruits of such plants are carried long distances before finally coming to rest. Frequently, when

seeds are large and heavy, as in the case of the Larkspur and Aconite, the fruit opens a little at a time, the wind rocks the fruit to and fro and a few seeds are jerked out now and again.

As a further aid to dispersal, some seeds are flattened. This is well illustrated in the Wallflower and the various mericarps of the Parsnip, Carrot, etc.

More commonly, however, special structures are formed which enable seeds, more especially achenes, to be carried by the wind. The simplest of the winged fruits is to be found in the flattened "Key" or Samara of the Ash. The spiral twist of the samara enables the fruit to be carried a short distance, even in a light breeze. Generally, however, the fruits are firmly attached, so that only a strong wind or gale will set them free and carry them some considerable distance.

Perhaps the Sycamore is even better known. The wing or blade is so balanced as to rotate when the fruit falls. This motion not only retards the fall but enables the fruit to travel far, especially if it comes from the higher branches of the tree. In the Birch and the Elm the samara is formed from an outgrowth of the pericarp. The fruits are so light that the distance travelled even on the lightest breeze is very great. The Reed Mace or Bulrush has perhaps the lightest fruits of all. When the poker-like head has broken up, the tiny fruits, each with silky tassels, set off on their journey, being carried away by the slightest of breezes.

The seeds of the Willow and Poplar and the Willow Herb have hairy outgrowths; Willow trees in June are white with the down of released seeds. Poplars are similar. These trees are

remarkable for the tiny seeds they produce. The Willow-Herb or Rosebay is so called because of the resemblance of its fruits to those of the Willow. The capsule of the plant is extremely fascinating to children. The opening can be observed in the classroom, and the light, plumed seed will float about in the room. Before opening, the seeds and plumes are neatly packed along the central axis, expanding as the capsule opens from the tip downwards.

Dispersal by Animals

Many fruits are sticky or possess hooks which may adhere to the wool or fur of passing animals. As a rule these contrivances are not borne by the seed, but are outgrowths of the fruit. The burrs (Infructescences, i.e. collection of fruits) of the Burdock, Burweed and Teazel are typical examples of the passive dispersal of fruits by animals. In the fruits of the Goosegrass, Hound-tongue and Wood Avens (*Geum*) are found examples of clinging fruits; the awn-bearing grains of barley also exhibit clinging tendencies.

Many succulent fruits are eaten by birds or animals as food, and the seeds of such fruits pass through the stomach and intestines without injury. In most cases the seeds are protected by hard stones, as in the case of the Cherry and Plum, or by a thick leathery pericarp in most berries. Very often, however, the hard part of the fruit is never swallowed, but allowed to fall to the ground after the fleshy part has been eaten. The Rose Hip is a typical example. Birds eat the succulent receptacle, and often get one or more of the achenes in their mouths. In addition to being hard, the achenes are

covered with fine hairs, which irritate the palate of the birds, who quickly cast them out. Generally the succulent part of the fruit is conspicuously coloured, and hence becomes attractive to the feathered world.

Non-succulent fruits such as the Acorns and Nuts may be accidentally dispersed by animals such as the Squirrels. Such animals lay up hoards of these fruits in the Autumn, and often forget some of the hoards they have made

One or two points are of special interest with regard to fruit and seed dispersal. Fruits

of the achene and plumed type are only dispersed during dry weather. It should also be noted that when the seeds are unripe and unfit for dispersal, the parts of the fruit used as food are firm in texture, green and sour. When, however, the seeds are ripe, the fruit changes to some conspicuous colour and, in the case of succulent fruits, becomes softer, sweeter and develops a characteristic odour.

The Seed and Germination

In the section on Fertilisation it was pointed out that after the fusion of the "reproductive cell" of the pollen grain with the "egg" cell of the ovule,

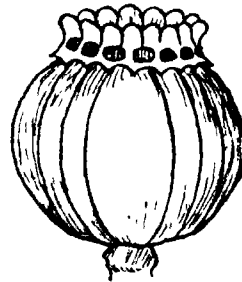
a seed was produced. The fertilised ovule contains an embryo plant together with a reserve of food material, generally stored in the cotyledon, for its

subsequent development. The nature and relationship of the component parts can best be understood when the seed has been allowed to grow and its development observed. A Broad Bean is one of the best seeds to study, for its parts are sufficiently large to be made out with the aid of a small pocket lens.

In the pod (Fig. 27) each seed is attached by means of a short stalk—the

funicle—and it is through this structure that all nourishment from the parent passes before and after fertilisation. When dry and ripe, each Bean seed is hard, and its surface uneven. On soaking in water for twelve hours or more, it becomes much softer, and its component parts can readily be observed. The outer skin, known as the "testa," has become smooth and has at one end a black scar, where the funicle was attached; this is called the Hilum. Quite close to the slightly broader end of the Hilum is a very minute hole—the micropyle—through which water will ooze if the soaked bean is squeezed slightly. The opening (as

FIG 26A



CAPSULE OF POPPY

THE CAPSULE OF THE POPPY.

The capsule of the Poppy opens by means of small pores, near the stigmata.

in the case of the ovule) communicates with the interior of the seed, and is the only one any seed possesses.

On removing the testa, which is a semi-transparent, leathery membrane (it will be found of much softer texture near the hilum), the cotyledons are exposed. These form two large fleshy halves, which are not completely separated from each other, but connected at the side with a conical projecting body, one end of which points towards the micropyle, the other end being turned inwards between the cotyledons. On removing one cotyledon, this can easily be seen.

When growth commences, the lower end of the small curved structure elongates and forces its way through the coat of the seed at a *point near to the micropyle (but not through the micropyle)* and assumes the form of a root. The upper half, bent between the cotyledons, also pushes its way out at the same opening and develops into the stem, from the tip of which leaves arise. Thus a seed is a packet containing a plant in a very rudimentary condition.

It should be noted that after the formation of fruits from flowers, the embryo plant within each seed assumes a resting or dormant state. In the Bean, the dry and hard appearance of the testa denotes clearly the dormant condition of the embryo. Under certain conditions, however, the plantlet or embryo begins to wake up, and on escaping from its protective coat is able to lead a separate and independent life. *This awaking to life from a resting condition to a state of active growth is called*

Germination

The conditions necessary for germination can be briefly summed up.

The embryo or plantlet must be alive. Air, water and heat are necessary to start it on its life's journey. The temperature varies greatly with the type of seed; some will germinate just above freezing point and others require a temperature of 9 or 10° C. to start growth. Beans will not germinate at 45° C.; it is too hot and they make, therefore, little or no progress. Water is obviously necessary to soften the hard coat, and oxygen (air) is essential to supply the necessary energy.

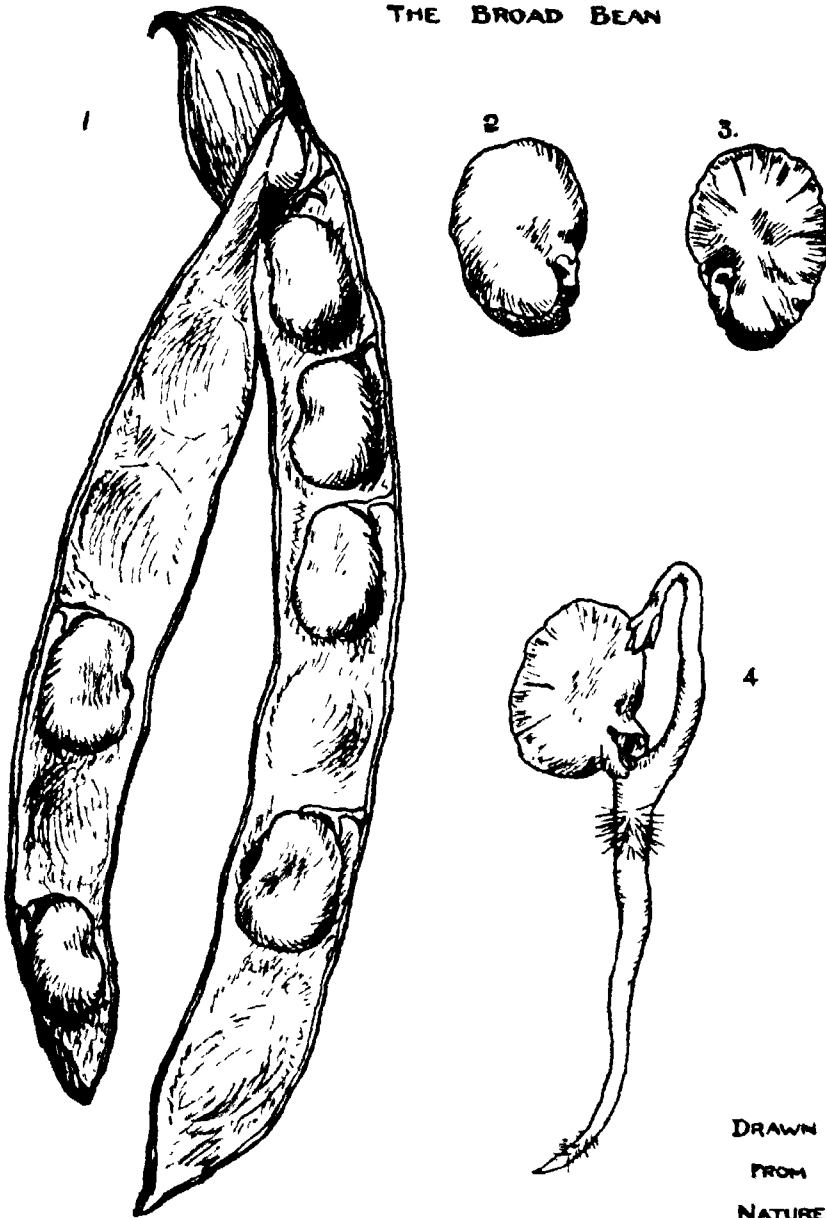
Seeds generally contain starch or carbon compounds in some form or other. In the case of the Bean, much of the solid material of the cotyledons will, on testing with iodine, give the characteristic starch reaction. Much of the work in the upper classes of a school will be based on the changes undergone during germination, and these will be dealt with as practical lessons. Briefly stated, the insoluble reserve food material found in seeds must be converted into soluble plant foods before the embryo can grow or germinate. This change is the result of enzyme action brought about when the temperature, amount of moisture and presence of air are sufficient.

To return to the Wallflower. It was mentioned in the section on fruit and seed dispersal, that the seed of the Wallflower had flattened sides and that this aided dispersal.

After a certain resting period, when the temperature is sufficiently high and the weather is moist enough to provide a supply of water, the process of germination begins. The testa takes up moisture from the soil, swells out and becomes a slimy coat which helps to fix the seed in the soil. Part of the water passes through to the embryo, and after

FIG 27

THE BROAD BEAN



DRAWN
FROM
NATURE.

THE BROAD BEAN.

(1) The "Fruit" of the Bean, showing the "seed" attached by means of short stalks called "Funicles." (2) The "seed" with the testa removed—the radicle can be clearly seen. (3) One cotyledon has been removed to show the position of the embryo. (4) A later development of the embryo.

enzyme action has changed some of the reserve food material into available plant food, the radicle or root elongates and breaks through the testa immediately above the micropyle.

In whatever position the seed may lie, the radicle, as soon as it is free, curves directly downwards and at once penetrates the soil. As soon as this has happened the root develops root-hairs or absorbing organs which take a firm hold on the soil and serve both as fixing and absorbing organs.

In the meantime the hypocotyle (that is the part below the point where the cotyledons are attached, and between the root or radicle) grows very rapidly and curves so that the apex of the stem comes to a point directly upwards. The cotyledons remain for a time imprisoned in the seed coat which is lifted up with them above the level of the ground, but they soon spread themselves out flat and in doing so strip off the seed coat.

The food supply necessary for germination is at first obtained from the organic substances (starch, etc.) stored in the cotyledons and also in a part lying, in the case of the Wallflower, on either side of the cotyledons, called endosperm, which is rich in proteid material. As soon as the root-hairs, however, have taken hold of the soil, they are able to supply mineral food to the growing plant, but it is only when the cotyledons have become green and expanded that new organic substances can be formed. The cotyledons have, therefore, a double function; in the early stages they serve as stores of food material for the seedling and afterwards act for a time as assimilating organs, manufacturing new food on their own account.

In both the Wallflower and the Bean the embryo has two cotyledons (Fig. 28).

In the Bean the cotyledons are food reserves only and remain underground. In the Wallflower the cotyledons come above-ground and act as assimilating organs until other leaves have developed. Further, the Wallflower has, independent of the cotyledons, a special reserve of food material (endosperm).

Seeds like the Bean, in which the reserve material is stored in the cotyledons, are called *Exendospermic*. The Pea, Vetch and Mustard are other examples. The Wallflower has a special reserve of endosperm, and is therefore called an *Endospermic seed*. The Castor Oil is an excellent example of an Endospermic seed. The cotyledons of the Bean also remain underground. Seeds of this type are termed *Hypogean*; those like the Wallflower, which come above-ground, are termed *Epigeal*. All seeds like the Wallflower and Bean, which have two cotyledons or seed-leaves, are known as *dicotyledons*.

Monocotyledons

Many commonly occurring endospermous seeds are not dicotyledons, and their structure varies in many respects from the type previously dealt with.

The Onion is typical of this variation. The seed is black, somewhat oval in outline, with one side convex, the other almost flat. Each seed contains an embryo embedded in endosperm (Fig. 29). When growth commences the curved part elongates and forces the end of the embryo out of the seed. The point, which is the radicle, forms a straight, slender, primary root. The part of this young

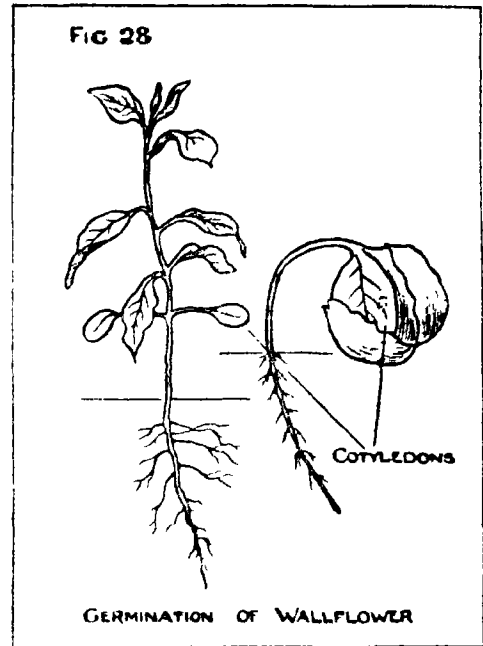
seedling which extends from the root into the interior of the seed grows very rapidly at first and assumes a bent appearance. Under outside conditions the bent "loop" comes above the ground, sometimes bringing the seed with it. The tip within the seed changes the endosperm into plant food and usually remains inside until all the nutriment has been absorbed.

The curved part of the embryo which comes above the ground is a hollow leaf—the cotyledon of the embryo. Within it is the plumule or primary axis, which consists of a series of hollow conical leaves, arranged one inside the other. At the point where the root and stem join is a swelling, and this indicates the position of the plumule. A short distance above this thickened part is a narrow slit through which the first green leaf of the plumule makes its appearance. Soon after one leaf has appeared, others follow, coming out through slits in the sides of those immediately older than themselves.

N.B.—In heavy soil, the seed does not come above-ground, owing to the close texture; in light, sandy or loamy soil the seed invariably comes above-ground.

Plants whose embryos possess one cotyledon only are known as monocotyledons, and such form the second large group of seed-bearing plants. The type described above is the best known.

Wheat, Barley and the Grasses are spoken of as monocotyledonous seeds, but in point of fact the so-called seeds are really the fruits. As an example the Wheat may be mentioned; the grain is a kind of nut with a single seed within it. The seed



THE WALLFLOWER.

The seed contains a small amount of endosperm. Note that the cotyledons form imperfect foliage leaves.

grows in such a way as completely to fill up the interior and becomes practically united with its inside wall. The embryo occupies only a very small portion of the grain, the remainder being taken up with the floury endosperm. The young plantlet is easily observed in the soaked grain on the side opposite to the furrow. It is separated from the endosperm by a fleshy shield-like structure known as the Scutellum. Attached in front of the scutellum is the plumule, which is a bud formed of sheath-like leaves, enclosing each other.

The embryo possesses as a rule three primary roots, which are protected by a sheath continuous with the scutellum and known as the *coleorhiza*. When germination takes place, this expands and bursts the seed coat and is followed

by the bursting through of the coleorrhiza by the developing roots. The grain remains below ground; the plumule grows upwards and appears as a thin, single, pale tube-like leaf. Later, through a slit in the cotyledon, the first flat green leaf appears, followed by other young ones, which grow from within the older ones in regular order.

Internal Structure of Plants

In the elementary schools, the internal structure of stems and roots, etc., cannot be taken in detail unless microscopes are available. Much can be done, however, with the aid of a sharp penknife and a good lens. In all schools the food of plants can be found or tested by means of sand or water cultures, but much of the work in this connection is purely informative. The contents of plant ash, for example, cannot be found experimentally in schools. A few details on cells and cell contents might be given in the upper classes and the osmosis, osmotic pressure, carbon assimilation, etc., explained in a simple manner.

The Cell

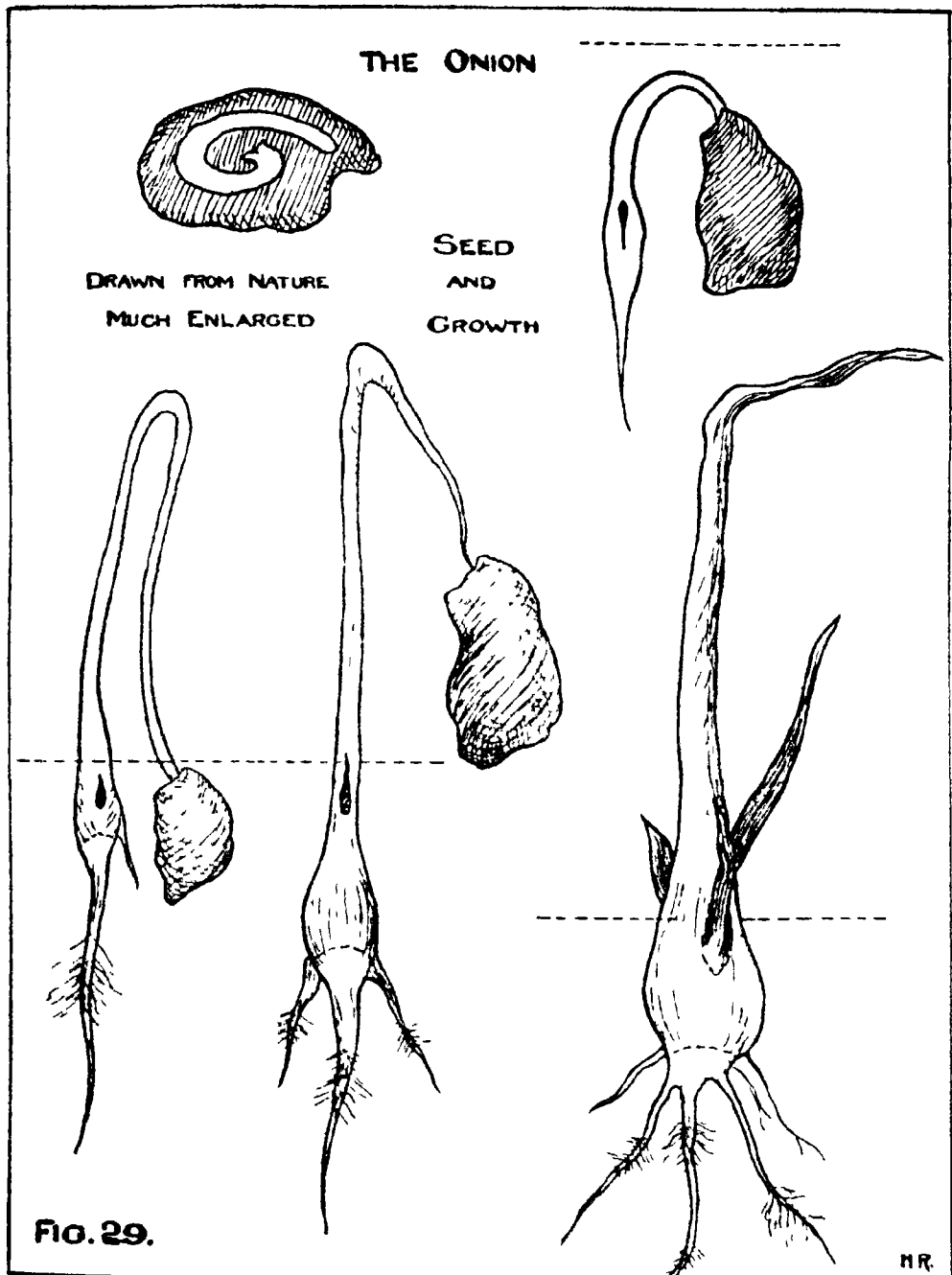
All life, animal or vegetable, consists of small cells. In plants the cells consist of a wall or cellulose, but in animal tissue this substance is absent. The contents of cells is much the same in both animal and plant, consisting of a complex chemical compound known as Protoplasm, a substance allied to the white of an egg.

The exact composition of this substance is unknown, but chemists have discovered, combined in protoplasm, the elements Carbon, Hydrogen, Oxygen, Nitrogen, Sulphur, and occasionally Phosphorus. A young plant cell

has for its walls a substance called cellulose, which is allied to starch, sugar and vegetable oils; that is, it contains carbon, hydrogen and oxygen. The interior of the cell contains protoplasm and a denser mass of protoplasm known as the nucleus. After reaching a definite size, the cell divides into two, the nucleus and the protoplasm dividing at the same time. These daughter cells increase in size and later may themselves divide. This division of cells is what is meant by growth.

Increase in length is brought about by division at the tip of roots and stems. Increase in size is brought about by the division of a special group of cells which form a ring inside stems and roots. This specialised group is known as the Cambium. On the inside of cambium cells, wood cells are made; on the outside bast. In older stems another specialised group of cells called the cork cambium produce cells which contain a substance termed suberin, and these form the bark of trees.

A number of cells grouped together, called vascular bundles, form the veins in the leaves. These consist of wood tissue and bast and give rigidity to the leaf. The remainder of the leaf structure consists of thickened wall cells on the upper face and thin wall cells with wide spaces in between on the underside. These open spaces are connected with the atmosphere by openings in the leaf tissues known as stomata, and it is through the stomata that the water taken up by the roots is passed off as water vapour into the air. This transpiration can be tested by inserting a leaf of a grown plant in a test tube and closing at the top with cotton wool. It will be found that water collects in the tube.



THE ONION.

This is a typical monocotyledon. The tip of the plumule remains within the testa until all the endosperm has been used. In light soils the seed is lifted above ground. The first foliage leaf of the onion breaks through the plumule just below the surface of the soil.

The leaves are very important parts of the plant. They are not only the organs of transpiration and respiration, but in sunlight they carry out the important work of splitting up the carbon dioxide of the air, and, with the carbon, manufacturing starch, sugars and oils.

The Food of Plants

The first step necessary in order to understand the nutrition of plants is to learn what chemical elements a plant contains. Most of the elements which exist have been detected at some time or other in plants; those, however, which are constantly present are only thirteen in number: Carbon, Hydrogen, Oxygen, Nitrogen, Sulphur, Phosphorus, Potassium, Calcium, Magnesium, Iron, Sodium, Chlorine and Silica.

Although these elements are constantly present on chemically analysing green plants, it does not follow that all are necessary to the life of the plant. Many of them are known to be essential because they enter into the chemical composition of the substances of which the tissues of the plant are composed. For example, C, H, and O constitute the starches, sugars and cellulose. Protoplasm, or proteids, contains these three elements, together with nitrogen and sulphur, while the nucleus contains in addition phosphorus. With regard to the other seven elements, plant analysis gives no clue as to whether they are necessary to the life of the plant or whether they are taken up simply because they are present in the soil.

This question can only be answered by experimental cultures so arranged that the exact chemical substances supplied to the plant are known.

The simplest method of examining the questions as to the necessity, or otherwise, of certain elements is by means of water cultures. A well-recognised food solution consists of the following:

Water, H_2O	1,000 c.c. (distilled)
Potassium Nitrate (KNO_3)	1.0 gram
Sodium chloride ($NaCl$)	.5 "
Calcium sulphate ($CaSO_4$)	.5 "
Magnesium sulphate ($MgSO_4$)	.5 "
Calcium phosphate ($Ca_3(PO_4)_2$)	.5 " (not quite soluble in water)
Iron chloride (Fe_2Cl_6)	a trace

It will be seen that the amount of the various salts is very small in comparison with the bulk of water. Plants, in nature, take up their food in so far as it is supplied to them by the roots in very weak solution.

To make the experiment of practical use it is necessary to germinate Peas, Beans, Wheat or Maize in damp sawdust or blotting-paper. The seedlings, when the plumule is about an inch long, should be washed in distilled water and then fixed to a split cork in a wide-mouthed bottle containing the solution. The young plant will grow strong and healthy and will ultimately flower and ripen its seeds if the solution is changed once each month. In fact, under these artificial conditions the plant may be brought through its entire life-history while the amount of organic substances is increased—it may be several hundredfold as compared with the amount contained in the seed to start with.

The success of the experiment proves that the compounds presented to the plant contain all that is necessary for its nutrition. Yet among the elements

contained in the water and salts one is conspicuous by its absence; no carbon was presented to the plant whatever. We know that every organic substance—cellulose, starch, sugar, proteids or any other substance—which goes towards the building up of tissue is a carbon compound.

From the water-culture experiment we prove that the carbon used by the plant must have been obtained from the air, this being the only source under the conditions; and it must have been obtained by those organs which are exposed to the air, namely the leaves and stem.

No compound of silica was added to the water, and this element cannot be obtained from the air. We infer that silica is not essential to plants, although it is generally present and is of great importance to grasses in hardening the outer surface of the epidermis.

Of the salts offered to the plants, sodium chloride can be proved unessential. It can be left out altogether from a food solution and the plant will come to maturity. The sodium can certainly be dispensed with. Some botanists regard chlorine in some form or other as necessary for some plants—but in the majority of cases it is not required. NaCl—these two elements are present in plants simply because they are present generally in the soil.

If, however, any of the other elements are left out from the plant food solution, the plant suffers, e.g. Fe. Without a trace of an iron compound the seedling grows normally for a short time; the new leaves when formed, however, are not green, but white—in fact they contain no chlorophyll. Hence no

assimilation can take place, and no increase in the organic substance of the plant can be produced. The green of the first few leaves is due to the iron in the seed. Hence iron is essential for the formation of Chlorophyll. When plants do not receive sufficient iron they are said to suffer from Chlorosis.

The necessity for the six elements which are known to enter into the compounds is self-evident and is easily proved experimentally.

For example—Phosphorus. To prove that this is essential, all we have to do is to leave out the calcium phosphate and substitute an equal amount of calcium sulphate. The growth of the seedling soon ceases—as soon as the phosphorus in the seed is exhausted—cf. iron.

In like manner the other tissue-forming elements can be proved to be necessary.

The presence of potassium, calcium and magnesium is also essential. If we substitute sodium nitrate for potassium nitrate, growth soon ceases; similarly by replacing the calcium and magnesium compounds by those of other metals, growth also ceases. These three elements are in some way, at present unknown, necessary for the process of assimilation. In their absence the formation of new organic substances is checked. Their exact mode of action is uncertain.

From a water culture we learn that the essentials for the nutrition of a green plant are ten in number, namely, Carbon, Hydrogen, Oxygen, Nitrogen, Sulphur, Phosphorus, Potassium, Calcium, Magnesium and Iron.

Nitrogen or the sources of Nitrogen need a further explanation. Nitrate such as Potassium Nitrate is quite

successful as a plant food. If Ammonium phosphate is used instead of nitrate the plant will still flourish, but it is possible that in this case the Ammonium compound is converted into a nitrate before being made use of—cf. Nitrate of Soda, Sulphate of Ammonia.

Most plants will starve without Nitrogen. The atmosphere consists of $\frac{1}{4}$ Nitrogen to $\frac{3}{4}$ of Oxygen. Except the Leguminosæ, plants cannot make use of the free Nitrogen. Bacteria (*Pseudomonas radicola*) in the roots help the members of the Pea family by symbiosis and form nodules on the roots.

Carbon Fixation—Photosynthesis

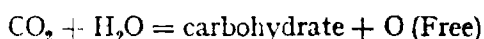
The source from which plants obtain the large quantities of carbon of which more than half their dry weight consists has been the subject of extensive investigation for years.

Parasitic plants like the Dodder, Broomrape and many fungi attach themselves to other living organisms, and absorb the carbon they need in the form of sugar, proteids and other elaborated carbon compounds from their tissues. The majority of common fungi, which, like the parasites mentioned, are devoid of chloroplasts or green colouring matter, obtain their carbon from the carbon compounds present in the remains of dead plants or animals on which they grow. It is probable that plants absorb and utilise carbon compounds from the humus present in the soil, but the supply produced by humus and fermentation has been proved to be insufficient for the requirements of ordinary green plants.

From the experiments with water and sand cultures, it should readily be found

that plants flourish and increase in carbon contents when their roots are supplied with a solution of food material containing no carbon, so long as the solution contains the other essentials. Under such circumstances the only available carbon is the carbon dioxide of the air.

After entering the cells by means of the stomata, the carbon dioxide, with a certain proportion of water, undergoes chemical changes which result in the formation of soluble carbohydrates, oxygen being set free during the process. The carbon of the carbon dioxide thus becomes fixed and a rapid accumulation of carbohydrates takes place, the oxygen escaping into the air.



As the operation is dependent on light, the term Photosynthesis is sometimes used, as also the term Carbon Fixation.

The exact nature of the carbohydrate first formed is unknown. Formaldehyde (CH_2O) has been suggested—



However, Formaldehyde has not been detected in the process of carbon fixation, and hence the view that this compound is the first step in the formation of carbon compounds from CO_2 and water is purely an hypothesis.

Sugars have been found in the cells of leaf tissues, and cane sugar is probably the first sugar to be manufactured, and subsequently dextrose, levulose and maltose make their appearance in leaves in consequence of enzyme action on the cane sugar.

In a great number of plants, when the accumulation of sugar within the cells reaches a certain point, the chloroplasts form starch grains from it; the starch

grains appear in the substance of the chloroplasts and are the first visible products of Carbon Fixation.

The manufacture or synthesis of carbohydrates is dependent on various conditions :

- (1) The plant must be living.
- (2) Carbon dioxide must be present in the air surrounding the plant.
- (3) The leaves must contain chloroplasts.
- (4) A certain intensity of light.
- (5) An adequate degree of temperature.
- (6) Mineral substances, especially compounds of potassium, but the exact part played by these substances is not known.

Carbon Fixation is a vital process, and the leading scientists are agreed that :

A. (1) Plants grown in air devoid of carbon dioxide do not increase in weight ; after a time death takes place from starvation.

(2) Plants cannot live in an atmosphere of carbon dioxide, but can exist in 20 to 30 per cent. of carbon dioxide and still carry on Carbon Fixation.

B. The work is carried on by specialised portions of the Protoplasm—Chloroplasts. The roots, petals and white portions take no part in Carbon Fixation. Leaves of Copper Beech, Purple Cabbage and Red Beet have reddish cell sap, which disguises the green colour of the chloroplasts.

The chloroplasts are small structures embedded in the cytoplasm of the cell ; their substance is permeated with a green pigment named chlorophyll, associated with which is a reddish-orange substance known as Carotin, and a yellowish material, Xanthophyll. The chemical nature of Chlorophyll is

unknown ; its production is in some way dependent upon the presence of iron, although it does not appear to contain this element. The red, orange and yellow rays present in sunlight are most effective in promoting carbon fixation. Purple and violet rays have little or no effect.

Osmosis and Osmotic Pressure

When a bladder filled with a solution of sugar has the opening securely tied with string and is then placed in a vessel full of pure water, it is found that a considerable amount of the latter soon passes through the walls of the bladder into the interior and mixes with the solution in spite of the fact that no visible openings are present through which the water travels. The result of this inward transference of H_2O is that an outward pressure is set up within the bladder, and it becomes more and more distended just as it would if water or air were forced into it by mechanical pressure.

The amount of internal pressure set up under these circumstances depends on the quantity of sugar dissolved in the solution and also upon the temperature at which this experiment is carried on. With a concentrated solution a greater pressure is produced than when a weak solution is used, and at a high temperature the pressure is greater than at a lower one. Similar internal pressure tending to expand the bladder is observable when solutions of potassium nitrate, copper sulphate and many other substances are used instead of a sugar solution. Each of these solubles possesses a different power of attracting water through the walls of the bladder ; the pressure set up by a 1 per cent. solu-

tion of sugar is not the same as that produced by a 1 per cent. of potassium nitrate.

It will be found that while the water passes into the sugar solution (or other solution in the bladder) a certain amount of the sugar passes out into the water. It is noticed that the diffusion or passage of the dissolved substances goes on through the membrane until the percentage or strength of the solution is the same inside as out.

Certain membranes are known, however, which will allow water to pass through them but which are not permeable to sugars and other dissolved substances.

The diffusion, or passage of liquids and solutions of substances through membranes in which no visible openings are present, is termed *Osmosis*; the pressure set up in the interior of closed permeable membranes is spoken of as *Osmotic pressure* and the dissolved substances upon which the pressure is primarily dependent may be designated *Osmotic substances*.

A bladder or other structure distended by osmotic pressure becomes firm or rigid instead of limp and flabby, and in this condition it is said to be turgid.

Application

Dissolved in the cell sap of all living plants are osmotic substances, such as sugars and salts of various kinds, which have the power of attracting water into their interior, and when plant cells are immersed in pure water they become turgid.

In the living parts of plants, and especially those which are adequately supplied with water and those in which active growth is going on, the cells are

distended by osmotic pressure and this stage of turgidity is the cause of the elasticity and firmness exhibited by the thin-walled parenchymous tissues of leaves, growing points and other delicately constructed parts of plants.

The pressure within young turgid cells usually amounts to five to ten atmospheres, and under its influence the cytoplasm (liquid part of protoplasm, finely granular substance) is forced outward into close contact with the cell wall at all points. The cell wall becomes stretched until its elastic recoil equals that of the outward pressure. In the cells of fruit containing considerable amounts of osmotic substances in the cell sap, the pressure set up in wet weather when abundant water is conducted to them is sufficient to burst the cell walls and the fruit splits.

The osmotic properties of a plant cell are, however, not the same as those of a bladder filled with sugar solution, for in most instances cells containing sugar and other substances do not allow these to pass out into water in which the cells may be immersed.

Whatever substances pass into or out of a living plant must permeate both the cell wall and the lining of cytoplasm. While pure water finds a ready passage through both membranes, the cytoplasm is very frequently quite impermeable, or permeable in a slight degree only, to many substances which easily pass through the cell wall. Also the permeability of the cytoplasm alters with the need of the plant.

When a turgid cell is immersed in a solution of a substance whose attraction for water is greater than that possessed by the substances dissolved in the cell sap, a larger or smaller

amount of water is withdrawn from the cell and the osmotic pressure is reduced, the cell becoming smaller and limp. If the vitality of the cell sap is not destroyed and the osmotic action of the solution is continued, more water is abstracted from the vacuole, but the cytoplasm, instead of remaining in contact with the cell wall and allowing the solution to penetrate into the vacuole, shrinks away from the cell wall and takes the form of a spherical ball in the centre of the cell cavity, and the living cell is said to be *plasmolysed*—the space between the cell wall and the shrunken cytoplasm being occupied by the solution.

Cells plasmolysed in this way do not lose osmotic substances, and regain their turgidity when immersed in pure water again. Hence, substances passing in or out of the living cell are controlled by the cytoplasm—the phenomena of turgidity and other osmotic property are destroyed when death of the cytoplasm takes place.

TREES

The story of trees in town and city schools may present difficulties. However, there is a general tendency in these enlightened days to have trees planted in the street wherever possible. Even when this is done the trees are seldom, if ever, allowed to take the natural course of development, and hence public parks should be visited in order to observe trees at their best.

In many towns and cities specimens of trees and twigs, etc., are readily supplied to schools taking a Nature-Study course, and every help is given by the controlling bodies. In at least one large town of the Black Country certain

parts of the parks are temporarily closed to the public during the afternoons on which schools visit them for observational work. During the winter months also, twigs of the various trees are sent to the schools taking Nature Study. This co-operation of the Town Council with the Director of Education has a stimulating effect on the Nature-Study teaching in the schools and reacts beneficially to the park keepers. Scholars learn that Nature-Study "instruction" and observational activity do not mean "destruction," and they become imbued with the idea that public parks have their uses and must not be abused.

In country districts more scope is available for the study of trees. The more common types, such as the Oak, Ash and Elm, are generally well known, but useful work can still be done. Many hedgerow trees, such as the Spindle Tree, Whitebeam, Wild Cherry, Sloe and Crab Apple, are comparatively unknown even amongst country scholars.

It is possible to regard the work on tree life almost as the individual observational work of the scholars. At about the age of 11 or 12 each scholar should be asked to select a tree to study throughout the year. Notebooks should be provided in which to make records, drawings, etc. These should be inspected by the teacher at stated times, the observations checked and useful hints for further work given individually. It is understood that at this age the scholars have a certain botanical knowledge, and this should be made full use of in the notebook. In addition to the individual work, tree life should be included in the Nature-Study scheme.

The identification of the common trees of the district by means of the branching, bark and alternate bud arrangement might be taken in the lower classes; identification by means of buds and bud arrangement of a spiral character in the middle classes, and later in the upper classes by means of the naked buds and by their leaves. In the top class, some information as to the value and uses of the wood of the trees studied should be given, full use being made of the knowledge gained by actual observation of the children.

The bud and bud arrangement give the widest scope for winter activity. The teacher should begin such work with the trees nearest the school, gradually widening the sphere of activity. The following information is intended purely as a guide. Much more information will be discovered by the personal observational activities of teacher and scholars, but this section is included in an attempt to point out to those whose knowledge of Natural Science is sparse, the paths of study which will provide a lasting interest.

The Yew

The Yew belongs to the coniferous trees. It is an evergreen, and its sombre green masses are common in churchyards. It is a native tree in some parts of England, especially in the south, where it forms thickets on the Downs. It is a large tree, though not generally tall, 50 feet being exceptional, but its girth is out of proportion to its height, 25 feet to 50 feet in many old specimens.

The male and female flowers are borne on separate trees. The male are round clusters of stamens, which in March send off immense quantities of

pollen, some of it reaching the little bud-like cones of the female, which afterwards bear the fruit and seed.

The seed is contained in the familiar red cup-like fruit. The leaves are poisonous, but the berries appear harmless to the birds.

The tough elastic wood was the material of the famous English long bow. The wood of the Yew is now valued, on account of its fine grain, for cabinet-making.

Cedars

There are three Cedars, none of them natives of this country. They are evergreen. The cones are erect and large. The largest Cedar is the Deodar, which may reach a height of 200 feet in its home in the North of India. The most celebrated, and the Cedar best known to us, is the Cedar of Lebanon. The timber of the Cedars, which is fragrant, is little used in this country. The tree was introduced into England in the seventeenth century.

The Beech

One of the most beautiful of our forest trees is the Beech. It is a stately tree, often reaching to a height of 100 feet, with a girth of 20 feet. The bole sometimes reaches to 20 feet without a branch; the bark is smooth, but not polished like that of the Birch.

In May, the male flowers hang on delicate green stalks, fluffy balls with little silver threads tipped with green. The female flowers are small and erect. Both are found on the same tree.

The fruit is a three-sided capsule, enclosing the seeds. The Mast, as the nut is termed, was in past times the staple food of herds of swine.

This tree is also very beautiful in

summer and autumn, although very few plants grow beneath it, the drip being fatal to them. Its beauty is increased in autumn, when the colour of the leaves changes from copper to scarlet, vermillion or gold.

The wood is fine-grained and easily worked.

The Beech is one of the finest hedge plants, and can be made to form thick hedges of great height.

The Sweet or Spanish Chestnut

This is a native of North Africa which may have come to Britain with the Romans. Sweet applies to the fruit as distinguished from that of the Horse-chestnut, which is bitter. The two trees have no relationship. The bark is a brownish grey, and becomes furrowed with age. After the tree reaches the age of sixty to seventy years the heart wood deteriorates, as a rule, but the tree lives on for centuries.

The leaves are large, oval and pointed, with a glossy, rich green surface. It is a magnificent tree, growing to a height of 80 to 100 feet, and the breadth of the crown may be as great.

The female flowers give rise to clusters of fruit. Except in good seasons the fruits in this country are small, though there are many very fine trees to be seen. The nuts are largely imported.

Unlike many of our forest trees, the Sweet Chestnut can be, and usually is, easily propagated by means of cuttings.

The Horse-chestnut

The Horse-chestnut is the most beautiful ornamental tree we possess in this country. It is a native of the

Balkans, and probably was introduced here towards the end of the sixteenth century. It is the only tree of temperate countries which bears a profusion of large, brilliant flowers. In winter it is a distinctive tree, quite easily recognised from other trees.

The trunk, tapering, reaches almost to the top of the tree, which may be from 70 to 90 feet high. It is solid and substantial, with no fine twigs. The bark is rough and scaly.

The terminal bud is fat, oval and very sticky, and contains the leaves, flowers, fruits and seeds for the coming year. Beneath are usually a pair of resting buds, containing leaves only, and just below each of these buds is the horse-shoe-shaped scar of the fallen leaf, the nails represented by dots where the wood strands were severed in the previous autumn. Some people affirm that the English name for the tree was derived from this feature (Fig. 31).

Early in the summer the tree attains its full glory in blossom. The flowers are white, with yellow blotches tinged with pink, and a tree in full bloom is a beautiful sight.

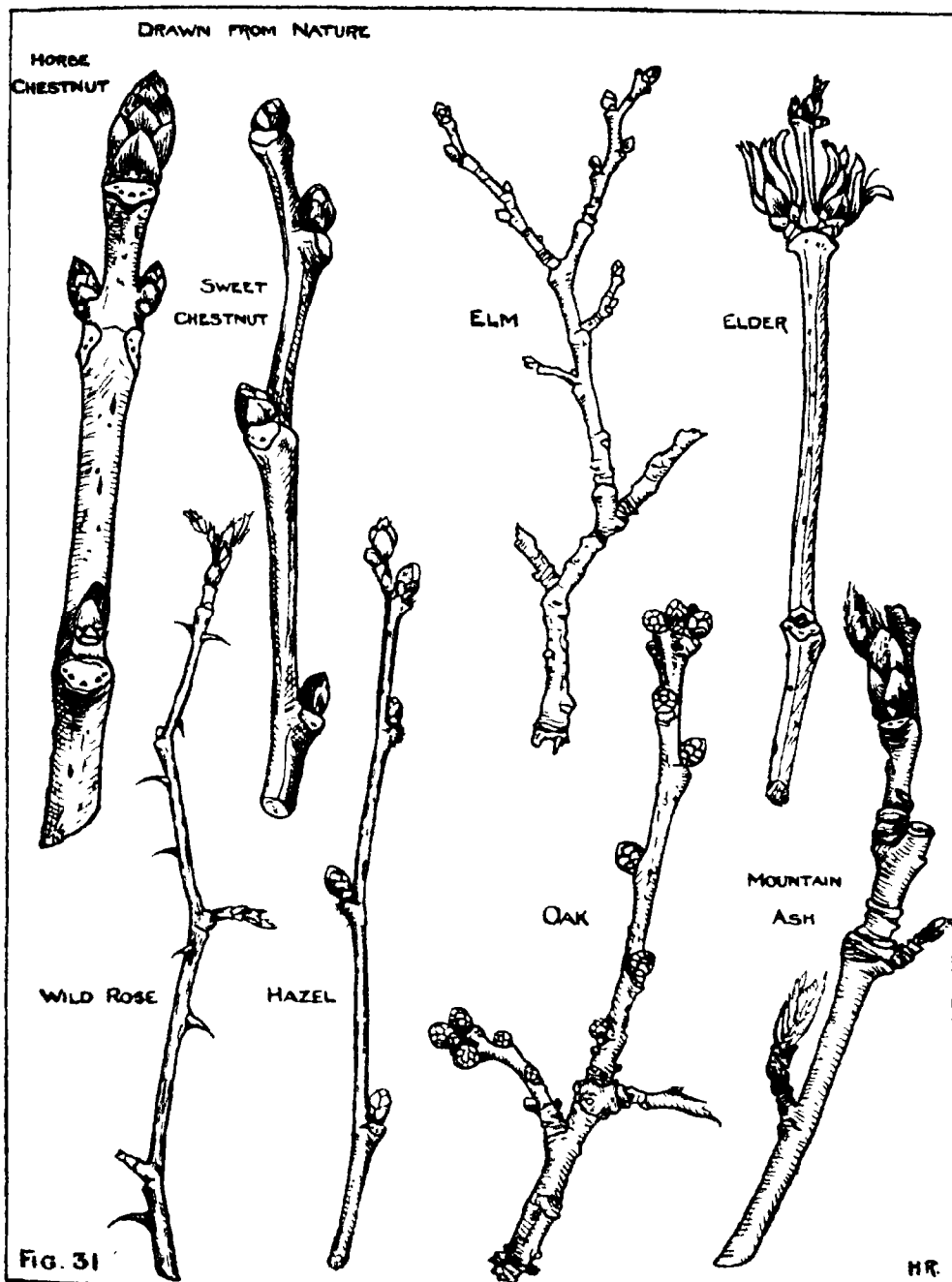
In the autumn the leaves turn to fine tints of yellow, orange and russet.

The rough green fruit is familiar, and small boys find a use for the seeds, or "conkers."

The tree seldom attains an age of more than two hundred years.

The Larch

This is remarkable as being one of the few coniferous trees which shed their leaves in autumn. It is a native of the mountains of Central Europe, and was introduced into this country in the seventeenth century.



BUDS.

The Horse and Sweet Chestnut twigs are given for comparative purposes. In the Horse-chestnut the large pointed buds are arranged opposite each other on the twigs—those of the Spanish or Sweet Chestnut are short and blunt and spirally arranged. The Oak, Elm and Hazel are examples of spirally arranged buds.

The trunk is tall and straight, the leaf short, narrow and needle-like.

The young female flowers in spring are rounded, about $\frac{1}{2}$ inch in diameter, with pale or brilliant carmine scales. The ripe cones have broad, brown, woody scales.

In form the Larch is a most graceful tree; the delicate green of its young leaves and the beauty of the female flowers make it a most pleasant sight along the highways or in the woodlands. It grows rapidly, and may reach a height of 80 feet in fifty years or may be felled for commercial use in forty years.

The wood is hard and resists decay. It is, therefore, much used for pit props, sleepers and telegraph poles.

The Birch

Perhaps the most graceful of our forest trees is the Silver Birch. In winter the gracefully curving silver stem, the branches and the drooping bronze-coloured twigs command admiration.

In summer, the tasselled foliage moves at the whim of the slightest breeze, and in autumn, it is again a beautiful sight.

The bark of the Birch was used by primitive man for a variety of purposes—the sides of canoes and the roofing of huts, while the fibre gave him fishing lines.

It is not a large tree, usually 40 or 50 feet high, with a girth of 2 or 3 feet.

The foliage exudes a sweet smell after rain. The bark is used in tanning, and gives the peculiar odour to Russian leathers.

The tree is a native of Great Britain, and also abounds in Russia, Sweden and Norway.

The Oak

"The Monarch of the Woods" is beautiful and useful in life and valuable afterwards. It is known to science as *Quercus rober*. ("Rober" is from the Latin, and signifies strength.) It is found throughout Europe and Asia, except in the extreme North. In Britain it is by far the commonest of our forest trees. A tree growing in a wood differs in appearance from an isolated oak. In crowded situations, the tendency is to develop lengthy timber, its whole energy being devoted to reaching the light, but where it has room to grow it makes a grand tree. It seems particularly liable to damage through electric storms.

The leaf is well known, but the flowers are not conspicuous. These appear about May, before the leaves expand. The male flowers are more numerous than the female, and are borne on long pendant catkins, having about a dozen flowers each. When ripe, the stamens burst and shed quantities of pollen, some of which, being scattered by the wind, ultimately finds its way to the female flowers. In the cases of wind pollination the flower must be produced early in the year, before the foliage is so thick as to be in the way and thus prevent the pollen from reaching the female flower. These will be noticed, standing erect, near the ends of the twigs, but, being small, are not so easily seen as the male.

The fruit is the well-known acorn. When the seed is mature, about October, the nut contracts, thus loosening itself from the cup, from which it is dislodged by the wind and falls to the ground. Autumn winds scatter the

seeds; Squirrels and other wood-folk carry and drop them about, and so the seeds fall from the parent plant often grow at great distances from it.

The Oak is of slow growth, and is thirty to forty years old before it bears fruit.

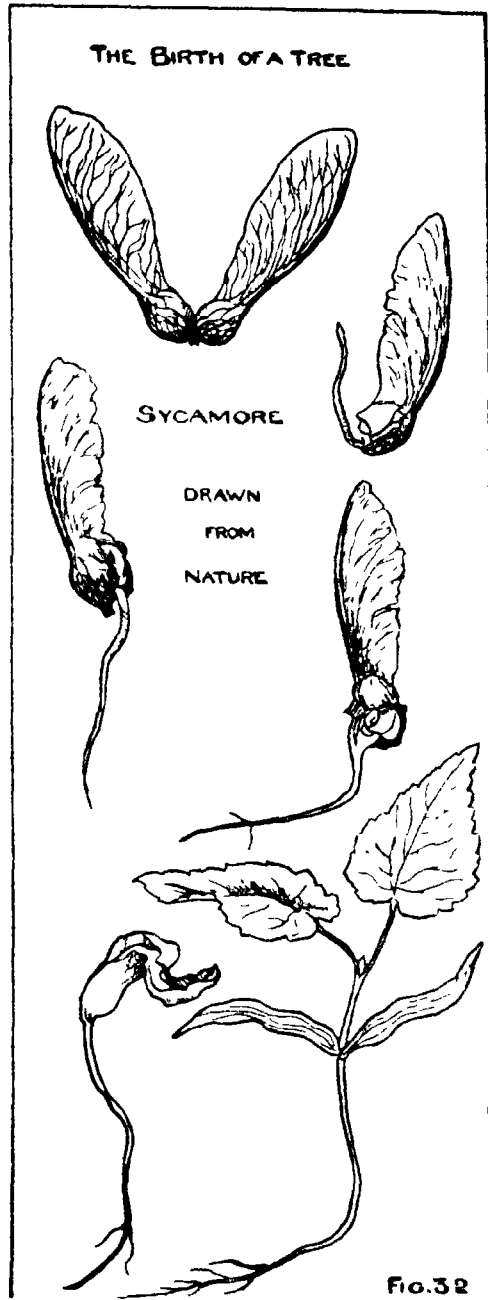
Oak timber is very hard and durable, and often shows a most beautiful silver grain. Next to the timber, its bark is most important, being used in tanning. The bark of some species of Oak, too, furnishes the cork of commerce. Large tracts of country in Southern Spain are covered with these trees.

There are many ancient and historic oaks which are objects of sentimental interest, Boscobel, near Wolverhampton, in which King Charles II is supposed to have sheltered from the soldiers of Cromwell, and the Shelton Oak, near Shrewsbury, from which Owen Glendower watched the Battle of Shrewsbury in 1403, being examples.

Oak trees often grow to a great age; they are said to be 300 years in growing, 300 years in maturity and 300 years in decaying. A monster tree which grew near Newport, Monmouthshire, was felled in 1810. The branches were said to have spread over 452 square yards, and the tree, which was sold for £600, yielded 2,400 cubic feet of timber and 6 tons of bark (Fig. 35).

The Ash

This is a tree which denotes strength and grace. Its trunk is firmly cylindrical, ash-grey in colour. The main branches grow gracefully in an upward oblique direction, the smaller branches first dipping down and then tilting up again, like the antlers of a deer. The tips of the branches are flattened, as



THE BIRTH OF A TREE.

The illustration shows the development of a young tree from the winged fruit. The double samara or the Sycamore should be compared with that of the Field Maple, Fig. 37.

if they had been pressed by a weight. Black buds are peculiar to this tree and make it the easiest to recognise.

The wood is used for all purposes where flexibility is required, such as the shafts of carts and traps, oars, axe and hammer shafts.

The leaves are compound pinnate.

The fruit is the well-known bundles of "ash-keys."

The Guelder Rose

This is more a shrub than a tree, and its wood is of little use commercially. As a common hedgerow shrub, however, its buds provide a useful study.

The buds are arranged opposite on the stems and closely pressed to them; the scales are generally of a pinkish nature.

The flowers of the Guelder Rose take the form of an umbel. The ray florets (or outer flowers) are incomplete and, therefore, cannot produce fruits. The true flowers are inconspicuous, but the fruits form beautiful red berries. In autumn the foliage is very conspicuous, changing from green to a mottled grey and later to a dark yellow.

The Sycamore

This is another of our hard-wood trees, the wood of which is used for the manufacture of furniture.

Its buds are opposite on the twigs and are protected by yellowish-green scales with dark brown margins and tips.

The bark is, as a rule, smooth and scaly. A full-grown tree has a sturdy trunk; strong branches, low down, are more or less horizontal, while those higher up the trunk have an upward

trend. The tree gives the impression of sturdy independence and offers a stubborn resistance to the strongest gale.

The fruit of the tree forms a double samara (Fig. 32). The wings are important from the point of view of wind dispersal.

Like all its allies, the Maples (Fig. 37), the tree has a very sugary sap, which often rises up and oozes through the leaves. This fact is a disadvantage to the tree and induces attacks from the Green Fly and also the Cuckoo-spit. From one of the Maples sugar is produced in America.

The Walnut

This is a fairly well-known tree in this country, and was introduced by the Romans. It is a very quick-growing tree, and reaches a height of 20 feet in less than ten years. When fully grown it may reach a height of 70 feet. Its trunk is covered with a rough, fissured bark, the branches being very crooked.

The leaves are similar to those of the Ash, but the leaflets are much larger.

The female flowers are formed on the new growth, the staminate flowers being produced at the tip of the last year's growth.

The seed of the Walnut is commonly termed the nut. After splitting open the hard shells, the two cotyledons are exposed. This is the part eaten. When carefully examined the embryo can be clearly seen between the seed-leaves.

The wood is valuable, and is used for furniture, piano cases, etc., the grain being a distinctive feature.

The Syringa

This is commonly called the Lilac, and is one of the most delightful of our flowering shrubs. It was introduced to this country from the east of Europe about the year 1595. There are many types now in this country. The white species, *Syringa Persica alba*, was introduced from Afghanistan, the crimson type, *Syringa japonica*, from Japan, etc. The shrub belongs to the same natural order as the Ash and Privet (*Oleaceæ*), and by reason of the early opening of the buds is useful for classroom work (Figs. 30 and 34). The wood is of little use commercially, the shrub being grown mainly for decorative purposes.

The Scots Pine

The Scots Pine (*Pinus sylvestris*) is perhaps the best-known conifer found in this country. It belongs to the second great group into which the Vegetable Kingdom is divided, viz. the Gymnosperms. The distinguishing feature of this plant division is that the seed is borne on an open carpel or scale. In the Pine the carpels or seed-bearing scales are situated together on an axis, thus forming the familiar "cones." There are only three types native to this country—the Pine, the Yew and the Juniper. At the present time, however, we have many plants belonging to this division, such as the Firs, Monkey Puzzles, Cedars, etc., which have been introduced and acclimatised.

The Scots Pine is found wild or self-sown in many places, but more often the young trees have been planted.

When young the tree has the regular pyramidal form familiar in its rela-



CATKINS OF THE WILLOW.

The male and female catkins are never found on the same tree. Each floret has a nectary, which contains a syrup very attractive to insects and night-flying Moths

tives used as Christmas Trees, but in older trees, the lower branches have usually perished and the crown of branches borne on the stout, tapering trunk is irregular but often beautiful.

If a leafy shoot is examined it will be found that the green leaves are not borne directly on the main stem. This bears only small brown scale leaves, which are spirally arranged and closely crowded. In the axil of each of these scale leaves is a lateral shoot. This has the remains of a few scale leaves and only two green foliage leaves. Between these the little growing point of the shoot will be found, but this remains inactive and the shoot bears no more leaves and does not increase in length. These two-leaved shoots, upon which all the foliage of the tree is borne, are called short shoots, in contrast to those to which the growth and branching of the tree are due. These long shoots bear only brown scale leaves.

The foliage leaves are the well-known needles; each is long, narrow and pointed, convex on the lower surface and flattened above. After living for several seasons, the short shoots, with their leaves, drop off and the older parts of the branch system are bare except for the scale leaves. The top of each long shoot ends in a large brown bud; this is covered with bud scales which protect it through the winter. In spring it grows into a shoot increasing the length of the branch, terminating in a resting bud. The short shoots have already developed on the new growth and have only to attain their full size.

Just below the terminal bud are several similar buds borne laterally. These, like the terminal bud, do not

develop further until the following spring, when they grow out into long shoots. Thus several branches stand at the same level, at the upper limit of each annual addition in length to the main stem or branch. Consequently the number of false whorls of long shoots denotes the number of years of growth of the stem which bears them. It is, however, necessary to add three to the number if we wish to calculate the age of the tree, because no false whorls are formed until the end of the third year of growth of the main stem.

N.B.—The female cones take the place of the lateral buds. The pine bears two kinds of flower, staminate and carpellary. The male inflorescences arise in the axils of scale leaves on the long shoots. They are inserted laterally on the more basal parts of the long shoots of the current year, and occupy positions taken by dwarf shoots on vegetative branches. Above the spike-like inflorescence a few foliage dwarf branches are seen. On older shoots, two or three years old, the spurs or scars of fallen staminate flowers are found (Fig. 36).

The female inflorescences are small, erect lateral cones, often two or three together immediately behind the terminal bud of the long shoots. They occupy positions similar to the lateral buds.

Thus a carpellary flower takes the place of a lateral long shoot, whereas a staminate flower replaces a vegetative short shoot.

With the Gymnosperms, special terms are used to indicate the various parts of the tree or shrub, and the following are the chief:

Leaves are arranged in pairs on a

OPENING OF BUDS (SYRINGA OR LILAC)

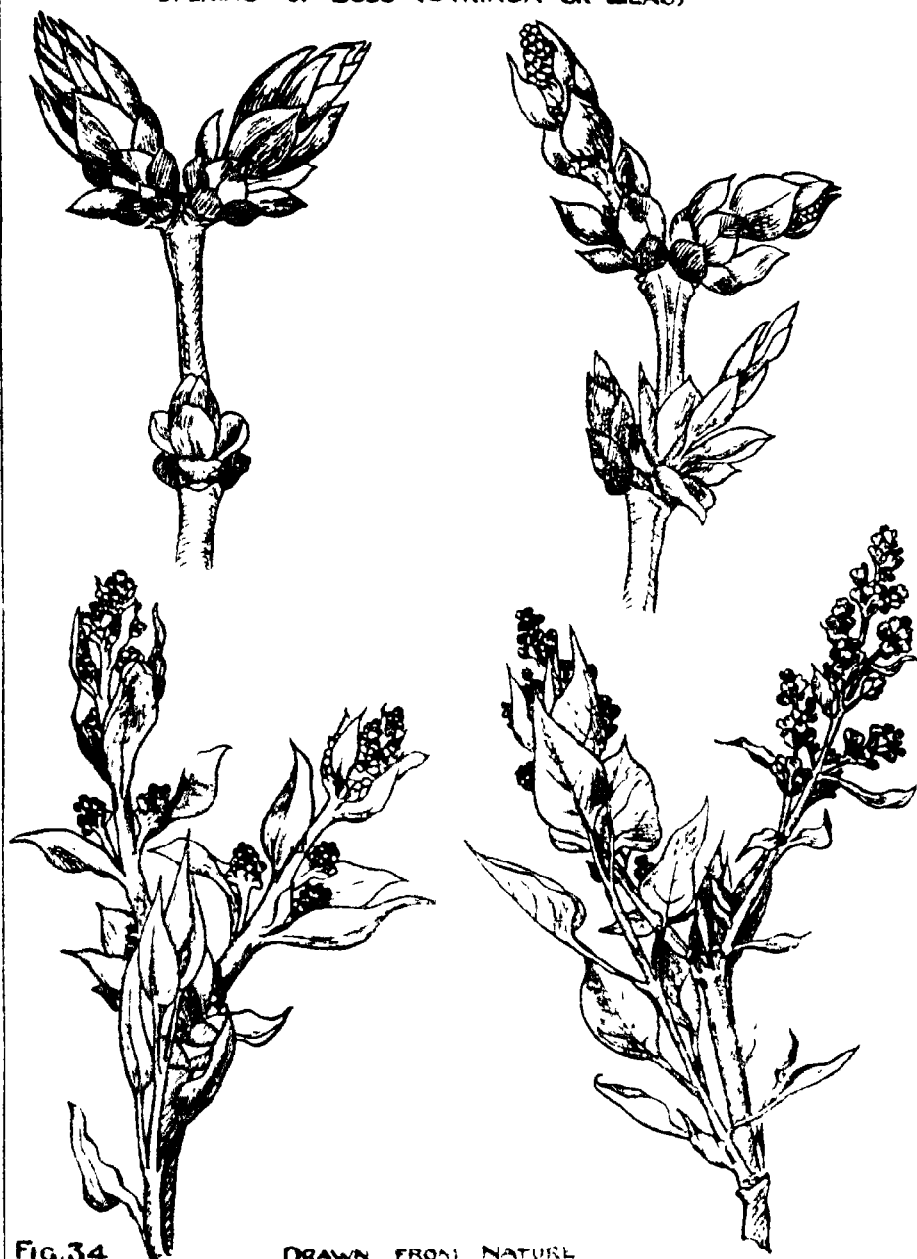


FIG. 34

DRAWN FROM NATURE

H.R.

THE OPENING OF BUDS

The two upper illustrations show the opening of the scale leaves, followed by the elongation of the axis of each bud. The two lower drawings indicate that in the twig used, the terminal buds produced flowers—the lateral buds formed vegetative shoots only.

short lateral branch in the axil of a small scale called a Kataphyll.

The term bifoliar spur is applied to the lateral vegetative short shoot; hence bifoliar spurs arise in the axils of scales known as Kataphylls.

At the end of the year's growth the bifoliar spurs produce scale leaves indefinitely. The spurs only last two to four years and then fall off; the whole short shoot or bifoliar is shed.

Sometimes the bifoliar spurs assume a different appearance altogether, taking the character of scales bearing sporangia.

The sporangia-bearing scales of sporangiferous leaves have sporangia on their undersides. The sporangia are always produced at the base of the year's growth. These sporangia are called Microsporangium, and each spore a Microspore. The spore has a balloon-like outgrowth on each side, and this enables the wind to bear away the pollen grain. The collection of male staminate cone is termed the Microsporangiate.

The staminal or sporangiferous leaves, termed microsporophylls, are arranged spirally on an axis. Each microsporophyll bears two microsporangia, containing a large number of microspores or pollen grains.

The Female or Carpellary cone is found at the upper part of the previous year's growth—occupying the position of a lateral bud. The cone has a fairly long stem, covered with scale leaves. Larger scale leaves are formed, on the upper surface of which is a large cushion, the Placenta, bearing a sporangium on either side of the base. These sporangia are termed Macrosporangia, the "spore" the Macrospore or embryo sac. The carpellary cone is, therefore, termed Macrosporangiate.

Each macrosporangium is covered with a coat or integument which has an aperture, mouth or micropyle at the base. Each sporangium contains only one spore.

Development of the Microspore

Before the pollen grain is ripe, important changes take place in its interior. Each microspore, when first formed by division of its mother cell, is merely a single cell with one nucleus.

(A) The wall of the cell is covered on the outside by a layer of cuticle. At two places on opposite sides of the grain the cuticle becomes separated from the inside cellulose wall. The spaces thus formed are filled with water, and when first formed are like blisters on each side of the pollen grain. The water is absorbed and the spaces become filled with air when the microspore is ripe. This curious arrangement has the effect of reducing the weight of the pollen grain in proportion to its surface—these lateral expansions acting as wings.

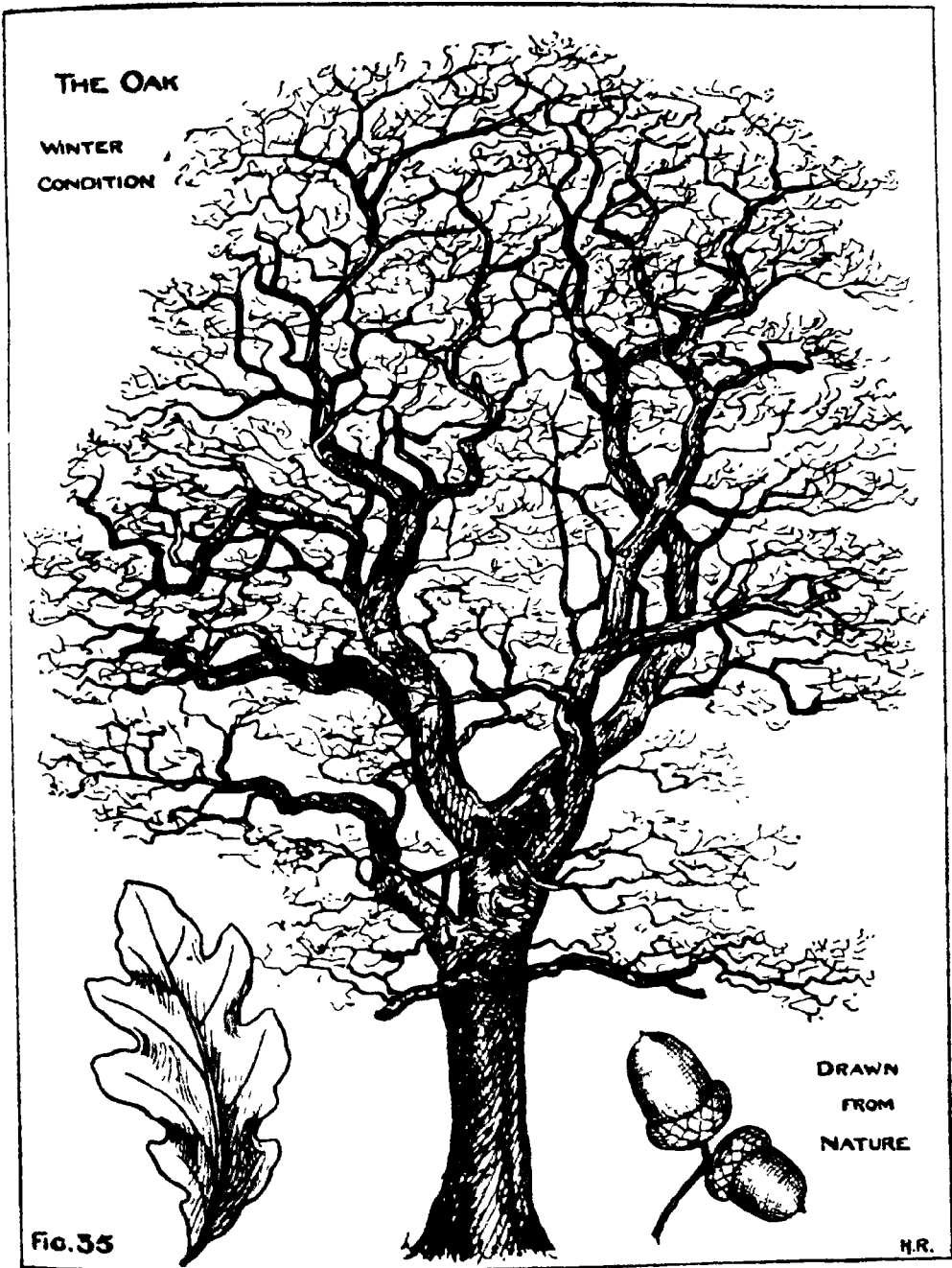
(B) Before the microsporangium dehisces, several changes take place.

(a) A small cell is cut off from the end furthest from the insertion of the wings, shaped like a watch glass.

(b) Two more cells are cut off, so we get three cells placed one above the other, and projecting into the cavity of the first cell. The first two cells collapse.

(c) The remaining cell grows rapidly and divides into two, forming a little Prothallial cell and a larger terminal cell (Generative cell), which is large enough to reach half-way across the cavity of the grain (Fig. 36).

The pollen rain or microspore of



THE OAK.

The "Monarch of the Woods" is the most valuable of our trees. Its thick trunk and large lateral branches give the tree the appearance of "rugged strength". It is typically English. The leaves are simple, yet deeply indented. Seldom are the flowers noticed, yet most people recognise the fruit—the Acorn.

Pines is, therefore, much more complicated than that of an Angiosperm.

Later Development, preceding Fertilisation

The large vegetative cell grows out at a point opposite to the generative cell to form a tube. At a later stage the antheridial cell or generative cell divides into two, each with a very large nucleus. The microspores are blown about by the wind and eventually come to rest on the Macrosporangiate.

The Macrosporangium

It has been noticed that the Macrosporangium consists of a conspicuous scale produced on the upper surface of a much smaller scale. These first small scales may be termed carpellary scales (bracts), and the larger outgrowths which bear the macrosporangia (macrosporophylls) can be termed ovuliferous scales. These scales may be regarded as a placenta, which, in this case, greatly exceeds the size of the carpel which produces it. There is much uncertainty as to the identity of the parts of the female cone.

Each macrosporangium consists of a mass of tissue known as the nucellus, surrounded by an integument which opens out into a wide, winged micropyle. In the nucellus one cell is much larger than the others, and this is termed the microspore, or embryo sac (Fig. 36).

In May or June the axis of the carpellary cone elongates, thus leaving spaces between the macrosporophylls. The microspores are carried by the wind on to the macrosporophylls, and alight on the micropyle of the integument. Later the nucellus closes up and draws the microspore down through the micropyle—the lips of the integument also close. More than twelve

months elapse before fertilisation takes place, but changes are going on inside the macrosporangium. Pollination occurs in May, but the process of fertilisation does not take place until the next year—in June.

The Female or Carpellary cones remain on the trees for three years, when the scales open out and expose the winged seeds. The wood is known as Red Deal, and is used for all kinds of school furniture. Often the smaller trees are cut into long lengths and used as pit props; scaffold and wireless poles are also made from the young trees.

The turpentine extracted from the wood is of medicinal value, but as a rule this material is imported.

The Elm

This is also a distinguished tree, found growing in all public parks and in country areas. It is a shallow-rooting tree, its main roots keeping within the first three feet of soil. The main branches are usually thick and brittle, rendering an avenue of Elms a very unsafe place in a gale. The bark is usually very thick and rugged, and often the smaller twigs show the corky nature. The inner part of the bark, the bast, is known as "liber." This is very tough and stringy, and is used for making rope and mats. The wood is hard, will take a fine polish, and is used for indoor purposes.

The winter buds are of two kinds, the small oval leaf buds and the larger round flower buds, which open first. The purple flowers open early in March, before the leaf buds have developed. Although winged fruits are formed and can be seen at the end of April, they seldom ripen in this country. This

PINUS SYLVESTRIS

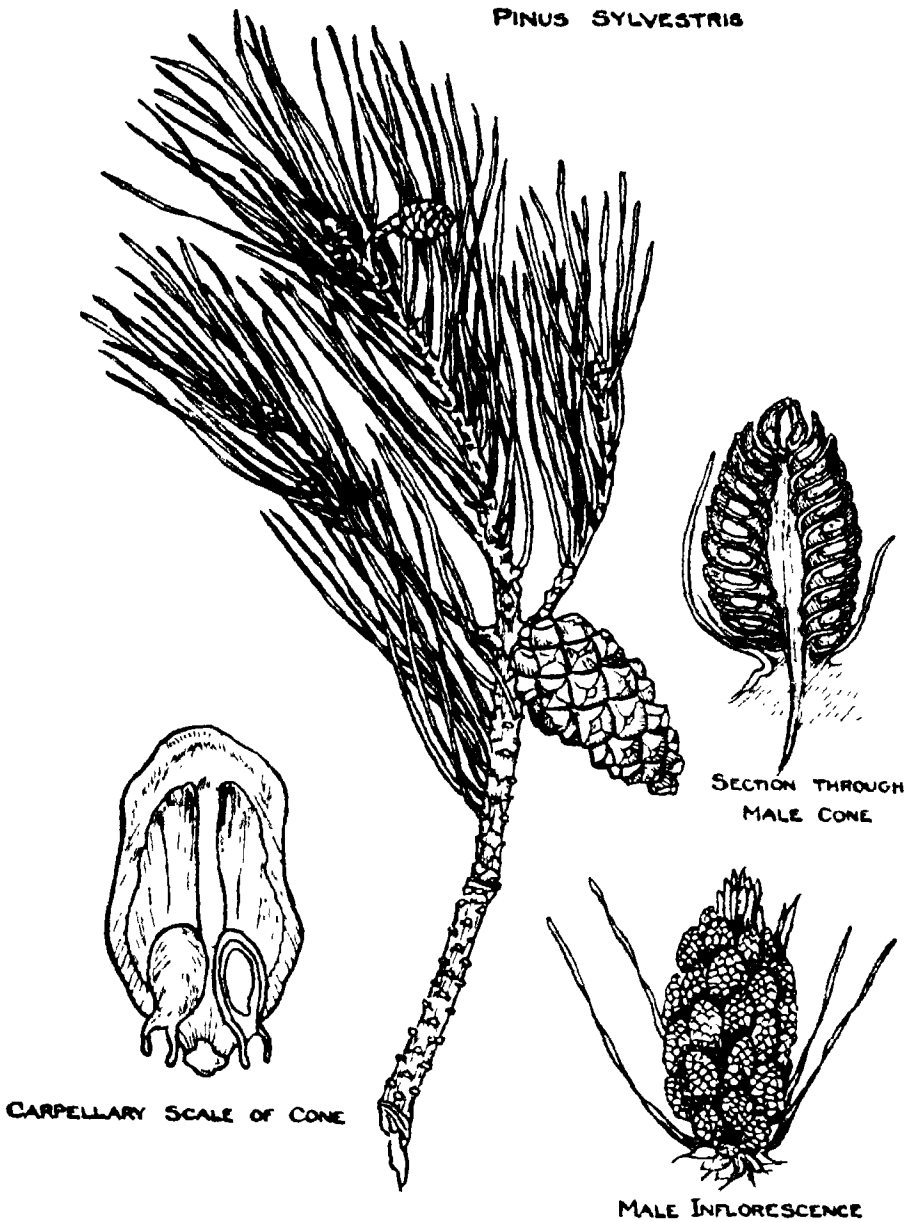


FIG.36

DRAWN FROM NATURE

H.R.

THE PINE.

The inflorescences of the Pine are interesting features. From the illustration it will be seen that the female inflorescences take the place of lateral branches. The male or staminate inflorescences occupy the position of short shoots, and are formed just below the growing point.

goes to show that the tree has not yet become acclimatised, although it was introduced to England by the Romans. To compensate for this disability, the Elm throws up from its roots numerous suckers. These soon develop, if in a hedgerow, into fair-sized trees, and ultimately become detached from the parent.

Generally the seed of the Wych Elm will germinate in this country. The winged seeds are somewhat similar to those of the Common Elm.

Both trees live to a great age—well over 400 years—but the most useful wood is obtained from those under 200 years old. Unfortunately these trees are often spoiled by the ravages of a beetle and its larvæ. The adult beetles eat into the bark until the cambium is reached. The eggs are laid nearby in the bast, and when the larvæ hatch out, they eat their way into the wood. This interrupts the food and water supply of the tree and ultimately brings about its death.

AUTUMN TINTS AND LEAF FALL

The leaves of most of the trees and shrubs in this country fall at the end of a growing season. This phenomenon is a distinct physiological process common to all the broad-leaved trees and shrubs of temperate regions. It is not a loss for a deciduous tree to lose its foliage in autumn, but a decided gain. Leaf-clad boughs would offer a greater resistance to the wintry gales and would undoubtedly be torn from the trunk. With the fall of the leaf this danger is avoided.

Further, during the summer the leaves have been manufacturing food,

some of which has been used in the building up of new tissue, supplying the embryo of seeds with a reserve supply, the remainder being stored in the tissues of the plants themselves. As the colder weather approaches, the delicate absorbing organs, the root-hairs near the surface, are destroyed; the absorption of food material cannot, therefore, take place at the usual rate. As the temperature lowers, the transpiration process also tends to lose its power, and hence the colder weather affects two vital functions.

As soon as these conditions arise, the chlorophyll and other materials in the leaves become disorganised and pass back into the branch or stem, leaving only the dry outer membrane and cell walls. This passing back of the chlorophyll, etc., into the branches gives the familiar autumn tints. Various leaves contain coloured pigments and other chemicals, which become visible only after the disorganising of the chlorophyll.

Tints vary with each particular plant and depend to a considerable extent on the summer conditions. The sickly colour of the Ash and the rusty brown of the Sweet Chestnut might be considered as natural colours. The leaves of the Horse-chestnut contain a yellow pigment which, with the natural colour, gives the beautiful lemon shades to the falling leaves. Red tints usually appear after the yellow, but in trees such as the Elder, Cherry, Vine and Virginia Creeper, the reds mingle with the decomposing green.

The Blackberry is one of the last to show the effect of the autumn temperature, and its beautiful tints of red and brown can often be found adorning the hedgerows in early winter.

The leaves, even when they have lost their function, are not torn from the trees. The dangerous effect of an open wound is prevented by the formation of a protective layer of cork (the Absciss layer) between the petiole and the stem. This originates some time before the actual fall of the leaf, its gradual development bringing about the first signs of autumn. When fully formed it only remains for the wind to detach the leaves, leaving a completely healed scar.

Even after falling from the trees, the leaves are of value. Many are dragged into the earth by the worms; others decay on the surface of the ground, but in all cases bacteria and fungi change them into nutritious leaf soil which, during a future season, will provide food for other plants.

Leaf-fall must not be regarded as the dropping of dead leaves. It is Nature's provision for the safety of the trees. Moreover, this process does not take place in branches detached during the summer, and leaves which are prematurely killed by excessive heat remain firmly attached to the branches.

A number of trees and shrubs appear clothed in green all the year through. These are described as evergreen. In such trees the leaves produced from buds in the spring do not fall in the following autumn or winter, but may live for several seasons. The length of time during which a leaf of a so-called evergreen tree may remain depends on the type of tree, the climatic conditions and the soil.

In Privet, the leaves often remain on the twigs during the winter and fall off when the new buds open in spring. The Holly sheds its lower or

oldest leaves first, losing a few every year.

Some leaves, especially those of the conifers, remain on the trees year after year; those of the Scots Pine fall after about four years, the leaves of the Cedars may last for ten years or even longer.

Buds and Bud Arrangement

(Figs. 30 and 31)

Trees having Buds Opposite on the Twigs

(1) *The Wayfaring Tree* has naked buds, that is, there are no protective bud scales. When young the twigs are blood-red in colour; generally smooth and slender.

(2) *The Ash* has one or two scales of a sooty black colour. The young twigs are smooth and a greyish green, showing flattened ends, as if they had been crushed. In winter the terminal buds are much larger than the lateral ones.

(3) *The Common Guelder Rose*—a common hedgerow shrub—has pinkish bud scales, generally one or two being prominent. Near the tips of the young twigs, longitudinal ridges are in evidence.

(4) *The Horse-chestnut* buds are the best known. In winter they are covered with brown scales and a sticky resinous substance which helps as a further protection to the immature shoots. The twigs are stiff and comparatively thick; the terminal bud is much more prominent than the lateral buds. The leaf scar in the shape of a horse-shoe is a distinguishing feature.

(5) *The Sycamore* is another tree which has stiff and somewhat thick twigs. The bud scales are of a yel-

lowish-green colour with brown margins and tips.

(6) *The Maple*, which is allied to the Sycamore, can be distinguished by its pinkish or ruddy-brown bud scales, which are generally green at their bases. The twigs are stout and firm and of a light-brown colour.

(7) *The Spindle Tree*, which is not so common as those previously mentioned, has twigs which are slender and bright sage green in colour. Its bud scales are closely and compactly arranged, generally green in colour, with pinkish margins.

(8) *The Buckthorn* also has very slender grey or brownish-grey coloured twigs. The terminal and lateral buds are small, being covered with closely compact, smooth, reddish-brown bud scales. Some of the branches form thorns.

(9) *The Common Privet* is a well-known shrub. Its buds are small, with olive-brown scales. The shrub is often regarded as an evergreen, for generally the leaves remain attached throughout the winter (cf. the Ash and Lilac).

(10) *The Honeysuckle* of the hedgerows is not a tree in the true sense of the word. Its buds are opposite on the greyish-brown, shining and cylindrical stems which cling round supports. The bud scales, which are very loosely arranged, are of a brownish-green colour.

(11) *The Elder* is another example of buds whose protective scales are very loosely arranged. The twigs are of a light greyish-brown colour, showing distinct longitudinal ridges. The loose bud scales are brownish-red and jut out slightly from the twigs.

(12) *The Common or Field Maple* seldom grows to the dimensions of a tree, but is a common hedgerow shrub.

The twigs are velvety, yellowish-green or a greenish-brown in colour, and when young are hairy. The bark of older twigs is deeply fissured longitudinally and often becomes very thick and corky. The buds, pressed closely against the twigs, are green to brown in colour (Fig. 37).

Another group of trees can be identified by their alternate bud arrangement. In this type the buds are found arranged in two longitudinal rows on opposite sides of the twigs, the buds being round, oval or pointed.

(1) *The Lime* buds are roundish-oval in outline, having one or two reddish-brown bud scales. The twigs are smooth, blood-red or orange-red, with a somewhat shiny surface. The terminal bud often dies during the winter, and hence the crooked appearance of the younger branches.

(2) *The Spanish or Eating Chestnut* has twigs of a deep red or reddish-green colour which are quite straight, but show longitudinal ridges. It will be noticed that the leaf scars are not immediately below the buds, but slightly to the sides. The visible bud scales are deep red in colour, with darker edges.

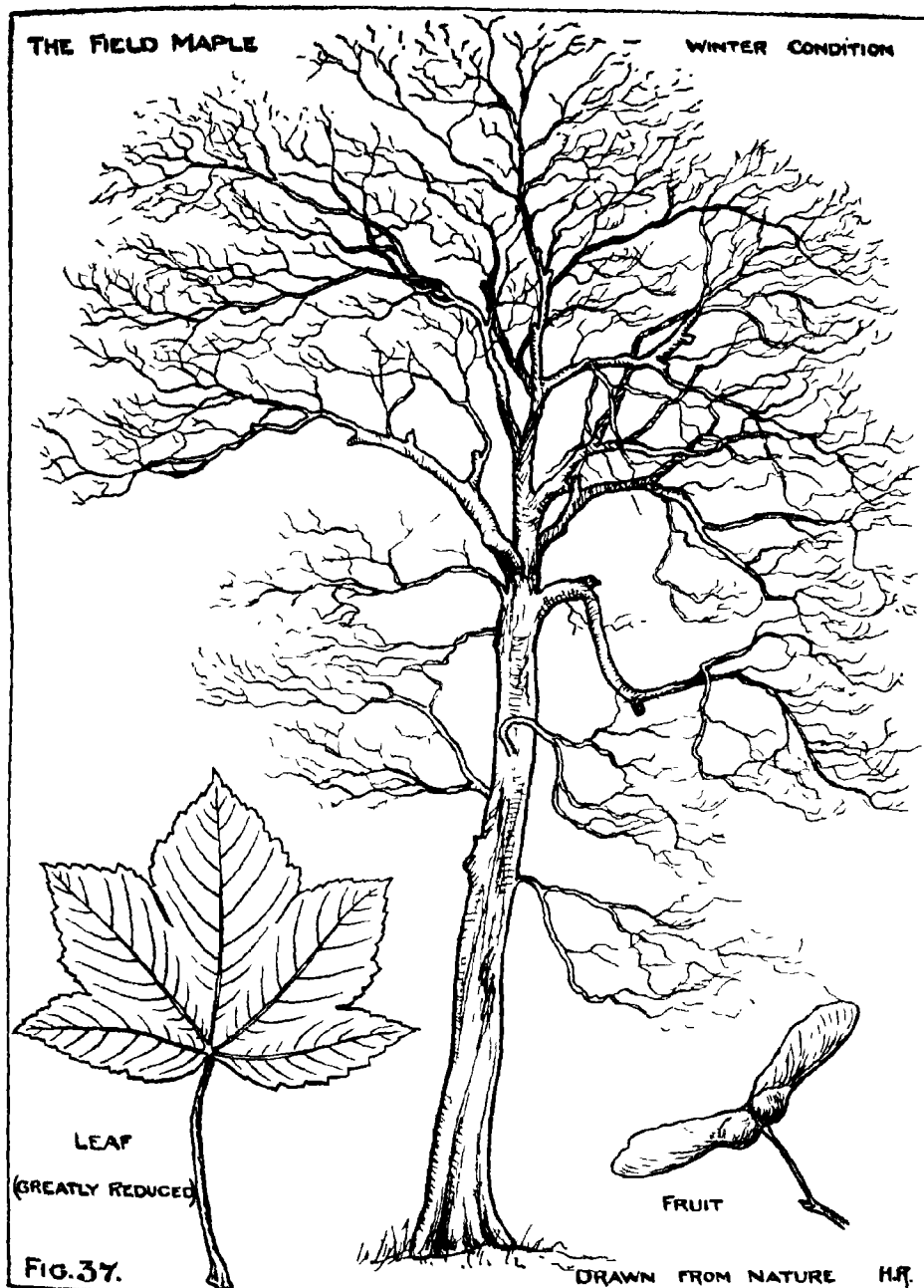
(3) *The Elm* is an interesting type. The buds are about twice as long as broad, dark brown in colour, several closely compacted scales being visible. The light-brown young twigs are more or less hairy. Older twigs show rich-coloured fissures on the bark.

The Wych Elm is very similar in appearance, but the buds are more than twice the size.

(4) *The Hazel* has its buds flattened on one side. They are generally covered with pale brownish or reddish-green scales. The young twigs, grey-

THE WATER CROWFOOT		THE PASSY FROOT		THE WHITE CROOKS	
1	1	1	1	1	1
2	2	2	2	2	2
3	3	3	3	3	3
4	4	4	4	4	4
5	5	5	5	5	5
6	6	6	6	6	6
7	7	7	7	7	7
8	8	8	8	8	8
9	9	9	9	9	9
10	10	10	10	10	10
11	11	11	11	11	11
12	12	12	12	12	12
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32	32	32	32	32	32
33	33	33	33	33	33
34	34	34	34	34	34
35	35	35	35	35	35
36	36	36	36	36	36
37	37	37	37	37	37
38	38	38	38	38	38
39	39	39	39	39	39
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41	41	41	41	41	41
42	42	42	42	42	42
43	43	43	43	43	43
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47	47	47	47	47	47
48	48	48	48	48	48
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51	51	51	51	51	51
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68	68	68	68	68	68
69	69	69	69	69	69
70	70	70	70	70	70
71	71	71	71	71	71
72	72	72	72	72	72
73	73	73	73	73	73
74	74	74	74	74	74
75					

THE PARTY PRINCE



THE FIELD MAPLE.

Like its near relation—the Sycamore—this tree is very common in most districts. In the winter, only keen observers can identify the Maple, a full description of which will be found in the text. The fruit is a double samara, the two wings of which are practically horizontal.

ish-brown in colour are usually hairy (Fig. 38).

(5) In *the Beech* the buds are pointed and three times as long as broad, often over $\frac{1}{2}$ inch long and round in section. The twigs are slender and smooth, and from these the buds jut out.

(6) *The Hornbeam* is somewhat similar in winter to the Beech, but its buds are not nearly so long. The buds lie close to the stems and are more or less angular in outline. By casual observers this tree is often mistaken for the Beech, but certain characteristics show distinguishing marks. The buds of the Beech are long and spindle-shaped and jut out from the stem; the leaves when young are downy, and the lamina shows eight to ten pairs of ribs from the centre veins. The Hornbeam buds are shorter and thicker; the young leaves do not have a downy or silky appearance, and the edges are serrate. The fruits of the trees are easily identified: the Beech has a capsule containing two triangular nuts—the Hornbeam fruits are in a long drooping cluster with triple extended wings to which two corn-like fruits are attached.

The other group of trees can be identified by their spirally arranged buds on the twigs. They can further be grouped under the following heads: (a) buds naked, (b) buds stalked, (c) buds sessile, with many visible bud scales and hairs or emergencies upon the twigs, (d) buds sessile, with several bud scales visible.

(a) *Buds Naked*

(1) The Black Alder is a good representative of this type. The young twigs of this tree are reddish in colour with dark red buds.

(b) *Stalked Buds*

(2) Stalked Buds are to be found in the Alder and Black Currants. In the former the young twigs are roughly triangular in section and of a brownish or reddish-brown colour. There is generally one bud scale visible on the angular dark-brownish bud, the stalk of which is often more than $\frac{1}{4}$ inch long.

(3) The Black Currant has smooth twigs of a pale-brown colour. The stalked buds are round and have several dark pink scales visible.

(c) *Buds Sessile on the Twigs*

(4) Buds Sessile on the Twigs with apparently only one bud scale are to be found in the Willows. Various members of this family, however, cannot be identified by their buds alone, for there are a large number of trees showing slight variations only in the bud but a great difference in the general growth. The White Willow is perhaps the best known. This has pale-green twigs and small yellowish-green buds. The older twigs become reddish-grey and dull in appearance. The leaves, when young, have silky hairs on the upper and lower surfaces, which give the appearance of whiteness.

(5) The Sallow has soft hairy twigs with large buds. The twigs are much the same as the White Willow, but the change to the dull grey is not so pronounced. The leaves show a variation, being slightly ovate in outline, those of the White Willow being lanceolate (Fig. 33).

(d) *Buds Sessile with Several Bud Scales Visible*

In this section are included those trees or shrubs which show hairs or emergencies upon the twigs.

(6) The Dog Rose (*Rosa canina*) has round twigs with emergencies called prickles, which have stout bases, the tips pointing backwards. The buds are smooth, round and blunt at the tips. The colour varies somewhat, but generally they are greenish-grey.

(7) The Blackberry has angular twigs. The prickles are more numerous than on the Rose and are irregularly placed. The buds, of a greyish-green colour, are hairy, pointed and long.

In the Gooseberry the prickles are straight and are situated beneath the buds only. The young, round twigs are bright yellow. The yellowish-green buds on slight stalks are pointed.

The Barberry, Raspberry and Loganberry are other examples of this section.

(e) *Buds Sessile—No Emergencies Present*

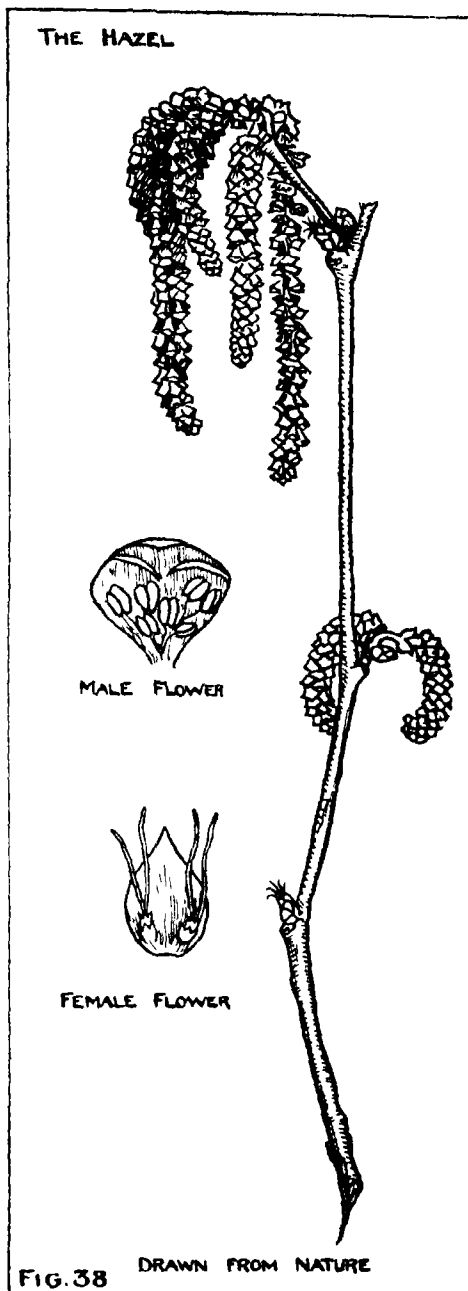
(8) In the White Beam the bud scales are green, with narrow brown edges and keeled. The buds are hairy at the tips and somewhat flattened on one side.

(9) The Mountain Ash or Rowan has black or dark purple bud scales. The buds are larger, often more than $\frac{1}{2}$ inch in length.

(10) The White Poplar buds, which are plump and pointed, are hairy all over. The twigs appear to be covered with a white, cottony film which gives the appearance of whiteness. The leaves also show this loose, white, cottony film.

(11) The Crab twigs when young are slightly hairy. The buds are more or less triangular in outline and pressed closely to the stem.

(12) The Black Poplar has long,



CATKINS OF THE HAZEL.

lamb's Tails consist of a large number of male florets. The female florets appear as ordinary vegetative buds, the red hair-like stigmas protruding from the tips.

narrow, pointed, smooth buds, which are covered with resin at the tips. The twigs are of a dark reddish-brown colour and are furrowed.

(13) The Hawthorn has greyish-purple twigs on which are brown-red-dish buds. Generally there are two together, one large and the other small. Spiny branches are found at the sides of the buds.

(14) In the Oak, the buds are crowded

together at the end of long, greyish-brown branches. The yellow or chestnut-brown buds stand out from the stem. Usually they are quite smooth, plump and rounded at the tips (Figs. 31 and 35).

Other trees showing spiral bud arrangement are the Apple, Pear, Plum, Cherry, Aspen, Lombardy Poplar, Walnut, Red Currant and Wild Service Tree.

CHAPTER IV

POND LIFE

THE study of pond life opens up a very wide field for the enthusiastic teacher. He has not only the plants which grow in the water or on the surface, but myriads of living organisms, larvæ, pupæ and adult insects, which provide an endless variety of subjects. Unfortunately the study of the inhabitants of the ponds does not receive the attention the subjects deserve. Much new work on the life-history of the various inhabitants has yet to be done, and some of this research work can and should be done by the enthusiastic Nature-Study teacher.

In this volume it is only possible to give the life-history of such types as can be examined and studied by means of the aquarium. Much of the work will be based on the practical side which has been carried out at the Farm School in connection with the Demonstration School of the University College, Reading, and in elementary schools by the Author.

This most interesting work should

be begun by taking the children to a pond and allowing them to secure specimens for the aquarium. The study will then be a matter of close observation on the part of the teacher and scholars.

The following section will contain a brief account of the plants found in ponds and the easily obtainable larvæ and adult insects.

Duckweed

The Duckweed is a very simple plant found on the surface of ponds. Its leaf-like fronds, which are really the stems, are the more conspicuous, for the simple roots hang down from the under-surface into the water. This is a typical plant of stagnant waters. It will be noticed that it is not attached to any object, but simply floats on the surface of the water. In autumn, buds are formed on the fronds, and these sink to the bottom of the pond, arising in spring to carry on the growth of the species. Occasionally flowers of a very

simple type are produced, from which seeds develop, but this is rare.

Water Crowfoot

The Water Crowfoot or Water Buttercup is an interesting type. In this plant two kinds of leaves are found; those on the surface of the water are flat and divided into three lobes; those under water are thread-like, and spread out in all directions. These submerged leaves show the adaptation for an aquatic life. By means of these leaves the plant is enabled to obtain oxygen from the water before the ordinary foliage leaves have reached the surface. This is a characteristic modification of leaves which remain completely submerged.

The Water Crowfoot has a typical Buttercup Flower; the petals, however, are white, tipped with yellow. Its achenes, when ripe, are carried on the surface film of water, and might be used as an example of dispersal by water.

American Pond Weed

Another type, extremely useful for aquarium work, is the American Pond Weed (*Elodea*), which is found in many canals and ponds. It lives wholly submerged, attached by roots to the bottom or side of the canal. The dark green, semi-transparent sessile leaves are arranged in whorls of three or four. In this country the female flowers only are produced, and hence the reproduction by seeds is impossible. Generally, increase is due to the breaking off of twigs by the water fowl or other inhabitants.

N.B.—The stem and leaves are very useful for showing that oxygen is given off by green plants during sunlight.

The Bladderworts

The Bladderworts, often found on the surface of deep ponds, are other useful plants for the aquarium. Each plant consists of long, root-like, branched stems, bearing on them thin filamentous leaves on which are borne the characteristic bladders. In such plants the animal nature seems to be prominent. By means of the bladders the plant is able to entrap very small aquatic organisms, crustaceans especially. Entrance to the bladder is quite easy, but once inside there is no escape, small hair-like structures preventing this. When the organisms die, the products of decay are absorbed and used by the plant. Flowers of a conspicuous yellow are produced in summer, well above the water. These produce seeds from which new plants arise the following spring.

The Water Milfoil

The Water Milfoil is another plant often found in ponds, and also in slow-running streams. This plant has a distinct rhizome, which creeps along the bottom of the pond, sending up shoots. The stems are slender and bear numerous filamentous leaves, similar in formation to the submerged leaves of the Crowfoot. The tips of the stems project above the surface of the water and bear very small pink flowers of two kinds, the pollen-bearing flowers occupying the highest parts of the spike.

The Arrowhead

The Arrowhead is another plant often found growing in open ponds. This plant exhibits three kinds of leaves. The first, more or less filamentous leaves are quite submerged; the tips of another type which assume a linear

shape are found floating on the surface of the water. The aerial and third type are sagittate in shape and from this kind of leaf the plant gets its name. The flowers have three white petals, each having a deep purple spot close to the point of insertion on the receptacle. There are two kinds of flowers, male (staminate) and female (carpellary). The lower ones on the flowering axis are the carpellary flowers, and these have shorter pedicels than the staminate flowers, the latter occupying the upper region of the axis.

The Water Plantain

The Water Plantain (*Plantago Aquaticum* L.) is another pond-side and often river-side plant. The large leaves are all radical (springing from the root stock) oval, lanceolate or subcordate in shape. The tall, loosely panicked flower stalk is a distinguishing feature. Generally the pale rose or lilac-coloured flowers are small. The perianth consists of three small outer coloured sepals and three inner larger petals. At the base of each of the six stamens are two nectaries. The fruits are generally dispersed by water.

The Skullcap

Growing near the banks of ponds may be found the Skullcap, a member of the Dead-nettle Family (*Labiatae*). The stem is square in section, typical of the *Labiatae*, and grows to a height of a foot. The leaves are arranged in alternate pairs along the stem, and from the axil of each leaf a flower arises. The bluish flowers all turn in the same direction. Unlike those of the Dead-nettle, the lips of the corolla are nearly closed. This is another adaptation for pollination, for only insects of a small

size can enter the flower tube in search of nectar. When the insect enters the flower, it becomes coated with pollen, which is transferred to the stigma of a similar flower on a subsequent visit.

The Forget-Me-Not

The Forget-Me-Not, also, is often met with when visiting ponds. Its stems are of rather a weak nature, but often reach a height of 12-18 inches. The sky-blue flowers are borne on a long raceme. All the petals are joined together to form a tube, which has a yellow centre or eye. Generally the size of the flowers varies with the conditions of growth, those in or near the water being the largest, often $\frac{1}{2}$ to $\frac{3}{4}$ inch in diameter.

The Iris

The Iris is another plant of the water-side. This plant grows from a horizontal root-stock, and its sword-like leaves are conspicuous. The yellow flowers appear in twos and threes round a flowering axis, which has on its lower parts a sheathing bract. The perianth consists of three coloured sepals and the petals; the former give the Iris its characteristic name of Flag. Over the inner segment there are three petal-like stigmas joined together on one style at the base. The three stamens are inserted on the sepals.

Meadow Sweet

The Meadow Sweet is a very common plant of damp places, often found on the edges of pools. Its small, rose-pink flowers have a distinct Almond scent. The reddish stem is usually about 3 feet high, and bears pinnate leaves. The terminal leaflet is divided into three others, all of which are green

above, and on the under-surface covered with a soft, white down.

Bulrushes

Bulrushes or Red Maces are often met with. These grow from a short root-stock, which creeps in the mud, throwing up stems 6-8 feet high. The linear leaves are very long, often reaching a length of 10 feet. The flower spikes in the early stages are most interesting. They are enclosed in lace-like bracts before they emerge from the sheathing leaves. As the flowers reach maturity these delicate structures float away in pairs, leaving the staminate and pistillate flowers free. After pollination the upper or staminate flowers die off, leaving the pistillate flowers as a closely compacted brown spike.

The fruits, which have been mentioned previously under the heading Fruit Dispersal, remain on the axis during the winter. On becoming detached in spring, they are carried away from the plant by the wind—the most beautiful of seeds. Other plants such as the Naiads, with their grass-like leaves, are often found. Water Violets, which are found growing near the edges of ponds, have primrose-like lilac flowers. The stems are entirely submerged. The leaves consist of finely divided segments, only the flowering axis coming above the water.

Water Lobelia

Water Lobelia is another interesting aquatic plant. Its leaves are radical, the flowering axis only coming above the surface of the water.

The Sedges, Rushes and Water Lilies

The Sedges, Rushes and Water Lilies are other types which may be found. *The Water Lily* sends up its large heart-

shaped leaves to the surface of the water in May. The flower buds appear on the surface later, showing five large sepals—yellow on the inside—a double row of smaller yellow petals, in the centre of which are numerous stamens and a syncarpous ovary. When ripe, the walls of the carpels separate; each carpel, by reason of an air channel surrounding it, floats on the water and is eventually dispersed by the wind.

Frogs and Toads

The inhabitants of the ponds are a delight to study. In early spring, Frogs and Toads abound, and much useful work can be done in schools by the study of the life-history of these creatures.

The adult Frogs hibernate in the mud on the sides of ponds or ditches during the winter time. During the early spring, often at the end of February, Frogs may be seen swimming about on the surface of the ponds and canals. The male may often be heard on a quiet, sunny day early in March making the peculiar "Crook Croak." This is the call to the female. After a female has selected her mate, the male mounts on her back, tightly clasping his two front legs under her breast. The ova or egg cells are passed from the female in long strings, and at the same time the male emits the fertilising male cells or sperms, which are very active and quickly become attached to the unfertilised eggs. Each sperm rapidly bores through the outer coat of an ovum, the nuclei fusing to form the embryo. The egg cell is surrounded with mucus, which takes up water readily, and rapidly gives the cell a jelly-like appearance. A large mass is formed by the eggs, and the

term *Spawn* is applied. The fertilised egg of the Frog does not develop a shell like the eggs of birds, but remains as a gelatinous mass.

During the pairing season Toads visit the ponds and lead an aquatic existence for a time. The pairing is somewhat similar to that of Frogs, but the Toads' eggs are emitted in two ropes of mucus, which may be from 10 to 15 feet long.

The pairing of Toads and Frogs has led to a curious belief in some country districts. When a boy, the writer well remembers being told that the young Frogs always killed the old ones.

As a keen desire to study Nature developed and knowledge was gained through observation, a doubt as to the accuracy of the story crept in. Eventually, finding out that the Frogs came apart, and acquiring a more accurate knowledge of their life-history, the old boyhood tale was entirely discredited. The story, however, is one which even adults whose knowledge of Nature and her ways is limited, might be forgiven for believing.

Another point especially worthy of note to country teachers ; it is a common practice to try to part the Frogs by stone-throwing ; many are killed in this manner. If children were taught the value of Frogs and their allies to the farmers and gardeners, this cruel practice would be eradicated.

The value of the mucus surrounding the fertilised eggs should receive consideration. Each envelope serves as a protective covering for the embryo and enables the mass to float on the surface of the water. Its slippery nature is also a protection from water fowls, such as the Coot. The spawn is usually blown about on the surface of

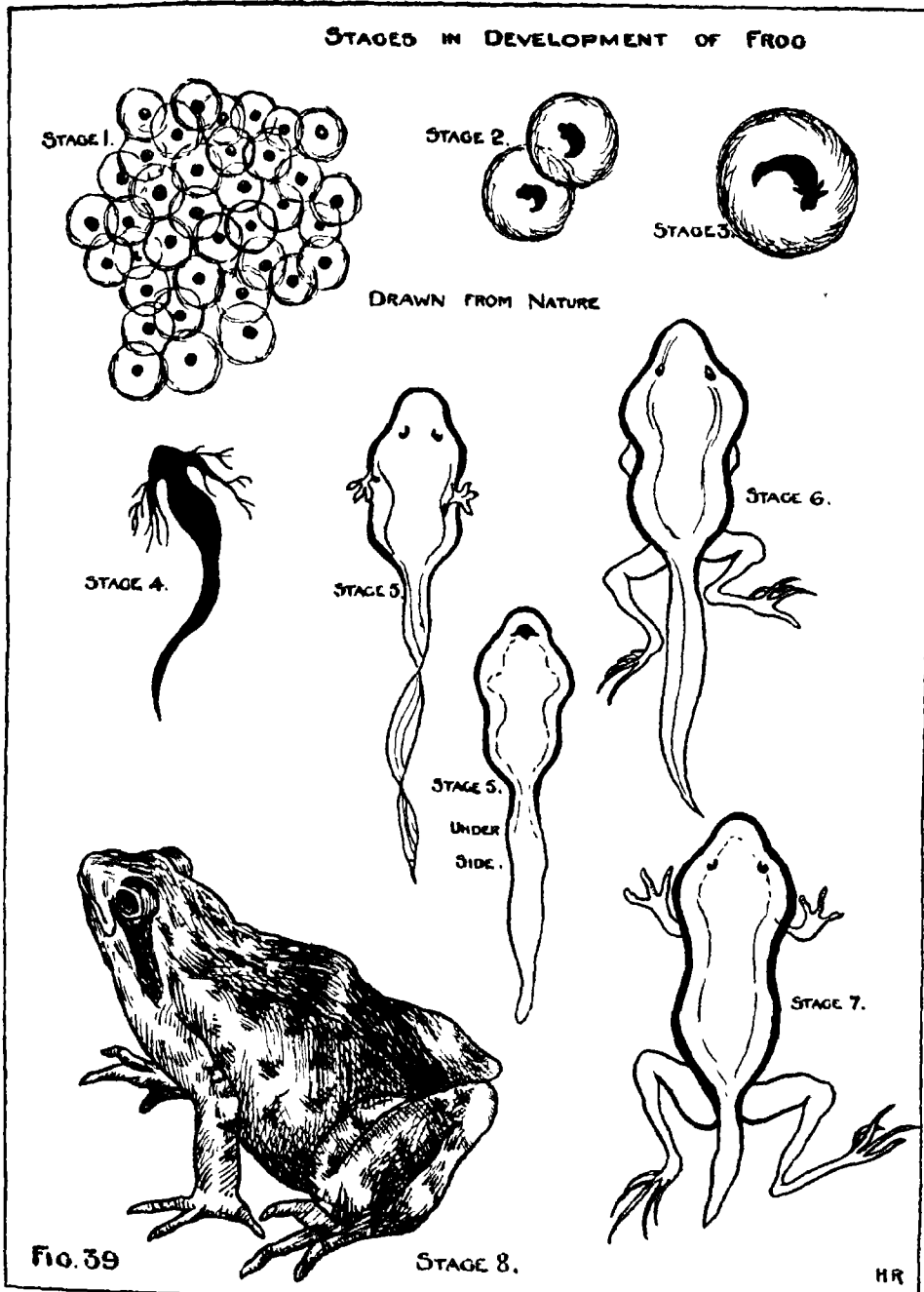
the water, but eventually becomes entangled by water-weeds.

About three weeks after production the embryo emerges from the envelope of jelly and becomes free. On first emerging, it is a very immature organism, yet distinct parts can be made out by the use of a lens. A head is indicated by a swelling at one end, a slight depression indicating the mouth. Behind the depression is a groove which exudes a gum-like substance, used in fixing the embryo to a water-weed. The rest of the organism gives the appearance of a rudimentary tail.

The Tadpole

Up to this period, respiration is of a very simple nature—through the skin. In about a week the first three rudimentary gills make their appearance ; eyes develop ; the mouth becomes a definite organ ; the tail takes a definite fin-like form, the embryo having developed into a Tadpole. Gradually true gills are formed internally, the mouth becomes harder and horny teeth become apparent. When this stage is reached, the Tadpole releases its hold on the aquatic plant and becomes a free swimmer. Its mouth and teeth enable it to consume tiny insect larvæ and Worms. A spiral intestine has developed, and an outer passage can be seen under the tail. The internal organs have also been developed, and a two-chambered heart has made its appearance.

After a week or so, the period varying with the temperature, a second stage is reached. From the root of the tail, hind limbs, each having five webbed toes, appear. At the same time the front legs, each with four webbed toes, are formed, but these remain enclosed in the gill chamber for some



THE DEVELOPMENT OF A FROG.

Illustrations 1 to 7 show the stages in development of "spawn." Stages 2 and 3 were drawn with the aid of a low-powered microscope—equally good results can be obtained with X10 lens. Stage 8 represents a fully developed Frog—two years old.

time. The hind legs help greatly in the swimming activity of the Tadpole.

At a later stage, generally three months or more after hatching, the Tadpole undergoes further metamorphoses. The tail is absorbed and used up in the building of body tissue; the mouth loses its horny appearance and widens considerably; the skin over the eyes disintegrates and the lids become flexible. The fore legs gradually emerge from the gill chambers, and the gills lose, to a great extent, their function, rudimentary lungs having developed.

At the same time a change is going on internally. The heart becomes three-chambered; the lungs continue development. When the lungs have reached their full capacity, the young Frog leaves the water, for the gills lose their function and the Frog must breathe by means of its lungs alone, or partly through its skin (Fig. 39).

On leaving the water, the Frog, by means of its tongue, is enabled to live on small insects and, later, on Worms. When fully developed, slugs form an appetising diet, and hence Frogs are of incalculable assistance to the gardener.

For classroom study an adult Frog should be kept in a terrarium. For some considerable time it will resent captivity, but ultimately it will become quite tame. The scholars will eventually discover the use of the Frog's tongue, for, when the Frog has become accustomed to its surroundings, it will consume small Worms and Snails readily. The author has taken this observational work with a Standard V mixed class, and on each occasion the method of obtaining food has been discovered. Observational work has been carried out in Standard VI on the process of respiration; the muscular movements

can be observed. In each case it was found that the children caught and tamed Frogs at home, the alternate opening and closing of the nostrils, the movement in the throat and sides of the body being discovered.

Not Cold-Blooded

Sometimes the Frog is spoken of as a cold-blooded animal. The term "cold-blooded" is not correct. Frogs, Newts and other amphibians have not a temperature-regulating nervous system, and hence the blood does not keep a constant temperature. It has been proved by eminent scientists that the temperature of the blood varies directly with the temperature of the surrounding medium.

At certain periods, all amphibians undergo a moult or change of skin. Generally speaking the skin peels off a little at a time, the pieces being swallowed.

In winter the adult Frogs hibernate. During the summer they become fat; food is plentiful. As winter approaches again they seek the water of pond or ditch, sink in the mud and give up breathing through the lungs, relying entirely on skin breathing. The heart beats slacken, and hence little energy is required to keep the body alive. The accumulated fat is used up to supply the necessary energy, and the animal remains in a dormant condition until the sunny days of early spring.

The life-history of the Toad is somewhat similar to that of the Frog. The general appearance of Toads differs in many respects from that of Frogs. Generally the latter have smooth, moist skins; the hind legs are much longer than the fore. Toads have a dark, warty skin, but their hind legs

are more in keeping with their bodies. The Frog's tongue is perceptibly notched, and the jaws have minute teeth. The rounded tongue of the Toad is unnotched, and there are no teeth in the jaws. Frogs hibernate in mud ; Toads usually hibernate in heaps of stone, under decayed trees or in holes in walls. Both types, however, visit the ponds for the breeding season. The spawn of the Toad sinks to the bottom of the pond unless entangled by weeds ; the spawn of the Frog always remains on or near the surface.

Newts

The Newts form an interesting study in the classroom. Three species are to be met with in this country : the Smooth Newt, the Great Warty Newt and the Palmated Newt.

Often in early spring the Smooth Newts may be found, evidently leaving their winter quarters. From personal observation the hiding places are numerous. In the school gardens they have been found in the light soil of the cool frame, in the manure heap and under the bricks forming the borders of the gardens. In each case the Smooth Newt has been found, but very poor, dark-looking, thin specimens they have been.

On being placed in an aquarium, however, providing they are three or four years old, rapid changes have taken place, the skin becoming an olive green and the emaciated body rapidly developing into a healthy-looking creature. The author was exceptionally fortunate two years back in securing both male and female specimens at about the same time, and their subsequent life-history was observed. They were placed in an

aquarium containing water taken from an adjacent pond ; a comparatively large mass of stones was placed in the centre in order that the Newts, if they wished, could remain entirely out of the water. After three days, about a third of the water was syphoned from the aquarium, this being replaced by ordinary tap water. This process was repeated from time to time. Water Snails were also introduced.

About a month after capture the Newts had undergone considerable change. The male had developed a crest ; his back and part of his sides became a deep olive green, the under-part orange and a colour intermediate between orange and yellow. The tail on the upper side appeared a reddish-green, and on the underside a bluish colour was observed. The female developed an orange colour underneath, and this continued from the throat to the tail. The upper parts were similar to those of the male, with the exception that no crest appeared. From observations carried out on specimens secured from the ponds, the above descriptions of males and females are fairly constant. In one or two instances the males have been found with a whitish throat, but this does not appear to be a constant feature.

The attitude adopted during the pairing season, early in April, was interesting to watch. The couple faced each other for several minutes, then had food, the process being repeated time after time for several days. The egg-laying could not be observed, but is somewhat as follows. In the ponds, the male pairs with several females in a similar manner to that already described. When satisfied that he has raised the interest of the females,

he discharges sperm cells near to each of his selected mates. The females seize a cell, and use it for fertilising an egg cell. The fertilised eggs are laid one at a time, the female attaching the egg to the leaf of a submerged water-weed, closing the lamina over to form an envelope, the edges of which are glued together by the mucilaginous covering of the egg.

The Newt Tadpole

The later development of the egg is as follows: In about a week's time the Tadpole can be seen coiled up in the egg-mucilage like a watch-spring, and if brought above water the springy movement can be observed. In ten days the Tadpole breaks through the covering and sinks to the bottom of the pond. At this early stage it has gills similar to the Tadpole of the Frog, and is probably a ground feeder.

For about a fortnight the Tadpole remains at the bottom of the pond, extracting its food from the mud. During this period the tail develops, and the sucker of the Tadpole changes to a mouth. The period of free swimming has now begun. In an aquarium the first stages can be observed. The newly-formed tail is quite transparent at first, but as time goes on a darker coloration becomes apparent. The front legs are the first to develop, and later the hind legs are formed. Internally, too, changes are taking place; the lungs and a three-chambered heart are forming, and in about three months the gills lose their function.

During this period the body becomes much shortened, the skin takes on the characteristic olive-green colour, and the tail increases in size and strength, losing its transparency. The

tail is the most important organ of locomotion; the legs simply act as balancing organs in the water. When fully developed—that is, when the lungs, heart, tail and legs have taken on their normal function, the small young Newt leaves the water and remains on land, in ditches and damp places until he is three or four years old.

Newts in the Aquarium

The study of Newts in an aquarium provides much interesting observational activity. During the present winter, one of the author's friends has kept a pair of Palmated Newts in the classroom aquarium. Although apparently quiescent during the greater part of the time, they have shown an active interest in life when the water has been changed and additional food in the shape of Worms, Ants'-eggs, etc., has been provided. The method of breathing, swimming, sinking down to the bottom of the aquarium provide excellent observational work for both teacher and scholars.

The Great Crested or Warty Newt will be found in some districts. Its skin is more or less covered with warts. Both male and female have a crest; that of the female, however, is not very pronounced. The tail of the male at breeding time is conspicuous. The orange colour common to both sexes is banded with a silver-grey streak. There is also a distinct division between the crest of the tail and the body. By this means recognition of the Great Crested Newt can easily be made.

All three species of Newts have the power of replacing a lost limb. In one instance this was discovered by a class. After a visit to a pond to secure larvæ of the Water Beetle, a Great Crested

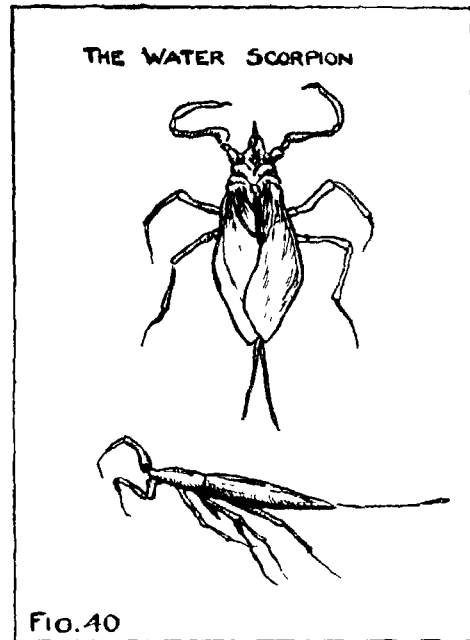
Newt was captured. On returning to school this was placed in an aquarium containing Palmated Newts. A battle royal took place which resulted in the loss of part of the tail of a small Newt. The intruder was removed and placed in a small vessel alone. In two months, the lost part was replaced; the Newt evidently suffering very few ill effects from the damage.

As a rough guide for identification purposes, the adult sizes may be of assistance. The Great Crested Newt is about 6 inches long, with a powerful tail and fairly stout body. The Smooth Newt also grows to a fair size, generally 4 to 4½ inches long, its body being quite smooth. The Palmated Newt is the most common one met with. Its length very seldom reaches more than 3 inches. The tail is its most striking part, and, although generally grey in colour, often shows a pale mauve coloration.

The smaller inhabitants of the pools and ponds are numerous. Free swimmers abound; on the surface are to be found the Whirligig Beetle moving backwards and forwards, but on being alarmed, quickly plunging underneath; the Water Spiders and Water Scorpions, which row and run on the surface; the Water Boatman, which rests on the surface and then rows backwards into the water by its own oar-like legs. Below the surface are to be found the larvæ of the May Fly, Dragon Fly, Brown and Black Beetles, Caddis Flies, Gnats, etc. The adult stages of the Brown and Black Beetles are met with also.

The Brown Beetle

The Brown Beetle larva and the adult Brown Beetle (*Dytiscus margin-*



THE WATER SCORPION.

This insect is sometimes seen crawling backwards along a submerged water weed. Its breathing organs are a characteristic feature.

alis) are veritable dragons of the pond, being carnivorous in both stages of their existence. When full-grown, the larva has a cylindrical-shaped body of a yellowish-brown colour. The head is broad, the powerful mandibles or jaws are arched, sharply pointed and perforated at the tips. Its body, which is covered with a thick, tough skin, consists of eleven segments, the head making the twelfth. The six legs are long and fringed with hairs, thus forming splendid organs for rowing through the water. When swift movement is required, however, the body of the larva forms into constricted curves, the releasing of which brings about a springing motion. The tip of the tail is supplied with two appendages of a feathery nature, through which the organism breathes.

Evidently its body is lighter than the water it displaces, for when its legs are still it slowly rises to the surface of the water in a slightly curved position, the appendages just coming above. Occasionally a larva may be seen attached to a pond weed, but in this case its legs grasp the object tightly. Its voracity is exceptional, and when innocently placed in an aquarium it will attack all the other inhabitants except the larger Newts. For school purposes it is best to keep a larva of this kind in a special aquarium, feeding it with small Minnows, Tadpoles and pieces of cooked meat. When attacking its prey, it seizes it with its sharp mandibles and by the aid of a "sucker" extracts the life-blood.

It is not advisable to keep two larvæ in the same vessel. If hungry, a battle royal will be the result, ending in the death of one, the other using its defeated foe for food.

The leading authorities on pond life state that the larva lives in the ponds for two years. It then forces its way into the mud at the water level and casts its skin, changing into the pupal stage. After undergoing metamorphosis, it changes into a fully-formed Beetle, having a body well suited for swift movement through the water. From head to foot it is covered with a horny armour, and the mouth becomes a powerful biting organ. The mandibles are still present, but in a stronger form which renders them very powerful weapons of defence or offence.

Its three pairs of legs are peculiarly constructed. In the male species only, the first pair have disk-like outgrowths covered with "suckers." These enable the Beetle to obtain a very tight grip on its prey or of the female during the

pairing season. The second pair are much longer and terminate in very strong hooked claws, eminently suited for climbing along water-weeds. The last pair are the chief swimming organs. The ends are somewhat tapering and fringed with long stout hairs.

Like the larva, the adult is an air breather, and frequently comes to the surface for a further supply of air. This it does with the tail end foremost, from which a bubble passes off. Fresh air is taken into a special part between the wing covering and the upper abdomen, and is used by the Beetle by means of specialised organs or spiracles.

The Beetle will attack any pond inhabitant and even a fair-sized Fish. It seldom leaves the pond except when food runs short, or in search of a female. In the aquarium, these Beetles form an interesting study, but it is advisable to have a perforated covering over them, otherwise they seek fresh quarters.

The Great Water Beetle

The Great Water Beetle is often met with and sometimes mistaken for the Brown Beetle. The Great Water Beetle, however, is black in colour and slightly larger than the Brown Beetle. When in need of air it comes to the surface head foremost. In general habits it is far different, living only on a vegetable diet, and although sluggish in the water flies swiftly when changing its habitation. A cyclist feels as though a stone has struck his face when he encounters the Great Water Beetle in flight. The larva is somewhat similar to the *Dytiscus*; its mandibles are not so pronounced, yet in this stage it is carnivorous.

The Whirligig Beetle

The Whirligig Beetle, perhaps the smallest Beetle living an aquatic existence, is about $\frac{1}{4}$ inch long. On a sunny day, the surface of the ponds seems alive with these objects, their steel-grey coats shining like burnished metal, but on attempting to catch them they quickly disappear below.

The two posterior pairs of legs are short flattened structures with strong hair-like appendages. By means of these limbs, the Beetle is enabled to swim or propel itself along the surface of the water. The front legs are much longer, and are used for grasping the smaller insects used as food. The eyes are of special interest. Their position on the head enables the Beetle, while on the surface of the water, to watch for its prey below and to keep a look-out for its enemies above. The larva is like its parent, carnivorous; it is generally of a creamy colour, and often $\frac{1}{2}$ inch long. Its jaws are strong and powerful. Like the larvæ of the other Beetles mentioned, it has a paired system of respiratory processes at the tip of its tail, but, in addition, it has breathing processes along the lower segments of its body.

The eggs of the three Beetles mentioned are either laid on or buried beneath the epidermis of the leaves of water plants immediately above the water level.

Pupation in the first two cases takes place in the mud at water level, but that of the Whirligig on the stem of a water plant above the water level. The larva spins for itself a greyish cocoon in which to undergo metamorphosis.

The Water Boatman

The Water Boatman is probably the most interesting aquatic specimen for school purposes; its backward swimming never fails to attract attention. The hind pair of legs are specially adapted for swimming purposes, being flattened like oar blades and covered with hair-like bristles. The latter offer the maximum resistance to water in the effective stroke and vice versa. The fore legs are much shorter and stouter. Aquatic insects are caught by these legs, and, with the help of the second pair, their captives are held in position while the beak or sucking organ is plunged into the body and the juice extracted. When at rest on a weed, the second pair keep the Boatman in position, for, being lighter than the water, it would otherwise rise to the surface. This tendency to rise is due to the large amount of air entangled in the hairs on the sides of the body and beneath the wings.

The eggs of the Water Bug are laid on submerged water plants. The larva is similar to the adult, with the exception that the wings have not developed. In the adult the wings are partly horny and partly membranous, and these enable the Bug to fly directly from the water.

A covered aquarium is essential for the study of the Water Boatman or the Whirligig. The Boatman (one of the Water Bugs), should opportunity present itself, will spring out of the water and fly away.

The Water Scorpion

The Water Scorpion is allied to the Boatman. In general outline this Bug resembles a leaf. Its front legs are

used for securing its food, which consists of larva; this is seized and all nourishment sucked out. The other pairs of legs are used either for walking on the bottom of the pond or for movement in the water, although they are not specially adapted for this purpose.

Its breathing organs consist of two long, hair-like appendages protruding from the region of the tail. Occasionally the Scorpion will be observed crawling backwards up the stem of an aquatic plant until the tips of its breathing organs break the surface (Fig. 40).

Dragon Fly Larva

The larva of the Dragon Fly is often found in ponds; its kitten-like head is attractive, having distinct eyes and short antennæ, together with a peculiar

organ known as a mask. The latter is a specialised organ for securing food, and is a modification of the lower lip. It consists of two prehensile pincers, by which the larva secures its prey and draws it within reach of the mouth. Generally the larva remains almost stationary at the bottom of ponds, waiting patiently for its prey. The respiratory process is somewhat complex. By means of abundant tubes in the posterior part of the abdomen, a pulsating movement is continually replacing the water from which air has been extracted.

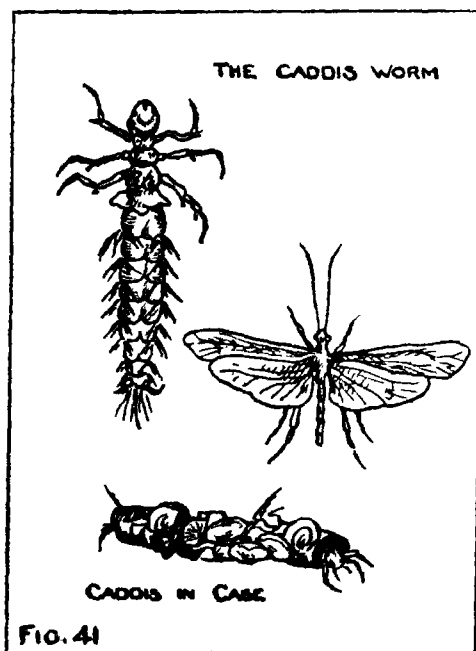
In the case of this larva there is no special pupa stage. The rudimentary wings develop on the larva. Very often the larva moults or entirely changes its skin, and with each successive moult, changes take place.

After about nine months of aquatic life the larva climbs up the stem of a water plant and in a very short time becomes the beautiful Dragon Fly.

The Caddis Fly

The Caddis Fly larva is another very interesting grub met with in the ponds. There are two kinds generally found; one hidden under loose stones—the other moving freely along the bottom of the ponds or climbing up the stems of water-weeds. Both grubs are the larva stage of the very common Caddis Fly, which is often mistaken for a small Moth. Generally these Flies are of a chocolate colour, having four very delicately fringed wings.

Eggs are laid as a rule on water-weeds quite near to the surface of the water. On hatching out, the larva moves into the water and immediately begins to form a protective case in



THE CADDIS FLY.

The larval stage of this fly is a great attraction to scholars. A small aquarium only is needed.



Photo 11-1-11

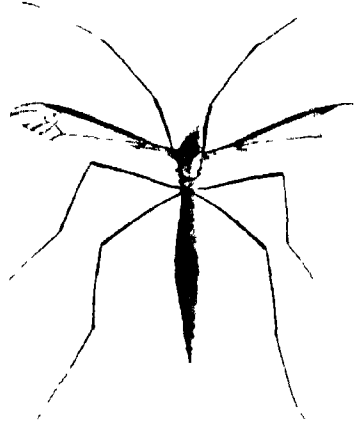


Photo 11-1-12



Photo 11-1-13



Photo 11-1-14

THE CRANE FLY, GNAT LARVA AND MAY FLY

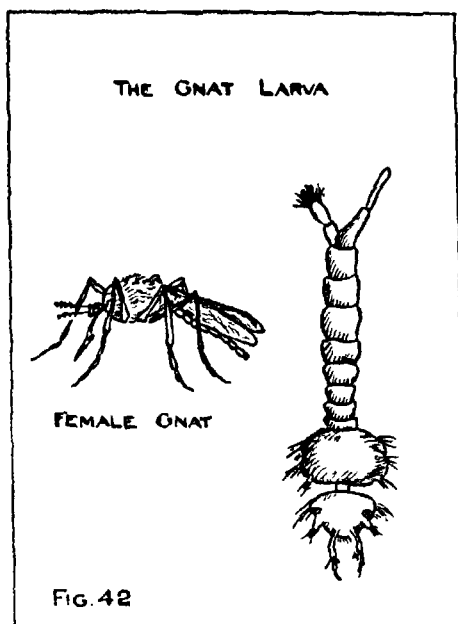
Three stages in the life history of the Crane Fly are represented in the two upper illustrations. The left hand photograph shows the Crane Fly larva (pupa) in its pupal case. On the right a fully developed Crane Fly is shown. The left hand lower photograph depicts the larva of the Common May Fly. On the right hand side the May Fly is seen just emerged from its subimaginal skin.

which to live. Almost any small object is used for the purpose—bits of reeds, small fragments of grass, very tiny pieces of stone, broken-up pieces of snail shells, etc. The completed protective structures may take various shapes on the outside, but the inside is generally tube-shaped and beautifully lined with silk. The interior is a fair size, somewhat bigger than the larval body, in fact large enough for the organism to turn round and face the other exit if necessary.

Often the Caddis Larva Cases are made entirely of small particles of sand. These are wonderful structures, and it is difficult to believe that such carefully prepared tubes are the result of larval activity. For aquarium work it is advisable to extract the larva from its case and watch the process of case-building. The larva will quickly construct another case, using whatever materials are available.

When removed from the case, the general structure of the grub should be noted. Its breathing organs are an interesting feature. Like the larva of the Water Beetle, etc., they are borne on the abdomen, and have a feathery appearance. However, there is no need for the Caddis Fly larva to move to the surface when air is required. Its breathing organs are modified so that the organism can obtain the air it needs from that dissolved in the water.

The larva lives in the ponds for a year or more and then changes to the pupa stage. Both ends of the case are partially closed, only sufficient space being left for water necessary for respiration to pass through. In this condition the pupa may remain for several weeks, but metamorphosis is steadily taking place. When ready for



THE GNAT.

The larva can be found in most water-butts during April and May.

an aerial existence, the pupa emerges from its case and swims in the water, finally reaching the surface. On a warm day the pupa case opens and the young Caddis Fly is able to escape from it (Fig. 41).

The Gnat Larva (Fig. 42)

The Gnat larva is met with in most ponds and ditches, and in rain-water butts, etc. When at rest, it floats on the surface of the water, head downwards. At this stage it has a large head and thorax and a long tapering body. The larva might be studied in the top classes of a school, but it is too small for young children to observe. Its breathing process is somewhat specialised, taking the form of a syphon, which, when the larva is at rest, is flush with the surface of the water.

In this position the organism is able to breathe, and at the same time feed on small insects which come into contact with its mouth.

After living for several months in the larval state, the organism is ready to enter the pupal condition. During this period it changes its skin three or four times, and after the last moult undergoes a striking change. It is no longer necessary for the organism to take in food, and often the tail changes its position completely, the anterior end of the pupa coming to the surface. In this inactive condition rapid changes take place. The thorax becomes much enlarged and the head is bent backwards. Two horn-like parts appear flush with the surface, these forming the breathing apparatus of the pupa.

At the end of this stage the pupa swims along the surface of the water. On coming to rest in a horizontal position flush with the surface, the skin of the thorax splits, releasing the adult Gnat. For a short time the pupa case acts as a raft; the wings of the Gnat open out and enable it to fly away. In this insect two wings only are developed, the remaining two being simply stumps. There is very little difference between the male and female Gnats; the slight differences are unimportant from the elementary school standpoint. The female lays her eggs on the surface of ponds or any stagnant water, generally a large number at a time. Each cigar-shaped egg has a mucilaginous covering, and hence a number of eggs become attached and float on the surface of the water as a kind of raft.

The Water Snails

The Water Snails should not be overlooked. There are a number of

shell dwellers to be found, including Snails and Fresh Water Mussels.

The Snails will be found creeping along on water plants, over stones or gliding along beneath the surface of the water, shells downwards. The most common type met with is the *Limnæa stagnalis*. Its shell is thin, horny and turreted, with a sharply pointed spire. In an aquarium the movements, feeding habits, etc., can be carefully observed. When undisturbed, its body will protrude from its shell, showing a broad, short head, with somewhat flattened tentacles near the inner base of which are the eyes. The movement, by means of the muscular "foot," can be plainly seen when the Snail moves along the sides of the aquarium. Generally its spawn can be found in oblong, transparent, gelatinous masses on the stems of water-weeds. It is interesting to note the development of the eggs.

Another common type met with is *Limnæa articulata*. This Snail has a much smaller shell, but the body whorl is much longer than that of *Limnæa stagnalis*. Both the above types are lung breathers. *Paludina vivipara* is another type often met with. It has a pretty shell, the whorls being ornamented with coloured bands. This Snail does not lay eggs, but brings forth tiny miniatures of itself. It will be noticed that there is a lid to the shell, which is a protection to the gills, this type of Snail being a gill-breather.

Fresh-water Mussels

The Fresh-water Mussels are often found in ponds and canals. The one type, *Unio*, is of importance, for this is the species from which pearls were at one time obtained. Another type,

the *Anodonta*, is found more often in rivers or in ponds supplied by streams. In the *Unio*, the shell is thin and the hinge of the bivalve is toothless. The *Anodonta* has a larger and much stronger shell, the hinge in this case being toothed. They both plough their way through the mud by means of a muscular foot similar in shape to a ploughshare. For aquarium purposes the *Anodonta* is the best type to use. When accustomed to its surroundings the partially opened shell will give a good view of its fringed syphons.

The Mussels are of very ancient lineage, fossils having been found in rocks of the Eocene period. Although the female produces thousands of miniatures like herself, few reach maturity. The eggs develop before leaving the gill plates. For a part of their life-history, the young Mussels must live as parasites on Fishes. Often these small, undeveloped shells can be found on the back or tail of Minnows or Gudgeons, firmly attached to the scales.

Spirogyra

If a strong lens or a microscope is available, the scum found on the surface of the pond should be examined. The green scum consists of a type of Fresh-water Algæ. It is a characteristic of the species to float, being buoyed up by the bubbles of oxygen produced during carbon assimilation. If a microscope is available, the structure of a cell might be taken with Standard VII, *Spirogyra* forming an excellent starting point.

The detail following will be found helpful by those who have not begun the study of cell structure from this standpoint.

Its filaments are free, that is, without attachment to any kind of substratum. There is no distinction into apex and base—all cells are alike throughout the thread. All the cells are similar, and all take an equal part in the development of the plant. Physiologically it is a unicellular organism—all the cells being equivalent and each capable of carrying out all necessary functions itself. In the ordinary state, the plant is morphologically multicellular, but sometimes it breaks up into separate cells capable of independent life.

The cells of *Spirogyra* are comparatively large, generally a little less than $\frac{1}{100}$ inch, hence they are favourable for study with a lens or a low-power microscope. Each cell consists of a cell wall of cellulose and a mass of protoplasm in which protoplasmic circulation can be observed. Embedded in the protoplasm are conspicuous chloroplasts, which take the form of green spiral bands with toothed edges. These vary in number from one to ten in each cell, according to the species, but the number is not always constant even in the same filament. Each chloroplast is studded at intervals with large pyrenoids or protein granules, which take a crystalloid form. Starch grains are deposited around these proteid bodies. Each pyrenoid becomes surrounded by a coating of starch granules. In every cell there is a large nucleus, often suspended in the middle of the cell by protoplasmic fibrils. These fibrils are attached to the chloroplasts where the pyrenoids are situated. Each nucleus contains a large nucleolus. The cell division coincides with the division of the nucleus. This is rather a compli-

cated process, resulting in the formation of two exactly similar daughter nucleii. At the same time a septum transversely divides the cell, appearing first as a mere ring, but gradually advancing until a complete disc of cellulose is formed across the cell, dividing the cell and its contents into two parts and separating the daughter nucleii.

Reproduction.—Spirogyra possesses no distinct asexual reproduction except for the occasional breaking up of the plant into its constituent cells. Normally, reproduction is sexual, or a form of sexual reproduction in the form of conjugation or the union of like cells. Conjugation takes place between two filaments lying side by side. The cells of each filament send out lateral appendages which exactly correspond with the opposite filament to which they become attached. The walls are absorbed and hence there is a passage between the two filaments. The contents of one of the cells contract and move towards the opening. The contents of the opposite cell also contract slightly. The contracted cell-contents next move towards the connecting passage and gradually work

through it, passing into the opposite cell and uniting with it.

The fusion of the nucleii of the conjugating cells takes place rapidly, and the united protoplasmic mass forms a round or oval organism. This surrounds itself with a cell wall which becomes thickened and cuticularised on its external surface. (What becomes of the chlorophyll bands is not definitely known, yet they reappear on the formation of a cell from a Zygospore, or resting spore.)

The Zygospore assumes a darker colour and the starch disappears, giving place to oil, which constitutes the reserve carbonaceous material during the interval of rest. The Zygospore can now survive a period of drought or the cold of winter.

On germinating, the Zygospore bursts its outer cell wall and the protoplasm grows out, clothed only with its inner cellulose wall. The bright-green colour soon appears, and starch is once more formed. In the very early stages there is a distinction into apex and base, for it remains attached at one end, which is pointed and colourless. This state soon disappears and the ordinary floating organism is produced.

CHAPTER V

INSECT LIFE

THE study of insect life is of great importance in country districts and is intimately related to horticulture, agriculture and bird life.

In town schools, much difficulty is often experienced in obtaining suitable specimens for the study of the life-history of any particular specimen. However, the observant teacher in town schools recognises that the Cabbages, etc., sold in the markets often contain Caterpillars, and from this stage the study of insect life should be begun. Ordinary glass jam jars, and Cabbage leaves on which Caterpillars are feeding, provide sufficient scope for keen observational activity. With the aid of a rudely constructed terrarium, the chrysalis stage and the adult insect might be studied. In a book of this character it is impossible to give as much space to the study of insect life as the subject deserves. Generally speaking, insects are so inconspicuous that their presence is unobserved, although they form three-quarters of the whole Animal Kingdom, many being of value to mankind but others of a very harmful nature.

General Remarks

For the benefit of the younger members of the profession, a few general remarks on insects are perhaps advisable. Insects (from the Latin *Inseco*—I cut into) belong to a very large group of creatures having certain definite features. In the first place they

possess, as the name indicates, a jointed body made up of segments, which is supported by a hard, horny skin in place of an internal bony framework. Secondly, they possess, on one or more segments of the body, jointed appendages modified to act as legs, jaws, feelers and antennæ. The body is made up of three parts, the head, the thorax and the abdomen.

The Head contains the eyes, and these are often most beautiful and complex. Generally the organs of sight are highly developed, enabling the insect to see the shape and size of objects, but in other cases only to discern the difference between light and shade. The mouth, situated on the underside of the head, is modified in several ways. In some types it takes the form of hard-biting jaws and finger-like organs to push food between them (cf. the mask of the Dragon Fly larva), in other cases the form of a tube or trunk which enables the insect to bore holes and extract juice. The fore part of the head bears the antennæ or feelers. These are highly specialised organs, and they are not only the organs of touch, but are probably connected with the organs of smell and hearing.

The great French scientist Fabre has given to the world the result of his life's work on insects, and his books provide delightful reading to the keen teacher. In one of his works he shows how the male Moth seeks his mate, and in some wonderful manner finds where she has

been hidden. Fabre's works suggest that the sense of smell is most highly organised in members of the Insect World.

The Thorax or second part of the body usually carries three pairs of legs and may have on the upper surface one or two pairs of wings.

The remaining part of the body is *the Abdomen*, usually termed the tail. This contains the gut or digestive tract and the organs of reproduction.

Passing through the whole length of the body is a long tube which acts as the heart, its pulsating movement bringing about the blood flow. Running along each side of the thorax and abdomen of an insect are a series of tubes called spiracles. These are connected by similar yet smaller tubes to every part of the body. By means of the

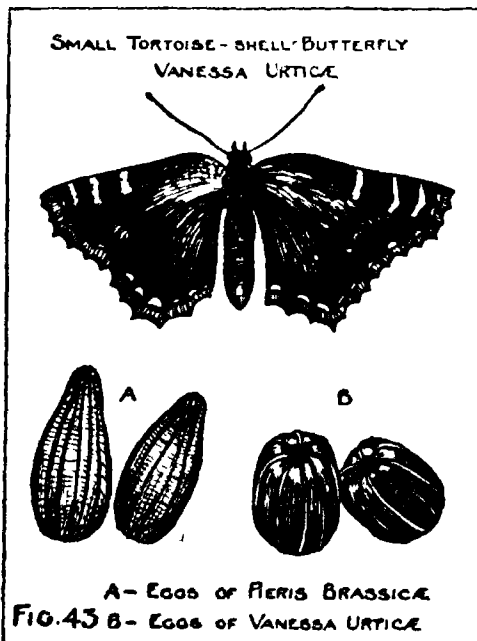
spiracles air is enabled to pass freely in and out, and thus lungs, as found in the higher animals, are unnecessary.

The Stages in the Life of an Insect

The life-history of insects generally takes the following stages. Usually eggs are laid by the adult female. These in due course hatch out, but the resultant organism bears only the slightest resemblance to the parent. From the eggs, grubs having six legs (Caterpillars) develop. These seem to have only one object in life, namely feeding. All Caterpillars are destructive and voracious eaters. When fully developed they change into a quiescent stage, the chrysalis, feeding and movement having apparently ceased. Rapid changes take place internally during the chrysalis condition, and at the end of a definite period the adult insect escapes. As a rule the adult stage is not greatly concerned with feeding, its main purpose being the reproduction of the species.

It is of enormous value to know the life-history of the harmful insects, and measures adopted to destroy harmful pests are based on such knowledge. The appearance of the eggs and the places in which eggs are deposited is a source of useful observational activity. In many cases the eggs are so small that a lens is essential. Clusters of eggs, however, may be found in many places. Those found on the underside of Nettle leaves belonging to *Vanessa urticae* (Fig. 43) are ribbed and shaped like a pumpkin. Those found on Cabbage leaves are the conical, ribbed yellow eggs of *Pieris brassicae* (The Cabbage White Butterfly).

The Caterpillars are perhaps the most interesting stage for classroom study.



THE SMALL TORTOISE-SHELL BUTTERFLY.

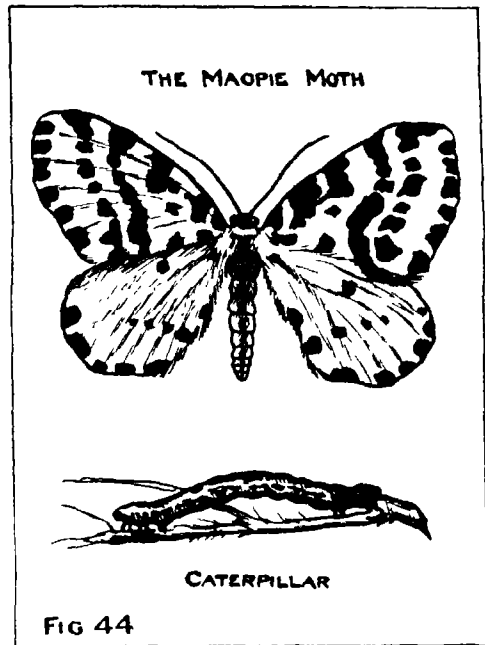
The eggs of this Butterfly are shaped like a pumpkin: those of the Cabbage White being conical.

These may be found in various places. Some seek their food in trees, along the surface of the ground, or on the succulent leaves and even stems of garden plants. The Butterfly larvæ, especially those of the White Butterflies, feed and repose quite openly upon their food plants. Many species, however, resemble portions of their food plants. Those which spend the larval stage on the Broom exactly resemble the twigs. The larva of *Angerona prunaria* may be mistaken for the twig of the Rowan or Mountain Ash. The larva of the Willow Moth resembles the leaf of the tree.

As the larva stage of various insects is the most destructive, it is of importance, especially for country children, to be able to recognise and determine the order of which a particular larva is a member. A legless, fleshy grub with a soft, pointed, retractile head is usually a member of the Diptera or two-winged insects. A six-legged larva with hairy head and strong jaws is usually of a Beetle (Coleoptera). The so-called Caterpillars, with their long, soft and often hairy bodies, prominent heads and jaws, and with sixteen legs,* belong to the Lepidoptera or scale-winged insects, the Moths and Butterflies. In some instances several of the intermediate pairs of legs are absent, the larva moving along in a looping fashion. The latter are known as "looper" Caterpillars, good examples of which are found in the Magpie and Amber Moths (Fig. 44).

Leaf-eating Caterpillars of the Sawflies (Hymenoptera) have eighteen to twenty-two feet, and are called false Caterpillars.

* In some instances caterpillars have as many as sixteen legs, six of which, towards the head, are hard and horny, and correspond to the six legs of the perfect insect.



THE MAGPIE MOTH.

This is a common pest on fruit trees. The looping movement of the caterpillar should be noted.

The Chrysalis stage of the insects is also interesting, and in a terrarium or vivarium provides much material for observation. The length of the adult stage varies considerably, but with the exception of a few species which hibernate through the winter, the adults pair, the female lays eggs and death follows in a comparatively short time.

Practically all parts of plants are subject to attacks from insects. Many pests, such as the Weevils and Bean Beetles, destroy seeds. Some are general feeders in the larval stage, especially Wireworms and Cockchafer grubs. These lie in the soil for several years, feeding on roots of grasses and the tap roots of garden and field crops. The Turnip Fly, Cockchafer and Ox Warble Fly are harmful in the perfect condition as well as in the larval stages. The wings are very important for recognition pur-

poses. The term "ptera" (=wings) is applied to all insects; the prefix gives the number and kind.

As a general guide to the identification of insects by means of their scientific names, the following classification will help when textbooks are referred to.

The term "aptera" is applied to all insects such as Fleas and Lice, which are without wings.

Insects such as the Water Boatman, Aphides, Frog Hoppers, etc., which have wings, horny in front but transparent at the back, are members of the order *Hemiptera* (half-winged).

Many insects possess two wings only; these are termed *Diptera*, examples being found in the Gnats, Flies and Crane Fly, etc.

The wings of Butterflies and Moths are covered with very fine scales. Such features place the insects in the order *Lepidoptera*.

Beetles are provided with wing-sheaths of a horny nature, formed by the two front wings; the term *Coleoptera* is applied to this class.

Certain insects, especially the Dragon Fly and May Fly, have delicate wings covered with a network of nerves, hence such insects are termed *Neuroptera*.

Insects having wings which fold up fan-wise belong to the *Orthoptera*—the Earwigs, Cockroaches and Crickets being examples of the order.

Other insects such as the Wasps, Bees and Ants have wings formed of transparent membranes. These are placed in the order *Hymenoptera*.

In most of the types mentioned, the life-history works out in the following manner. The female insect lays her eggs, from which sooner or later the Caterpillars or larvæ emerge. These

feed actively and grow rapidly for a certain period. When fully developed, and after reaching a place of security and in many instances spinning cocoons, they change into a quiescent stage, forming a chrysalis or pupa. Their Caterpillar skins are thrown off (moult), and under the protection of the strong outer covering they develop into the mature winged insect or imago.

Certain groups of insects—those belonging to the Apteræ, Hemiptera and Orthoptera—have no quiescent stage after they leave the egg. The larva, on first emerging, is very similar to the adult form, which is arrived at by a series of moults. All perfect insects have six legs. Spiders have eight legs, and although in some respects they resemble insects, they are not of the true order.

Enemies of the Insect

Insects have many enemies, even among their own class. This fact is of great importance, and considerably assists the farmer and gardener. Lady-birds devour all kinds of plant Lice (the Aphides), and it is, therefore, of the utmost importance that this insect should be recognised as a friend by children and adults. The Ichneumon Fly often lays its eggs in the Caterpillar of the Crane Fly or other ground larvæ. On hatching, the larva feeds on its host, ultimately bringing about its death.

In another chapter the value of bird life will be dealt with. Before leaving the natural enemies of insects, however, it is perhaps wise to introduce the insect-destroying birds. Starlings, Plovers, Robins, Titinice, Swallows, Swifts, Martins and Hedgesparrows all do their share in keeping insect life

within bounds. Insect-eating birds such as the above are invaluable to mankind, and should be encouraged. The Cuckoo is of special importance. It is one of the few birds that will eat hairy Caterpillars such as the Woolly Bear. Frogs, Toads, Hedgehogs and Moles are also larvæ eaters and should receive the protection of man. The "Little Gentleman in the Black Coat" is unfortunately unmercifully persecuted. He certainly makes the lawns, gardens and fields look untidy with his "hills," but his value in destroying ground larvæ alone far outweighs the extra work involved by his upheavals.

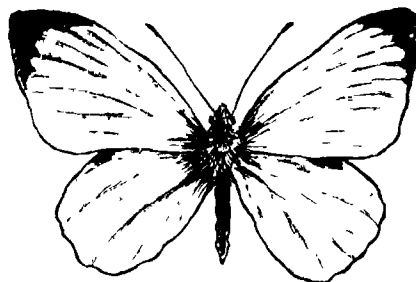
A life-history of a few insects will be given in detail. In the majority of cases the stages in development can be observed in all schools. For the benefit of town and city schools, for which eggs of the types may have to be purchased, the scientific names are inserted.

The Cabbage White Butterfly

The Cabbage White Butterfly (*Pieris brassicae* L.).—The larvæ of this type are perhaps the easiest to obtain. Often they are found in groups in between the leaves of Cabbage. The Caterpillars are of a dark bluish or greenish-black colour, with a line of yellow along the back and along the sides, the whole body being thinly covered with hairs. Generally they are 1 inch to 1½ inches in length, and when well fed are proportionately stout.

The Caterpillar or larval stage lasts for about a month, after which each Caterpillar leaves its host and finds its way to a suitable wall, fence, tree or Pea or Bean stick, up which it crawls. In this position a change to the chrysalis stage takes place. Often

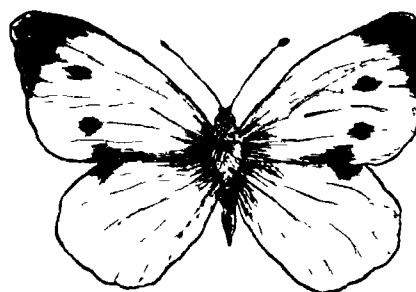
CABBAGE WHITE BUTTERFLIES (*PIERIS BRASSICAE*)



MALE



CATERPILLARS



FEMALE

NATURAL SIZE

FIG. 45

CABBAGE WHITE BUTTERFLIES.

The caterpillars of this Butterfly do considerable damage to the leaves of Cabbages and other members of the Brassica family. The female Butterfly can easily be recognised by the markings on its wings.

these chrysalides, which are yellowish-white in colour, hang down by the tails and a silken thread from the middle of the body.

This stage lasts for approximately three weeks, at the end of which period the perfect Butterfly emerges. Immediately after "pairing" has taken place, eggs are laid and a further generation of Caterpillars is produced. The White Butterfly is very well known and easily recognised, and the male and female can be identified by the dark markings on the tips of the fore wings (Fig. 45). The Butterflies appear in early spring, lay eggs and die. Generally the second generation of Butterflies appears in July or early August, and in a warm summer the Caterpillars may be found feeding as late as November. From the second brood of Caterpillars the chrysalides generally remain in pupa stage until the following spring.

The Small White Butterfly

The Small White Butterfly (*Pieris rapae* L.) lays her eggs singly on Cabbage leaves. These give rise to the familiar green Caterpillars, which have a peculiar velvety appearance and a narrow yellow line down the back. The life-history is practically identical with that of the Cabbage White, with the exception that the adults do not grow so large.

The Green-veined White

The Green-veined White (*Pieris napi* L.) is another well-known species, the Caterpillar of which is similar in general appearance to that of the Small White. The Caterpillars, however, do not show the yellow line down the back, and hence the two kinds can easily be identified.

The Cabbage Moth

The most difficult Caterpillar to identify is that of the Cabbage Moth (*Mamestra brassicae*). It is impossible to give any definite clue to the coloration, for many variations are found, in fact the Caterpillar (larva) is often mistaken for that of the Cabbage White Butterfly. The eggs are laid singly on a variety of food plants, but especially on members of the Cabbage family. These hatch out into small green Caterpillars which feed voraciously on the leaves. Growth is very rapid, and as the more mature Caterpillar develops, the colour scheme varies from light green to greenish-brown, or brown to black on the upper side, the underside varying from yellow to green. I have mentioned the Moth because the chrysalis is one often met with. When fully grown—about 1½ inches in length—the larva buries itself in the soil and forms a protective case of shiny brown chitin. Chrysalides are often met with in gardens, and the movements of the pupæ inside the cases are a source of wonder to the people who find them.

These chrysalides can be kept in the classroom during the winter (see Section 5) and the adult stage examined in spring. The Cabbage Moths are probably not well known, even in country districts, for they fly only at night. Occasionally they may be found resting on tree trunks, in sheds and on palings. They are a dingy, greyish-brown colour, with white markings as indicated in Fig. 46.

The Daddy-long-legs

The Daddy-long-legs, or Crane Flies, are met with even in towns. Their long legs give the insects a character-

istic appearance, hence the generally accepted name of Daddy-long-legs. The adult insects make their appearance early in June. The female begins the process of egg-laying shortly after she has emerged from the chrysalis stage. By a special egg-laying apparatus she is able to deposit the small, oval black eggs just below the surface of the soil. In about a fortnight the eggs hatch and the young larvæ become free to commence their destructive work. They attack all kinds of roots and show a particular liking for grasses and cereal crops. As they develop, the skin becomes exceptionally tough and leathery, and for this reason the term "Leather Jacket" is applied to the larva.

Fully-grown Leather Jackets are about $1\frac{1}{2}$ inches long and usually of an earthy or greyish-brown colour. They are cylindrical in shape and have not the slightest indication of legs. The black head is retractile, and when the larva is resting is drawn back out of sight. The hind part of the body is furnished with two fleshy projections, which protect the two breathing pores or spiracles. In the larval stage, which generally lasts for nine months, they remain in the soil, 1 inch or so below the surface, and feed voraciously during the mild weather of autumn, winter and early spring. Early in summer they cease feeding and change into the pupæ or chrysalide state. After about a month, the chrysalides wriggle half-way out of the ground, burst open and release the imago of the Daddy-long-legs.

The Wireworm

The Wireworm is another destructive larva which can be used for observa-

tional work in schools. It grows to about 1 inch in length. Generally the larva is yellowish-brown, like a short piece of polished wire. Its skin is very tough and considerable force is necessary to destroy it. The head is slightly darker in colour than the rest of the body and is fitted with powerful biting jaws. The three segments behind the head bear a pair of legs each.

Wireworms live in the soil for years, feeding mainly on the roots of plants. Potato tubers are often affected as well as the tap roots of Carrots. The pupa stage is not at all well known. Only on one occasion has this stage been observed by the Author, and in this case the organism died during metamorphosis. The adult stage of the Wireworm is a Beetle. This has the peculiar feature, when placed on its back, of bending up in the middle so as to rest on its head and tail, and then with a sudden jerk and a click it springs from the ground and comes down the right way up.

It is narrow and flat, about $\frac{1}{2}$ inch long, with very short legs. The most common ones met with have reddish-brown wiry cases, striped with long furrows, a black head and thorax. The females lay their eggs among the roots of plants slightly below the surface. On hatching out, the Wireworms immediately begin the work of destruction.

The Cockchafer

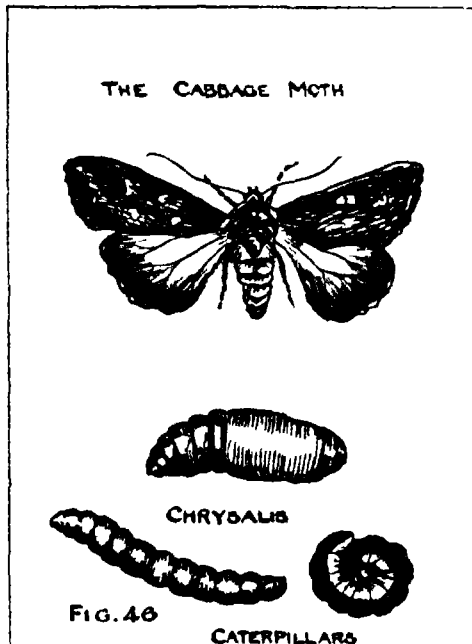
The Cockchafer Beetle (*Melolontha vulgaris*) is another interesting type, the larva of which can be studied in school. The Beetle is very large, sometimes 1 inch in length. Its wing-cases are reddish-brown in colour, with five raised lines on each and usually covered

with hairs. Along the sides of the abdomen are to be found five triangular white marks. The head and thorax are black, and the end joints of the antennæ form club-shaped bodies.

The larva has a large brown head fitted with a strong mandibled mouth. The body is thick, fleshy and a dirty white; often the tail end is swollen and assumes a dark purple colour. Six legs are attached to the fore part of the body, these also being of a powerful nature. When discovered in the soil, the grub appears sluggish and remains in a curled-up position. There is little difficulty in identifying it. A fully grown grub is about $1\frac{1}{2}$ inches long and as thick as a man's little finger. When ready to pupate it constructs a "nest" of soil, cementing particles together by the deposition of mucus.

If found in the nest or cell, it will be seen to have lost its hard, tough skin and is easily injured unless great care is taken.

Pupation takes place at the end of summer, the adult Beetles appearing above the ground the following May. The Beetles are night fliers and are seldom seen during the daytime unless found resting on trees and shrubs. After pairing, the female lays her eggs, thirty to forty at a sitting, by burrowing into the soil during June and July. The eggs hatch out in about six weeks, but the larva does little damage for some time. When about a year old, however, it feeds voraciously on the roots of grasses, young trees and almost any vegetable crop. Its life in the soil may last four or five years.



THE CABBAGE MOTH.

The caterpillar is often found curled up in the heart of a Cabbage. It is difficult to remove.

Heart and Dart Moth

The Caterpillars of the Heart and Dart Moth are very often met with in gardens, allotments and fields. They are a dirty-grey colour, often showing a tinge of chestnut brown, and have rows of black dots along their sides. The legs are short but strong, and this fact distinguishes them from the Leather Jackets. The brown or brownish-black head is fitted with a powerful biting mouth which is used effectively in eating the young stems of growing seedlings. During a warm summer these surface Caterpillars feed rapidly, and in July or August pupate; the adult Moths emerging a month later. The Moth can be readily recognised. It has brown fore wings, extensively mottled with black, the hind wing being white or pale brown. After pairing, eggs are laid on the leaves or stems of weeds and cultivated plants,

producing Caterpillars in about fourteen days.

The Large Yellow Underwing Moth

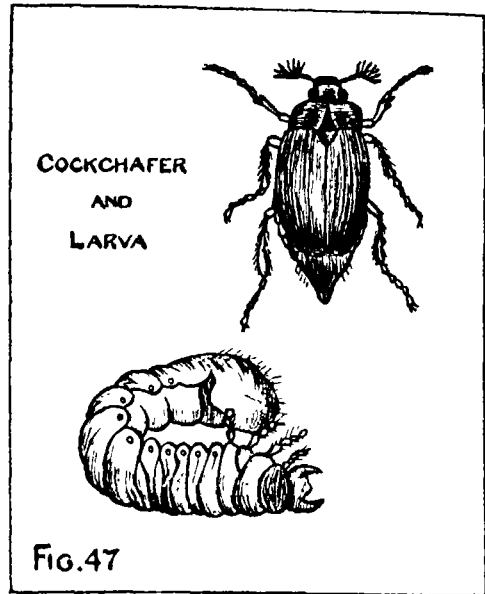
The Large Yellow Underwing Moth also lays eggs which give rise to surface Caterpillars. The colour of these, however, is variable; sometimes grey, greenish, or even reddish-brown. Their destructive work is similar to that of the Heart and Dart Caterpillar, and both types grow to about the same length, $1\frac{1}{4}$ inches.

The Lackey Moth

The Lackey Moth is an example of a different type. It is extremely common in the south of England and in the Midlands, but is not so well known in the north of the country.

The larvæ can be found usually in April, but the most destructive work is done during June, July and August. When fully grown they are rather beautiful objects, and their distinguished colour scheme renders identification easy. The body of the Caterpillar is a blue-grey, having down the middle of the back a white line, on either side of which and passing along the sides of the larva is a broad orange-red stripe followed by a black one; this is succeeded by a second orange stripe followed by a bluish stripe, a third orange stripe completing the scheme; orange spots may be continued on the underside of the Caterpillar. With the exception of the black head, the whole Caterpillar is covered with reddish-brown hairs.

These Caterpillars feed on the leaves of various trees, such as the Oak, Willow, Hawthorn and Elm, and on



THE COCKCHAFER BEETLE.

The larva of this pest, when fully grown, is $1\frac{1}{4}$ inches long.

all the fruit trees. They live together in large numbers, for, when young, they spin a delicate web between two or three leaves, enlarging the nest as necessity arises. Often such nests are conspicuous objects on trees, reaching sometimes 1 foot or more in length and over $\frac{1}{2}$ foot in breadth. These nests are used by the Caterpillars as shelters from rain, but on sunny days they may be found lying on twigs in a resting condition or eating the foliage. As growth progresses, the Caterpillars change their skins; this process is generally accomplished while the larva is resting.

The foliage of a tree infested by the larvæ of the Lackey Moth is sometimes completely destroyed.

When fully fed, the Caterpillars leave the nest and select a suitable leaf or an outstanding piece of bark; they may even leave the host tree and climb up

palings, etc. A yellow or white cocoon is spun by the Caterpillar, after which the larva changes to a black chrysalis, showing yellow markings, from which the adult insect emerges in about a month's time.

The Moths are brown in colour, the shades varying greatly, and no general description would be satisfactory. They are night fliers and are greatly attracted by artificial light. To obtain adult specimens it is only necessary to leave the light on in a bedroom, the blinds up and the windows open. They often appear in numbers, but generally more males will be captured than females.

After pairing, the females lay eggs in a characteristic formation on the twigs of the trees on which the Caterpillars will thrive. The greyish-brown eggs are laid together in rings round a twig, completely encircling it to a depth of $\frac{1}{4}$ to $\frac{1}{2}$ inch. As many as 150 eggs are laid at a time. The adult Moths die off early in September, the next generation appearing early in the following July.

Bees

In country districts it is possible to study the life-history of Bees in the schools. Several schools in Staffordshire take Bee-keeping as a complement to School Gardening and these subjects considerably help the inhabitants of the districts. In one school an "Observation Hive" is fitted to the inside of the classroom window, the sides of the hive being made chiefly of glass, and the work of the bees inside the hive can be closely followed.

The Hive Bees, or Honey Bees, are, perhaps, the best-known type; still, a

few general notes will perhaps enlighten the young teacher (Fig. 48).

The so-called Honey Bees—those generally kept for commercial purposes—are the most highly organised members of the Insect World and exhibit many modifications of structure to meet the needs of the community to which they belong. In the wild state the conditions of life and work are practically identical with those of the bees kept for the production of honey, except that the hives are to a certain extent under the control of man. Even in the natural state the Bees form a colony in almost any place which is weatherproof. The tower of a church is a favourite spot, but often colonies are found in hollow trees. The old thatched roof was at one time a useful abode, but modern construction has practically eliminated this type of Bee-home.

The Queen

In the wild state or in the hive, three types of Bee are met with. For convenience these are termed Queen, Drones and Workers; there is only one Queen to a colony. She is the female, and her whole purpose is that of reproduction or egg-laying. The three types vary in several respects. The Queen is the largest, her abdomen being elongated; her legs have only a few hairs on them, in fact the reddish-brown tinge of the skin or exoskeleton can be seen.

The Drone

The Drone, or Male, is heavily built; he has a much wider body than the Queen, but not so long. His work is that of pairing with, and impregnating the female Queen. His eyes occupy the

greater part of the sides of the head, the antennæ are much shortened, and the thorax and legs are covered with thick short hairs. In a colony there are generally three to four hundred drones. They live an idle life, seldom leaving the hive except to accompany the Queen on her nuptial flight.

The "Worker"

The "Worker" Bees, of which there may be seven or eight thousand in a colony, are sterile females sometimes termed neuter. These are much smaller than the Drones and are specially adapted for the work they have to perform. The head is fitted with a pair of compound eyes, which occupy the greater part of the right and left sides. The thorax is of a very hard and horny nature; on this part the six legs and two pairs of wings are attached. The wings are thin and membranous, supported by series of nervures or veins which are of definite arrangement. Along the front of the fore wings the veins are of a much firmer texture than the remainder.

The two pairs of wings act together when the Bee is in flight. On the downward stroke, the thinner part of each wing bends slightly upwards with

the pressure of the air, and in this manner the insect is drawn forward. The three pairs of legs are similar in general structure and are covered with

a tuft of stiff bristles at each joint. The hind pair, however, are much longer and are provided with many bristle-like hairs which act as a curry-comb for removing the pollen dust from the hairs which cover the body. The thigh of each leg is broad and hollowed out to form a groove, the edges being covered with stiff, bristle-like hairs placed transversely, thus forming what is known as the

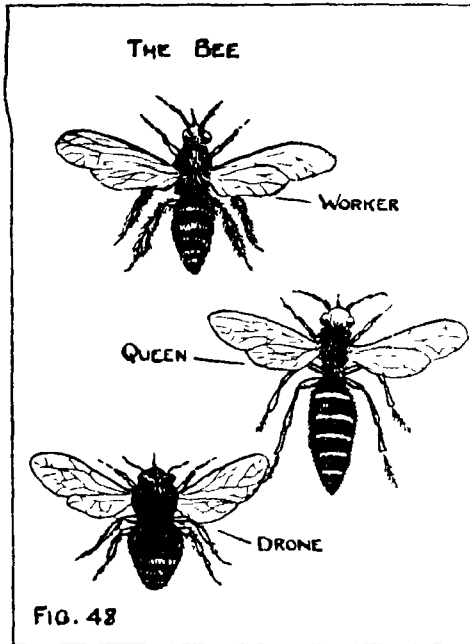


FIG. 48

BEES.

The Worker Bee is the smallest type. Note that the legs of the Queen are hairless.

"pollenbasket." After collecting pollen, the Worker moistens it, rolls it up into a ball and packs this into a "basket."

The jaws of the Worker are strong and smooth. The tongue is a most remarkable structure, being the extension of the under lip. This consists of six or seven different parts, which lie perfectly together lengthwise and form a tube within a tube, the innermost part being longer than the rest. When searching for nectar, the trunk is thrust into a flower and the inside part, which terminates in a hairy spatula, laps up small quantities of the fluid and by muscular movement passes this on through the mouth to the honey sack,

or first stomach. Whilst passing through the mouth, two glands secrete a small amount of acid, which mingles with the nectar. The combination of acid and nectar is the first stage in the manufacture of honey.

"Chyle"

If the honey is intended for feeding the larvæ, or grubs, it is passed through a valve into the lower or second stomach. Pollen is also passed through, and by a process of digestion the honey and pollen are converted into a brood-food known as "chyle." When about to feed the larva, the Worker regurgitates small portions of the material and, when acted upon by the substance excreted from the glands in the mouth, Bee-milk is produced. This is the chief food of the larvæ and Queen, and often small quantities are presented to the Drones. If the Worker is engaged in the production of honey for storage purposes, she visits the storage cells and from the first stomach regurgitates the fluid.

In the colony, however, certain of the Workers act as nurses to the developing brood; others spend their time in attending to and feeding the Queen; a further number expend their energy in the production of honey; others again act as policemen guarding the entrance to the hive, while another section act as scavengers, whose main work is to keep the hive clean. Another set are the builders, whose chief duty is the construction of the cells either for the reception of eggs or the storage of honey.

The Workers engaged in the production of wax for the building of cells, pass through rather an interesting stage. The Bees fill their stomachs

with nectar and then hang in clusters from the top of the hive, warmth being essential to the process. In this condition they remain for twenty-four hours. During this period certain glands in the stomach secrete a substance which converts the honey into liquid wax. When formed, this passes through tiny perforations on the underside of the body into eight small packets situated on the last four abdominal segments, where it becomes hard and wafer-like. When this process is complete, the Bees visit the part of the hive in which building is to take place. The small wafers are extracted by the jaws one at a time from the packets, moistened by the tongue into a kind of paste and then used in cell construction.

Again, when the larvæ are fully fed and ready to undergo metamorphosis, the Workers cover over the cells with wax mixed with pollen, this mixture forming an air-porous covering.

The Sting

The Worker, like the Queen, is provided with an excellent weapon of offence or defence—the sting. This is situated in the last segment of the abdomen, and consists of three separate blades. The central blade fits into grooves on the inside of the other two. These other two blades slide up and down the central one, but the beaded edges prevent their being pulled asunder. At the base of the sting are special poison-glands, which come into action when the insect thrusts her three-bladed weapon into a victim, the poison passing between the central and the outside blades. The sting of a Worker is straight, that of a Queen being curved slightly and hence, from



Photo: J. J. Ward



Photo: J. Dobson

THE GREAT WATER BEETLE AND THE GREAT CRESTED NEWT.

The Great Water Beetle (*Hydroporus*) is a very common water beetle, and is found in most ponds and streams. The Great Crested Newt (*Amphibian*) is much smaller than the Great Water Beetle. The Great Crested Newt is found in most ponds and streams. The Great Crested Newt is found in most ponds and streams.

the sting of a Queen, much more poison enters the victim.

The Drones have no stings, in fact they are the least developed in the Bee colony. They have "tongues," which are too short to gather nectar from the flowers; no pollen baskets are found on the legs, and they have no wax-secretion organs; hence their existence depends entirely on the Workers. In the hive they feed on the general reserve of food and receive Bee-milk from the Workers. However, as winter approaches, their use to the community is at an end. The Workers become infuriated with them, and one by one they are prepared for death. The Workers bite through the strong veins of their fore wings, drive them out of the hive and leave them to die. Before winter sets in all the adult Drones are expelled, and the Drone larvæ and pupæ meet with a similar fate. Food must be conserved, and hence Drones are only allowed to exist as long as their functions are necessary.

The mouth of the hive is partially sealed over during winter, the Bees in the wild state slowly consuming their stores of honey; but as the sunny days of spring come along, the process of cell-making, egg-laying, etc., is recommenced.

Bees kept for commercial purposes are fed during winter. The cells in which the Worker Bees are raised are about the same size as those used for the storage of food (honey). For town and city schools a section of honey should be purchased. This consists of a thin wooden framework $4\frac{1}{2}" \times 4\frac{1}{2}" \times 2"$. The cells are built end to end, each one being hexagonal in shape and a little over $\frac{3}{4}$ in. deep. Brood cells are usually $\frac{7}{8}$ in. deep—

the Bees leave only a passage $\frac{3}{8}$ in. wide between the brood cells, this being sufficient to accommodate the Workers during the summer and to cluster in for warmth during the winter. The cells to accommodate the Drones are much larger, but are the same shape as those constructed for the Worker. Royal cells are the largest; these are rounded at the entrance and are constructed on the edge of the ordinary comb.

The Queen of the hive is really a slave; she is allowed to leave the hive for mating purposes only. When once a young Queen has been fertilised by a Drone, no further act of fertilisation is necessary during her whole life, which may last for four or five years.

Much more information could be given on these interesting insects. However, space will not permit this. More has been written on the life of the Hive Bee than on any other insect. For details as to the keeping of Bees, the kinds to purchase, etc., useful information is found in the excellent leaflets issued by the Board of Agriculture and Fisheries. For further information on the Hive Bee, Maeterlinck's "The Life of The Bee" is of great value.

The Humble Bee

The Humble or Bumble Bees form another group of insects which are worthy of consideration. They differ greatly from the Hive Bee, the colony only lasting for one season. The females, or Queens, which are fertilised at the end of the summer, hibernate during the winter, generally in the driest parts of mossy banks. When spring comes, each female constructs a few cells, stores these with honey

and pollen and deposits an egg in each. She continues cell-building and egg-laying, and attends to the needs of the developing larvæ until they complete their metamorphosis. Even after the first batch of Workers have hatched out, her work of cell-making is still carried on, the newly hatched Bees, which differ only slightly from the Queen, assisting in this process.

When a number of Workers have been hatched, the Queen gives her whole attention to egg-laying, often being helped in the process by the Workers, which are more or less imperfect females. Males are produced during the summer, and after fertilising the young Queens, die off. At the end of the summer the whole colony, which may number twenty-five females, forty males, and one hundred Workers, die off, with the exception of the fertilised Queens.

These Bees are not so highly organised as the Hive Bees. The cells are rudely constructed and vary in shape and size. Generally the "nest" is made in the side of a bank or under moss and litter. No special preparation is made for winter, the Queen remaining in a dormant condition during the cold weather. These Bees do an important work, however; they are the chief pollinating agents of the Clover, and hence are of immense value to the Agriculturist. Another Bee is often found living with the colony of Humble Bees. Such Bees have no pollen bags on their hind legs and seldom take an active part in the work of the community; in fact, they exist as parasites, living on the food collected by the Humble Bees.

There are over two hundred known

species of Bees in this country. Some live solitary lives in the hedgerows, mossy banks, rotting trees, etc. Others form small colonies of their own, while in several instances the females deposit their eggs in the cells of other bees.

The Wasps

The best-known Wasps (*Vespidæ*) are very similar in general construction to the Hive Bees. Their characteristic bands of yellow and black on the abdomen make them conspicuous and easily distinguished from Bees. The head, thorax and abdomen are similar to those of the Bees, but the legs are all about the same length.

The life-history of the Social Wasp is somewhat the same as that of the Humble Bees. Young fertilised Queens hibernate during the winter, often in holes in walls, anchored to curtains in rooms by the jaws or under the eaves of houses and farm buildings. Unfortunately the Queen Wasps are persecuted, and in some areas children are induced to kill the Queen, a reward being given for each one destroyed. There is much to be said for and against this cruel practice from a fruit grower's point of view, but to inculcate destructive habits in young children is bad. The life-history of the Wasp will show that even Wasps have their use.

The Choice of a Home

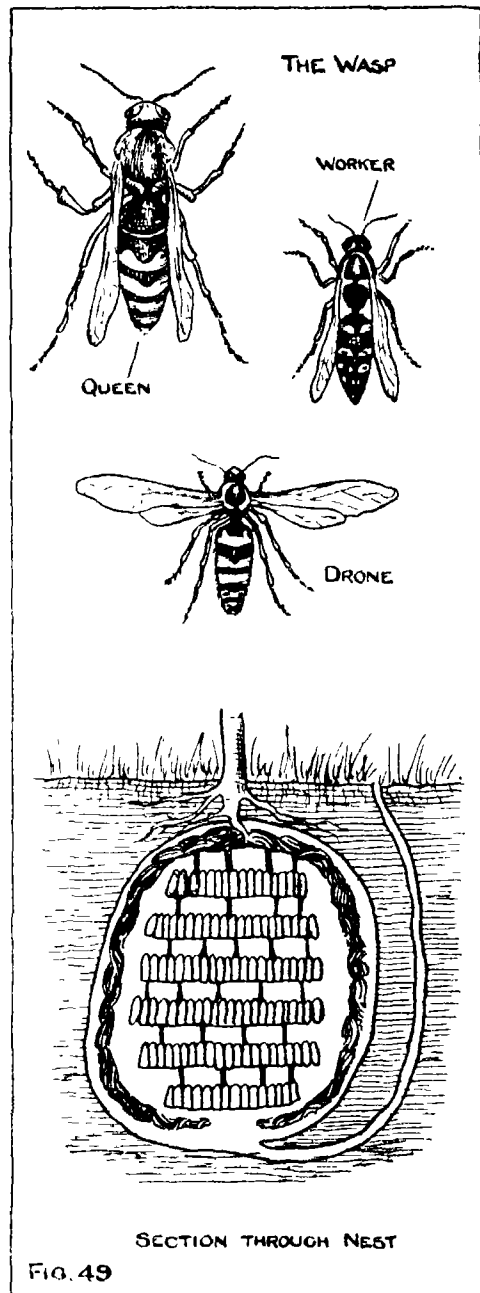
Early in spring the Queen Wasp leaves her winter quarters and seeks a hole in the hedgerow. With her powerful legs and jaws she enlarges the hole immediately below the root or rootlet of a hedgerow shrub. After visiting wooden palings, etc., and scraping off wood, which is mixed with

saliva, she constructs an umbrella-shaped waterproof dome and a few cells, generally four hanging downwards, in which to deposit her eggs. The larvæ she carefully tends, and during the time occupied in their metamorphosis, she enlarges the sides of the umbrella and prepares other cells for egg-laying.

The first-laid eggs provide her with Workers, and as these increase in number the work of cell construction and enlarging the cavity devolves on them. As time goes on and the number of Workers increases, the Queen gives the whole of her time to the process of egg-laying. The Workers concentrate on cell structure, and the nest, even before completion, is a beautiful, regular structure. The cells are hexagonal in shape and are built side by side, forming a cone four to five inches in diameter. Each succeeding comb is attached to the one above by a series of three to five short pillars; a good-sized nest consists of twelve to fifteen rounds of comb. The umbrella-like covering of the nest originally constructed by the Queen is enlarged as necessity arises, so that the whole nest is enveloped in a thick paper covering which is waterproof (Fig. 49).

Grub to Perfect Insect

The Queen deposits one egg in each cell; this is glued to one corner. After a few days the "egg" hatches out into larva, that is, a small white legless grub, fitted with jaws, eyes and mandibles; the last segment remains for some time within the egg, thus preventing the grub from falling head foremost from it. In this comparatively helpless condition, each grub is supplied with food consisting of small insects such



THE WASP

The nest of the Wasp is wonderfully constructed. The drawing represents a section through a nest secured in October, and shows clearly that the cells are arranged in tiers.

as Aphides, Flies and small Caterpillars. As each nest may in a season produce thirty to fifty thousand grubs, the adult, or Worker Wasps, are certainly worth the amount of fruit they consume. Millions of insects must be used up in the feeding of the larvæ, and if allowed to live they would do equally as much, if not more, damage than the Wasps.

The grubs, after about three weeks, are fully fed. On reaching its full size, a grub spins itself a cocoon and becomes a chrysalis. The change to the imago stage is rapid, for at the end of the fourth week from the egg stage, the pupa is ready to leave. After eating through the end of the cocoon the perfect insect emerges. At first it is weak and its colours are undeveloped. In a few hours, however, the vigorous perfect insect is ready for work.

Royal Cells

At the end of August or early September, royal cells are formed. These are somewhat larger than the brood cells of the Workers and contain the larvæ of the young Queens of the next generation. Sometimes a well-fed Worker lays eggs. These are not fertilised, for, like the Worker Bees, they cannot be impregnated. Often young Queens lay eggs, and these, like those of the Workers, are unfertilised, giving rise to Drones only. Towards the end of the Summer, the Queens and Drones pair. The Queens when fertilised continue feeding for some time, but later seek a suitable spot for hibernation. About the middle of October food is very scarce; the Worker Wasps devour all the grubs and pupæ in the nest, eventually become sluggish and die. The Drones are usually the first to die. As with the Bees, Drones are produced

when needed; when their function has been carried out their life is at an end.

Wasps are looked upon as troublesome and dangerous insects. If they are disturbed, they will certainly use their only weapon of defence, but usually they are quite harmless. To secure a complete nest for work in school, it is advisable to mark the entrance during the summer months. Towards the middle of October when the Wasps are practically all dead or dying, the complete structure should be carefully dug out of the bank. If left later than the end of October it is quite possible that Mice, Beetles, etc., will have partially, if not entirely, destroyed the structure.

There are seven well-known species of Wasps in this country. The Hornets are much bigger than the Social Wasps and build their nests on trees, out-houses and in the thatch of country cottages.

The Wood and Wall Wasps are fairly common, but neither of these produce a brood during the season.

Spiders (Fig. 50)

Although Spiders do not belong to the large family of insects, they are included as interesting specimens for terrarium work in schools. There are a very large number of Spiders known to Science. The colour, size, habits, etc., vary considerably, but a few characteristics are common to all species.

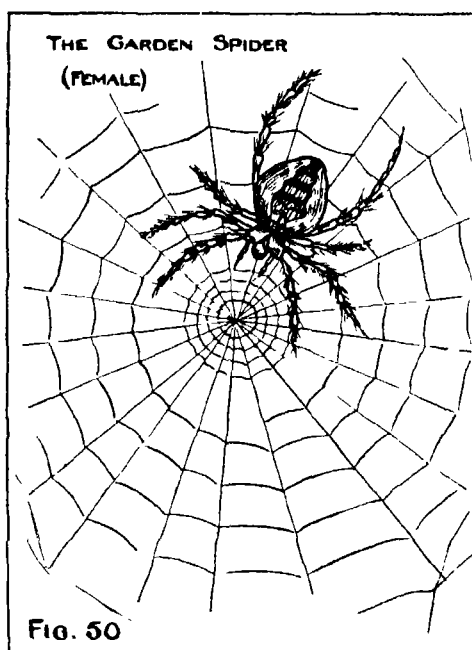
The body is divided into two distinct parts only, the cephalothorax, which is protected by a shield-like horny structure, and a soft abdomen which is unsegmented. Its eight legs, each being made up of seven segments or joints,

terminate in sharp claws. The latter are usually three in number.

The jaws are double-jointed, consisting of a base, often containing a poison gland and a hook-like fang which can be folded upon the base like a pocket knife. Close to the fang is a special structure used for ejecting the poison from the base after the fang has entered its victim. The fore part of the cephalothorax contains the eyes, which usually number eight. A pair of large-jointed hairy organs, the palpi (feelers), one on either side, give the head a ferocious appearance.

Beneath the soft abdomen the Spiders are provided with special organs known as spinnerets, usually six in number, but this varies with the species. These are connected with glands or tubes which are again connected up with the silk glands in the abdomen. The number of spools varies considerably, and in the most common type, the Garden Spider, they number about seven hundred. The male Spider is relatively small when compared with the female. His existence is somewhat precarious, especially during his courting days. If the lady of his choice is not prepared

for his advances, he either loses a limb or his life. Even after mating has taken place, this voracious female attacks and consumes her lover.



THE GARDEN SPIDER.

The web of the Spider is delicately woven. Seldom is the male observed - being smaller than the female.

Weaving the Web

In preparing to secure food the female Garden Spider constructs her web very ingeniously. She generally selects a suitable twig and attaches a thread of silk to it, walking away with the thread dragging behind until another spot is reached on which she decides to attach the other end. A number of such foundation lines are laid, and these she connects up with

spokes radiating from the centre.

When the spokes are completed and strengthened in the centre, the last step is commenced. Working upwards in a spiral manner, she lays down a special thread, which here and there is dotted with a gummy secretion. Finishing off in the centre, the Spider may remain at this point or leave the web, taking up a waiting position hidden under a leaf, but in direct telephonic communication with the web. When a Fly comes into contact with the spiral thread, its legs become temporarily fixed. The Spider leaves its hiding-place and hurries to its victim. After

apparently dancing with glee in front of her captive, she entangles it still further by covering it completely with newly-spun silk from her spinnerets. She may consume her victim immediately after capturing it; in this case, one bite is sufficient to eject poison from the poison gland. This material renders the victim incapable of fighting, and the Spider is able to consume her meal without additional exertion.

After pairing, the Spider lays eggs, covering them with a delicate silken cocoon. Such cocoons contain several golden-coloured eggs, and these may often be found in the crevices of walls and under the bark of trees. Generally the Garden Spiders hibernate in bark crevices, or under the eaves of houses and outbuildings during the winter;

many, however, die when the cold weather begins.

The eggs hatch out in May or June. There is no special metamorphosis, but before the adult Spider is produced, several moults or changes of skin take place.

Young Spiders have a peculiar and interesting method of seeking fresh quarters. They climb up a post or tree to a fair height, cast out a large quantity of silken threads from the spinnerets and then spring from the position taken up. The silken threads act as a parachute, and in the summer the Spiders are carried some considerable distance, eventually reaching the ground. The threads of silk are released and float about in the air, becoming what is known as "gossamer."

CHAPTER VI

BIRD LIFE

It seems a pity, truly, that humanity should stain
Its reputation by an act some sordid end to gain;
Oh! could we wisely to the plan of Nature's laws attend,
We then might learn to recognise in every bird a friend.

THE above words are taken from a poem written by Thomas Watts and published in 1880. They are worth repeating for even in these enlightened days, Man has not yet learned to follow Nature's plan. Surely birds were not created "to supply a pastime, man's vicious will to please." Unfortunately there is still a large number of people with no knowledge of the value of birds to mankind, and it is the duty of the teachers of this country to remove as far as possible

the cruelties and acts of callousness which such ignorance brings in its train.

Everything alive has some special purpose. The birds not only cheer the countryside with their delightful songs, but are, without exception, the guardians of our food supply. In country areas, with very few exceptions, birds are looked upon with suspicion by most farmers and gardeners. Few take the trouble to investigate what the birds do among their

crops. If seedlings are found above-ground, the birds are blamed and the shot-gun is brought into use. Often the poor little Hedge Sparrow is ruthlessly destroyed; an elementary knowledge of its food would be enough to convince the greatest enemy of birds of the harm done through ignorance. Again, Starlings, whose food consists almost entirely of ground larvæ, are persecuted, often through sheer lack of knowledge.

Much work, therefore, can and should be done in and through the schools to save the lives of our feathered friends. Boys will still go birds'-nesting and egg-collecting; this is more or less an hereditary tendency, and under certain conditions should be encouraged. If the boys are to find out for themselves some of the characteristics of bird life, they necessarily must go nesting. However, if simple, elementary lessons on birds and their value were given from the Infants' School upwards, the smashing of eggs for the mere "pleasure" of the action, the destroying of nests in a vicious manner, the cruel practice of stoning young fledgelings and the shooting with catapults of birds on their nests will eventually become things of the past.

The Economic Value of Bird Life

Birds, with the exception of the insect-eating migrants, do take, it is true, a certain amount of ripe grain; many attack the seedlings of Wheat, Turnips, etc.; others again have a liking for ripe, succulent fruits. The question arises, however, "Does the amount of good done by all birds during the breeding season, especially March, April and May, outweigh the damage done to ripe crops?" The opinion of the

leading authorities on bird life is, in every case, in favour of the birds. In dealing with the life-histories of various birds at a later stage, the question will receive more attention. To the keen student of Nature Study, the economic value of bird life becomes a most absorbing study. The writer has not forgotten an early experience, the utter foolishness of which resulted in a careful study of the food of birds. The ripening fruit in a bed of Strawberries was being damaged. As usual, the birds were blamed, and a .22 rifle obtained. The first victim was a Thrush. On picking up the dying bird it was noticed that a half-swallowed Milky Slug protruded from its beak. The bed was carefully examined and many slugs were discovered.

This personal experience of the harm done through ignorance is given because it indicates the general outlook when crops are damaged. Such soft-billed birds as those of the Thrush family are suited for dealing with grub food. It seems unfair to condemn such birds, however, because they are adapted for dealing with soft fruits also. The obvious cure for the depredation is to gather the fruit when ripe.

Farmers are continually complaining of the damage done by Rooks. In most cases they do not trouble to inquire why Rooks follow the plough in spring-time. In this case ignorance is displayed. In ploughing the ground, larvæ such as the Cockchafer grub, Wireworm, Leather Jacket, etc., are brought to the surface. These are sought after and consumed by the "Black Rogues." Certainly, when young crops, Potatoes especially, are attacked much damage is done, but generally speaking it is only during

drought that Rooks eat such succulent foods. During the breeding season the young are fed entirely on insect grubs and larvæ; the amount required for each nest must be enormous.

The Starling

The Starlings (Fig. 51) are among the best friends the farmer has. They seldom, if ever, feed alone, and with the exception of the small amount of fruit eaten in July and August, their food consists of ground larvæ and insects. Meadow land is their favourite haunt. Here they may be found, often in large numbers, running about close to the feet of Sheep and Cattle, picking up insects, such as the Crane Fly and Beetles, disturbed by the movements of the animals. Often their sharp beaks prod into the ground; each time the larva of some insect or Beetle has received its death warrant.

Again, some will be seen perched on the backs of Sheep. Here they are in search of ticks, the Sheep Maggot Lice and many other harmful insects. The Wireworm, too, has another enemy in the Starling. Like the Rooks, when fields are being ploughed and cultivated, the Starlings make full use of their opportunities.

During the spring and summer as many as three broods, each consisting of at least five or six fledgelings, may be reared. Here again is a good example of the value of Starlings. All the young must be fed entirely on soft larvæ, Snails, Worms or insects. A young bird is known to consume its own weight in food in twenty-four hours. Professor Newstead, writing in a supplement to the *Journal of the Board of Agriculture*, under the title of "The Food of Some British Birds," published in 1908,

states that: "On a low average, a Starling visited its young with food 169 times in seventeen hours of its day, and the food in that time included 269 injurious insects to only four beneficial ones; among them were fourteen Snails and Slugs. In eighteen minutes, eighteen Caterpillars of injurious Moths and four Wireworms were brought."

From the point of view of Nature Study in schools, the study of Bird Life should be considered as giving scope for individual or group observational activity. Individuals or teams may select a certain type of bird and, by continual observation, discover to a large extent its value to the community. Lessons in school will be mainly for the purpose of correcting or criticising the knowledge gained. Class lessons should deal with the general characteristics of birds—their covering, general skeletons, stomach, legs, wings, feet, etc.—in order that the observations may be guided into the right channels. Collections of birds' eggs are not particularly inspiring, nor have they any educational value. Boys have an innate love of collecting, but so long as the teaching is of the right kind and collections of eggs, for example, are obtained in the right way, it is quite reasonable and even advisable to utilise these qualities rather than to stress the futility of collections.

Feathers

Although certain bird characteristics are seen in other mammals, they stand alone in the possession of feathers. These completely cover the head, neck and body, and in some instances extend to the toes. From a casual inspection it would appear that the

feathers are evenly distributed over the surface of the body. This is not so.

Feathers are arranged in definite tracts on the body, with spaces of varying distances between each. In many instances the spaces are narrow and the tracts wide, but the reverse is also often found. A comparison of the Duck and the Fowl will show conclusively what is meant. In the Duck the tracts of feathers are wide and the spaces between narrow; in the Fowl the spaces are wide and the tracts narrow.

Some birds also possess "down" feathers, which correspond to the underfur of animals, whereas others possess, between the tracts, hair-like feathers (those singed from a Fowl after the body or contour feathers have been plucked). The body feathers are of much the same structure, consisting of the quill and the shaft. Along the shaft are arranged a series of barbs, or flattened rods, which are attached to each other by a series of smaller hooked barbules, which interlock the barbs. At the quill end of the shaft the barbs have a backward tendency, and these are held more loosely together. Sometimes from the base of the shaft or vane a secondary shaft arises. This is a common feature of scratching birds such as the Fowl or the Partridge. In perching birds this feature is generally absent.

Young birds are generally covered with a downy coat. There is a notable feature of the birds whose nests are easily observed; for instance, the covering of young Chickens exhibits more of a feather-like appearance, and this is also a feature of game birds and birds which begin an active life quite early.

Anatomical Features

The wings, too, are interesting; they represent the arms or forelegs of the higher mammals. There is an indication that the five fingers have been modified to support the flight feathers. In flying, a bird has to pull against its weight, and the muscles used to pull down the wing against the air are remarkably strong. The principal flight muscle is attached to the breast bone and to the "arm" bone. The wings are opened out by straightening the joints corresponding to the elbows and wrists and folded by bending the elbow and bringing forward the wrist joints.

The feet and legs of birds are encased with a scaly covering. These are modified to serve the function they have to perform. The number of toes varies from three to four, but a fifth is never present. Birds which spend most of their time in woods have the hind toe long, and this makes the organ specially serviceable in grasping branches. In other cases, for example in birds which spend most of their time on the ground, the hind toe is considerably shortened, enabling them to walk comfortably. With Ducks and Water Fowl the toes are united by a web, which acts as a paddle in the water. The legs vary considerably with the kind of bird. In the scratching birds, such as the domesticated Fowl, they are strong and powerful; in birds such as the Swallow they are thin and short, and are seldom, if ever, used for walking.

The skeletons of all birds consist of very light bones and contain air. The breast bone is large and broad and more or less convex in shape. In all

flying birds this is fitted with a "keel," to which the flying muscles are attached.

The skull is a notable feature also. The bones become completely united very early in life. Only a very thin bone separates the eye sockets, which are exceptionally large, even in a small skull. The neck bones are exceedingly flexible and articulate on saddle-shaped surfaces; the number of vertebrae forming this part varies considerably.

The beak is an interesting part; it may consist of a comparatively soft material or become a very hard and horny structure. The shape also varies very much. In some birds it is fine and slender; in others short and thick; spoon-shaped; hook-shaped; wedge-shaped; short and flat, etc. Generally the type of beak is an indication of the kind of food eaten by the particular type. Teeth are never present, but some birds are provided with useful and well-developed tongues. This feature is noticeable in the Wood-Pecker, which uses its tongue for seizing its prey.

The stomach is a peculiar feature. Having no teeth, birds cannot masticate food and hence the stomach is of the utmost importance. Food is swallowed and passes into an extension of the gullet known as the "crop." (When a Fowl has been killed, the contents of this part are often interesting.) From this part the food is gradually passed into a strong, rough muscular part of the stomach, known as the "gizzard." Here the food is ground up, by the additional aid of small stones and grit swallowed by the bird, into minute pieces and passed on to the intestines. From the intestines all nutriment from the food

is absorbed, the indigestible part being finally expelled.

The Persecution of Birds

Birds are, of course, of two sexes, male and female. In most cases the male is the more conspicuous. They are monogamous during the nesting season, and each bird does its share in nest building and feeding the young. Unfortunately the bright plumage of many birds has led to their persecution, bright feathers, wings, heads, etc., being at one time considered as suitable ornaments for the head-dress of ladies. Gradually this practice is becoming *infra dig.* and more thought is being given to the welfare of the feathered tribe. Much good work in this respect has been done, and is still being done, by the Royal Society for the Protection of Birds; every Nature-Study teacher should be a member of the Society. Apart from the valuable prizes offered to children for essays on Bird and Tree Life, the informative leaflets supplied gratis to schools, or at a purely nominal cost, are invaluable.

The classification of birds is much too involved a subject for schoolwork. If children are taught to observe the general characteristics of birds, their food, methods of flight, their value to mankind, etc., confining activities to a few birds, the Nature Study will be of lasting value to the community.

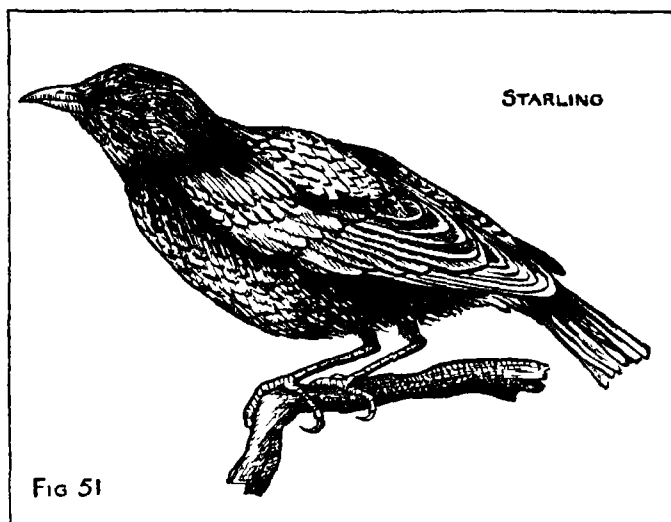
A few points in the life-history of one or two birds will be sufficient in this volume. Many excellent books have been written on the subject, but for school purposes the leaflets mentioned previously will be found to contain all the information necessary, supplemented, of course, by the personal observations of the teacher.

The House Sparrow

The House Sparrow, found always near the habitations of man, is noted for its pugnacious and cheeky manner. Its total length is approximately six inches. The crown of the head of the male is ash-grey; the underpart of the throat black, the cheeks being a dirty white. The general colour of the upper part of the body is chestnut brown, the underparts being of a lighter shade; the wings have one light bar. The legs are pale brown and the toes are characteristic of the Perchers (or Passeriformes). The hopping movement is also characteristic. When flying for a short distance the flight is rapid and straight. The female is much the same in general colour, but does not have the black bib or such prominent marking on the head.

The nest is built high up under the eaves of buildings, in ivy, on houses and occasionally in trees, but never in hedges.

Often the nests of Swallows, when nearly completed, are stolen by the Sparrows, the pugnacious intruders driving out the rightful occupants. The nest, very untidy on the outside, consists of straw, hay, pieces of rag, wool and almost any easily obtained material. The inside is more carefully constructed, and is lined with feathers. Generally five light-blue eggs, spotted and blotched with brown, are laid, and these hatch



THE STARLING.

Starlings seldom feed alone, even in the breeding season they may be seen in numbers of ten to a dozen searching grass lands for worms, etc. In the early morning they approach human dwellings, where they do good service as scavengers as well as insect and grub eaters.

out into helpless naked birds in fourteen to sixteen days.

In the early stages the young are fed entirely on insects and small Caterpillars, Aphides providing tasty morsels. At a later stage, when able to find their own food, Sparrows enjoy a mixed diet. Small seeds are readily consumed, but Insects, Flies and even Butterflies lend variety to the diet. Near houses the chief food consists of the grubs of House Flies, Bluebottles, and even the winged insects themselves. Their courageous nature enables them to seek food in stables, dog-kennels, back yards, etc., and in this manner they act as scavengers, ridding the community of many noxious insects which the purely insect-eating birds, owing to their shyness, would miss. Often Sparrows may be seen tackling Butterflies in flight, and the insect seldom gets safely away.

Sparrows, however, do a certain amount of damage in cornfields, which

they visit in droves when the grain is ripe. Against this, on behalf of the Sparrows, it must be pointed out that their favourite diet consists of the Cockchafer Beetle or the Daddy Long-legs, the larvæ of which would do considerably more harm to field crops than the Sparrows.

Again, the hardy temperament of Sparrows, their power of supporting life on anything that turns up, their fondness for insects and Caterpillar life in the early spring, long before the migrant insectivorous birds arrive, render them useful servants throughout the year. Their cheeky chirpings, even on frosty mornings, must find a soft spot in the hearts of intelligent people. Although their numbers increase at a rapid rate, such birds are verily a boon to the country, and taking all things into consideration they rank high among the birds useful to the community.

The Thrush Family

The Thrush is another common resident bird, and is very useful both to the farmer and gardener. The upper part of its body is usually an olive brown, the head being of a similar colour. On the underside and especially the throat, the general ground-colour is yellowish white, but spotted with dark brown. Its pale-brown legs are thin and enable it to run quickly for a few steps. The Thrush has also a characteristic sidelong leap, which is always introduced when it is in search of a suitable stone on which to break the shell of a snail. When flying, the movement is rapid and straight.

Probably Thrushes are the best harbingers of spring. Even before winter has passed the melodious song

of the Thrush can be heard early on a sunny morning.

Before the end of March the nesting season has begun. Thrushes build in various places, but seldom, if ever, more than ten feet from the ground. The favourite place is in the fork of a bush or tree, but often nests are found in hedgerows of hawthorn. The nest is made of rough grass and hay, the inside being lined with mud, smoothed carefully to form a deep cup. Five pale-blue eggs are laid, the thicker ends having a few purplish or black spots; those of young birds show no markings.

In about sixteen to twenty days the young and almost naked birds are hatched. The hen bird does all the sitting necessary during the incubation period, but the feeding of the young is carried out by both parents. In the early stages, earthworms form the chief diet, but later, larvæ and insects provide a suitable variation. After three weeks, sometimes less, the young birds are able to leave the nest, and at the end of a month are quite independent. The older birds usually raise three broods each season, the last one being ready for flight early in July.

The food of Thrushes, Blackbirds and other members of this family, the Fieldfare and Redwing, consists chiefly of slugs, snails, earthworms and insects. In autumn, the first two mentioned are extremely partial to ripe fruits, such as Currants, Raspberries, etc., and it is necessary to protect such fruits from their beaks. Early in winter, when this diet partially fails, they take to wild berries.

The Fieldfare and the Redwing are winter visitors only. During this

period all the members of the Thrush family work entirely for the benefit of Man. Snails and slugs are sought out in their winter quarters, and in this work they exhibit much ingenuity. On finding a snail, the captive is carefully carried to the nearest stone. Here, by continual tapping, the shell is broken, and with a gulp the succulent body disappears. Chrysalides are eagerly sought after also. The destruction of the molluscs and chrysalides during

the winter season alone amply repays Man for the small loss of fruit during the ripening season. Throughout the spring and early summer, snails, worms, insects, cockchafer beetles, wireworms and caterpillars provide delicacies for the Thrush family.

The Missel Thrush

The Missel or Mistle Thrush, another resident bird, is larger than the Common Thrush. Its general colour is ash brown, the throat being white, speckled with dark brown; the outer tail feathers are tipped with white. When standing, its body is erect and its hopping movements are quick, as if startled. The name Mistle

was applied from an old idea that through this bird the Mistletoe seeds were dispersed. It is stated by some authorities that the bird seeks out

the berries, eats the succulent part and in cleaning its beak by scraping on the bark of fruit trees, accidentally places the seeds in positions suitable for germination.

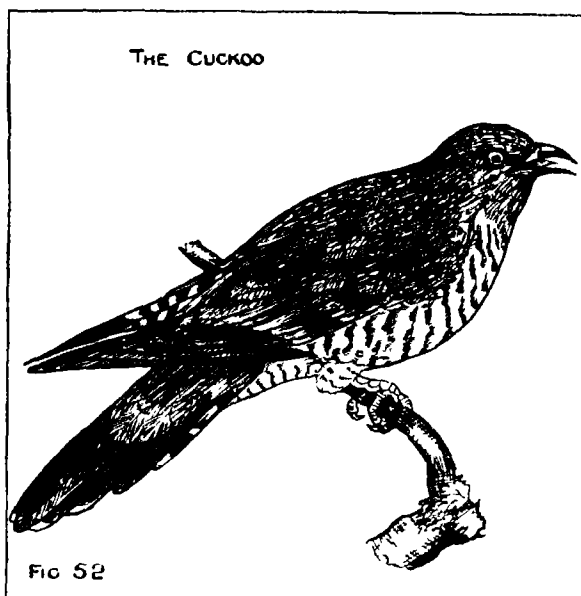
The Fieldfare

The Fieldfare is distinguished from the Thrush by its grey head and rump and by its golden-brown breast

streaked with black. It is also a larger bird than the Thrush and only visits the country in the winter.

The Redwing

The Redwings visit this country in flocks of a dozen to twenty towards the end of October. The males are a uniform olive brown on the back and wings; the chest is a pale buff streaked with brown; the under-part of the wings and the flanks, from which the name is derived, is a rich, reddish chestnut. The females are very similar in colour to the males, but not such a deep brown. As spring approaches, the birds leave again for more northerly climes.



THE CUCKOO.

The Herald of the Spring, whose note is listened for by country folk.

The Blackbird

The Blackbirds are resident. The male and female can readily be distinguished; the cock bird has black feathers, an orange-coloured bill and black legs; the female has a sooty-brown coat, a light-brown bill, but, like the male, black legs. The flight is rather unsteady. When alighting or hopping, the fan-shaped tail is elevated. The nest of this bird is usually found low down in hedgerows, but often in trees and shrubs. It is similar in general construction to, but larger than, that of the Thrush; the inside, however, is not lined with mud, although mud is used for the foundation. The four to six pale-blue coloured eggs are thickly mottled throughout with reddish markings. Often, however, the conspicuous markings are absent, the ground-colour appearing as a greyish blue. In other instances the eggs are only blotched at the larger end.

A certain number of Blackbirds find their way early in winter across the Channel. The majority, however, remain, and as spring returns, visit the haunts of the previous year. The song of the Blackbird is a special feature. Even in the wild state, he can be trained to imitate certain notes. The first three bars of "The Policeman's Holiday" he can usually manage quite easily. The author has pleasant recollections of efforts made, during college days, by fellow-students to persuade a Blackbird to complete the second three bars, hours being spent on his instruction.

The Cuckoo (Fig. 52)

The well-known note of this bird is most eagerly listened for by all country

dwellers. Even in town there seems to exist a certain amount of rivalry, and many persuade themselves that they have heard him, and notify the local papers accordingly. Generally, the bird does not reach these shores until the early part of April, reaching the Midlands about the middle of the month. The bird has a hawk-like appearance, and is very similar in flight to the Sparrow Hawk.

In colour, the head, throat and back are of an ash-grey tone; the under-part of the body is a greyish white with darker bars, and the legs are yellow. When on the ground it moves with rather awkward jumps, but when perching in a tree it has a characteristic upward-raised tail.

The Cuckoo evidently has not sufficient time, or perhaps energy, to build a nest in this country. She prefers to utilise a ready-made home and instinctively chooses the nest of an insectivorous bird. With her keen sight she selects a suitable nest, that of the Hedge Sparrow, Meadow Pipit, Reed Warbler, etc., lays her own egg on the ground and then carries it in her beak to the selected spot. Often she carefully takes out the eggs of the rightful owner—some writers state that she consumes the inside. This point has not been satisfactorily examined, but eggs having been found unbroken outside a Hedge Sparrow's nest, the question is still open to doubt.

The egg is larger than that of the Hedge Sparrow; it is of a greenish-blue colour, generally, with reddish spots. It is not known exactly how many eggs a Cuckoo lays; a single egg is usually found in one nest. The incubation by the foster parent usually takes three weeks. In a very short time the

young Cuckoo acts as a murderer. By his superior size he consumes all the food the foster parents can supply him with and still asks for more, keeping the other natural occupants without food. Within a couple of days the young Cuckoo, by twisting and turning, gets the progeny of his foster parents on to his back one by one; these he pitches out of the nest. In less than a month the bird is fully fledged, but even in this condition it does not resist the kind attention of its foster parents. When once on the wing, however, it takes a southward course, and towards the middle of September leaves this country for a warmer clime.

During its stay of approximately four months, the Cuckoo does much useful work. The leading ornithologists agree that it is the only bird which tackles successfully the Woolly-Bear

Caterpillars of the Tiger Moth. These Caterpillars, which are covered with a coating of dense, long, hairy fur, are capable of doing a great amount of harm. They are usually found on members of the Dead Nettle family, but will consume any green stuff. (In a terrarium they exist quite well on Cabbage or Lettuce leaves.) The Lackey Moth Caterpillar also has a deadly enemy in the Cuckoo. When the Moth has laid her eggs in an orchard, the Cuckoo finds this a happy hunting ground.

Migration is a subject which should receive consideration in schools. Little, however, can be done except recording the migratory birds, the time of arrival and departure, etc., the food consumed, methods of flight, and whether they are of gregarious habit or otherwise.

CHAPTER VII

ANIMAL LIFE

ANIMAL Life should receive as much attention as possible in country schools; town and city schools, however, should not neglect the subject. The work must of necessity be observational activity outside the school, but with the smaller animals such as Mice, Rats and Rabbits, good work can be accomplished in the classroom. In the first place it is necessary gradually to broaden the outlook of the children as to the meaning of the term Animal Life.

Mammals

It has previously been noted that all living things belong to one of the groups, either plants or animals, and

the characteristics of each group have been mentioned. Children are taught to recognise Birds as Birds, Insects as Insects; therefore they should be taught to recognise the so-called animals, such as Dogs, Cats, etc., as Mammals. Birds and Reptiles are recognised because they lay eggs—hence it is an easy step to recognise the animals which suckle their young as Mammals. Horses, Cattle, Sheep, Pigs, Dogs.

Vertebrata

Cats and Rabbits, although easily distinguished from each other in outward appearance, are yet very similar in their general structure. They belong to that group of the Animal Kingdom

known as *Vertebrata*, and all have backbones. In this group there are five classes—Mammals, Birds, Reptiles, Amphibians and Fishes. To the first class, Mammals, all animals which provide milk for their young belong, this class including, of course, Man.

It is not necessary to go deeply into the anatomical structure of an animal, yet the main parts can easily be understood if comparisons are made with the human body. No child can pass a butcher's shop without observing that animals are made up of different parts. When a Sheep is hung up before being cut into "joints," bones are seen as well as the lean and fat parts. It is true that certain parts—the inside—have been removed, but even town and city children realise that tripe comes from the inside of a Cow. Since all animals are similar in construction so far as the skeleton is concerned, a few features of the Horse will be given, reference being made to the variations exhibited by other animals.

The Anatomy of the Horse

The bony framework, or skeleton, is made up of an axis, or trunk, which consists of a skull and backbone. Appended to the trunk are a pair of fore limbs and a pair of hind limbs, these articulating on certain bones known respectively as the shoulder girdle and the hip girdle. The backbone, like that of a Man, consists of a number of bones, each termed a vertebra. In each vertebra is an aperture, so situated that when such bones are placed end to end the apertures form a tube known as the "neural canal." Through this canal the nervous axis, or spinal cord, passes,

half the canal being easily seen in the thick end of a mutton chop.

In the living animal the bones do not come in direct contact with each other, but are separated by a pad of cartilage or gristle. Thus the backbone has a certain amount of elasticity, otherwise the "trunk backward bend" order in Physical Training could not be used. The Cat, when danger approaches, arches her back by reason of the cartilage, and a Horse is enabled to jump by the pliancy given to the backbone by this material.

The Vertebral Column

The vertebral column is divided into several distinct regions. Seven vertebræ form the neck, and together are known as the cervical vertebræ. In the horse these are succeeded by eighteen bones which support the ribs, these being known as the thoracic vertebræ. Behind these come six lumbar vertebræ, followed by five sacral vertebræ fused together into one piece, then about seventeen vertebræ forming the tail, or caudal, vertebræ. The sacral and caudal bones have no neural canal; the caudal bones of the Cow, for example, used for Ox-tail soup, are simply horny cylinders.

The Skull

At the forward end of the trunk the central bony axis is modified to form a skull. The neural canal extends into a large cavity known as the cranium. This is surrounded by thin, flat bones, the parietal bones at the sides and the frontal bones in front extending above and below the eyes. Below the cranium is the facial part of the skull. Much of this part is underlaid with the nasal bones, which



Photos: Charles Fred

FARM ANIMALS.

The above photographs represent typical country scenes. In the upper picture, Shropshire Sheep, Dairy Cows and Dr. night horses are seen. The lower photograph shows Short White Pigs and a Black Berkshire.

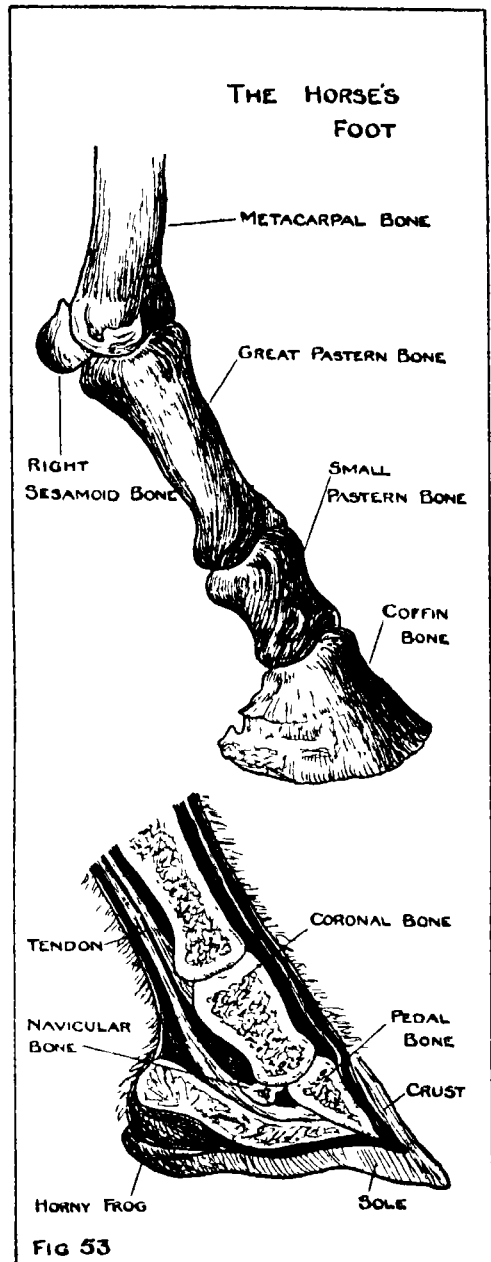
are long triangular bones extending down in front of the nose cavity. The forward extension of the frontal bones carries the upper cutting teeth. Two large and flat bones form the lower jaw. Each carries half the number of the lower teeth, being fused in front but receding from each other backwards, the ends articulating by a convex surface with the lower part of the skull.

The Ribs

The Horse has eighteen ribs. The first eight, or true, ribs are connected separately with the sternum, or breast bone, which is narrow and keel-like. The remaining ten are united together by cartilage and form "false" ribs. In the Cow the breast bone is broad and flat—this gives the animal a broad-chested appearance.

The forelegs of a Horse can only move backwards and forwards, hence the shoulder girdle consists only of a pair of shoulder blades, no clavicle or collar such as is found in a Man being present. The hip girdle is a more complicated structure. It is made up of two similar halves, each half consisting of three bones which meet together in a deep concavity into which the end of the femur, or thigh bone, fits. The two sides of the hip girdle do not meet, but are inclined towards each other on either side of the sacrum. Together they form the "quarters" of a Horse, and on their size depends the width of the quarters.

The legs of a Horse are similar in general construction to those of a Man. Each foreleg contains the humerus, or shoulder bone. This is hidden by muscles, but when the



HORSE'S FOOT: ANATOMICAL DETAILS.

The structure of the leg and foot of the Horse is fully described in the text. Note that the "foot" consists of one toe only.

animal moves, the movement of the humerus forwards or backwards can be

observed. From the joint corresponding to the elbow, the ulna and radius are present; in the Horse, however, they are joined together. The "knee" of the Horse corresponds to the "wrist" in Man. This is made up of carpal bones consisting of an upper and a lower row. In the Horse there are three upper and three lower bones. An additional bone projects at the back; this is the pisiform. Each bone has a smooth surface covered by a delicate membrane, which secretes a type of lubricating oil. The arrangement of the knee joint is such as will permit free movement and yet prevent fracture when drawing heavy loads or alighting after a jump.

The Foot

The foot is somewhat different from the hand of a Man. The bone corresponding to that extending from the wrist to the back of the middle finger is the only one well developed. This forms the hard shank, or cannon bone, of the Horse.

On either side of the cannon will be found a slender bone; these are termed splint bones, and correspond to the first and ring fingers of a Man's hand; they do not extend the whole length of the cannon bone. In the middle finger of a Man, three joints are present, the end one bearing the nail; the foot of the Horse has the corresponding parts. The upper joint nearest the cannon is termed the pastern, the middle one the coronet (the crown of the hoof being around it), and the third, or coffin bone, is buried in the hoof. The part representing the hoof not only covers the back of the coffin bone but extends round the front and sides.

The "Navicular Bone"

Behind the joint formed by the coronet and coffin bones is a floating bone called the "navicular bone." It is in this region that a disease known as the navicular disease is often found. The hind legs of the Horse correspond to the legs of a Man. The femur or thigh bone is covered with integuments; its movement can be seen, however, when the animal moves. The end of the femur is rounded and articulates in a cavity formed by three bones of the hip girdle; hence this, like the corresponding joint in a Man, forms a "ball and socket."

In the Horse the femur of the hind leg has a projection about a third of the way down in the form of a compressed ridge curving forward, termed the third trochanter. This forms the point of attachment for the powerful muscles which move the legs; Cattle, Sheep and Pigs do not show this special modification. Corresponding to a Man's leg, the Horse has both bones, the tibia and fibula, the latter being a very slender bone. The patella of the knee has its counterpart at the stifle joint, the patella being attached by three ligaments to the strong tibia (Fig. 53).

The Hock

The hock of the Horse corresponds with the ankle region of a Man. The tarsal and metatarsal bones of the Horse, however, approach a perpendicular position. The corresponding bones of the foot are similar in name to those of the fore foot and may be compared with the bones of a Man's foot. The middle metatarsal bone forms the cannon; on either side metatarsal

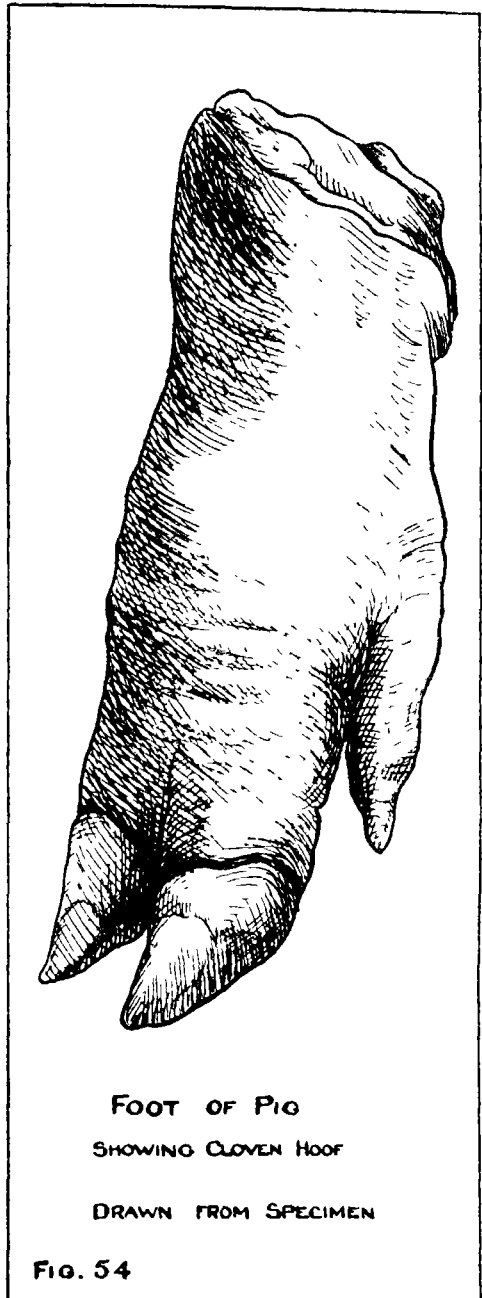
bones form the splints. The foot is formed by the joints corresponding to the middle toe, which are called the pastern, coronet and coffin bones. Behind the junction of the coffin and pastern bones in each limb there are two floating bones, termed the sesamoids. The latter are covered with a horny growth and a long tuft of hair, termed the fetlock. These hairy growths are a peculiar feature of the Horse and vary in length with the breed.

The Hoof

The hoof structure is important. The coffin bone, the navicular and the lower end of the coronet form the articulation of the foot. The part which is seen resting on the ground is known as the wall, or crust. Underneath the foot is seen the sole and the frog, the latter being a pyramidal mass of horn lodged between the two re-entering portions of the wall. Between the sole and the wall is the "white line." This is soft and flexible, and so prevents the breaking of the sole from the wall. The sole and the frog do not continue to grow indefinitely; the wall does, and, unless kept down after reaching a certain length, begins to peel and break off in a similar manner to the nails of the hand.

Anatomy of the Cow

The Cow is similar in general construction to the Horse. The bones of the skull, however, are much larger, and from this, conical projections arise which support the horns. The horny covering is formed by secretions from the skin in a similar manner to the formation of the human nails and the hoofs of animals. A further variation



FOOT OF PIG

SHOWING CLOVEN HOOF

DRAWN FROM SPECIMEN

FIG. 54

THE FOOT OF THE PIG.

Each foot consists of four toes; the phalanges of two only reach the ground, forming the familiar cloven hoof.

is noticeable in the foot. The cannon bone is formed from the bones corresponding to the second and third metatarsal bones of the hand, joined together on their inner faces; the digits or phalanges are, however, separated, and hence the divided, or cloven hoof. The Cow has thirteen ribs, eight true and five false. The tail contains eighteen to twenty vertebræ.

The upper or premaxillary bones do not carry teeth, their place being taken by a hard pad, against which the lower incisors bite.

The Pig

The Pig shows one or two slight variations. Four of the metacarpal and metatarsal bones are developed, two only of each forming a "hoof" (Fig. 54). Its head has a prominent ridge, or crest, and at the nose end a special scooping bone strengthens the snout. The lower jaw is adapted for movement in any direction. Fourteen ribs are present, seven true and seven false. The caudal vertebræ usually number twenty.

The Stomach of a Ruminant

The internal structure of animals such as the Horse, Dog, Cat, Rat, Mouse, Rabbit, etc., is very similar in general construction to that of Man. In the Cow, Sheep and Deer the stomach is of special form. Generally the Cow is said to have four stomachs; actually the stomach comprises four separate compartments: the Paunch, the Honeycomb, the Manyplus, or Manyleaves, and the Reed, or Rennet, stomach.

The food obtained is passed into the first stomach or paunch (Fig. 55). When resting this is regurgitated in small quantities and reduced to a fine

condition between the teeth (chewing the cud), passing again down the gullet into the second division, on to the third and finally to the fourth, or rennet stomach. The latter is the only part having digestive juices. After being mixed with the gastric juice in the rennet stomach, the material is passed on to the intestines and follows the same course as in other animals.

Muscles

When alive the bony framework of all Mammals is covered with flesh. This consists of a large number of cells arranged to form fibres, these being collected together to form bundles. Each bundle is connected with two or more separate bones and has the power of extending or contracting. Bundles which have the power of contraction and extension are termed muscles, and movement in any form is due to their orderly movement. At the ends the chief muscles usually taper off and lose their fleshy appearance, changing into white and fibrous elastic cords. The movement of the muscles above the wrist, when the hand is tightly closed, or the swelling of the contracted biceps muscle when the forearm is bent towards the shoulder, will demonstrate the work of muscles.

Most Mammals have a special covering of fur, hair or wool. This covering is an outgrowth of the skin, and forms a protection against adverse climatic conditions.

All Mammals have a four-chambered heart and breathe by means of the lungs. The heart and lungs are separated from the intestines by a special partition known as the diaphragm, and this arrangement is not found in other animals.

The Senses

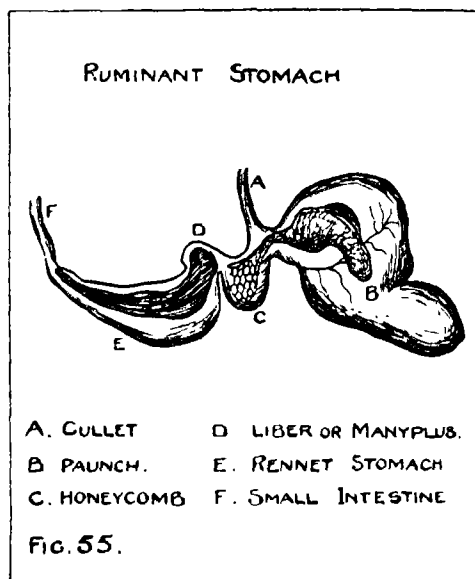
In most Mammals one or other of the senses is well developed. Hearing is generally good, and most Mammalia have large external ears. The Horse, Donkey, Cow, Rabbit and Hare have ears well developed. Other animals such as Dogs, Foxes, etc., have an exceptionally keen sense of smell. The sense of touch is highly developed in practically all Mammalia. Horses, Dogs and Cats have this sense well developed in the skin, the Cat having an additional aid in the whiskers, or vibrissæ, around the mouth.

Sight is generally well developed in Mammals. The Mole, however, often spoken of as blind, and the Bats, "blind as a Bat," have eyes of very small dimension and development, but these animals can see. The Bat, for example, recognises "light," and will fly round the ray of a flash lamp if this is directed upwards. Moles have the hearing well developed, and people who live in the country realise how sensitive they are to the sound of movement.

The Rabbit

The Rabbit in the wild state has the sense of hearing very well developed. When feeding in the fields, the

slightest sound, such as the falling of a leaf to the ground, is sufficient to cause the pricking up of its ear-lobes. The click caused by the drawing back of the hammer of a gun is sufficient to start it on a rapid homeward run. When danger approaches, the Rabbit has a characteristic habit of stamping on the ground with a hind leg, this serving as a warning to its companions some distance off. The sense of touch is also highly developed, and, like the Cat, the vibrissæ help considerably in this respect.



STOMACH OF THE COW.

This consists of the paunch, honeycomb, liber and the rennet stomach.

Rabbits belong to a group of Mammals known as Rodents, or gnawing animals, the teeth being the outstanding characteristic. The front teeth, the incisors, have the peculiarity of continuous growth from the base. In order to keep the teeth within reasonable bounds the animals must gnaw hard substances like the bark of trees. The wearing-away process renders the teeth sharp and chisel-shaped, and hence Rabbits often do much harm to young trees. The upper lip is divided into two parts, enabling this portion of the mouth to be drawn away when the cutting teeth are in operation.

From head to foot, Rabbits are covered with a thick fur, generally light brown in colour, the belly part

being of a whitish shade. The underneath of the tail is a pure white. Since Rabbits feed generally in the evening, the under-tail serves as a guide to others when on the run to the holes or warren.

The body of the Rabbit is long and slender (approximately 20 ins.). Its hind legs are longer than the forelegs, this formation enabling the Rabbit to move quickly by leaps and bounds. Each foot has four toes, which, like those of the Dog, are thick, blunt and strong. Generally Rabbits shun inhabited districts and live gregariously in colonies underground. When about to produce its young, the female Rabbit leaves the warren and seeks out a dry bank. Here she scratches out a hole, less than a foot deep, hollows out a part sufficient for her body to turn about and with fur from the underside of her body a very comfortable and cosy nest is constructed. The young, four or five born at the same time, are quite blind and naked.

After nine days the eyes open, and in three weeks the little Rabbits are able to run about and nibble the leaves of grasses, etc. When a little over six weeks old, the Mother Rabbit leads her offspring to the usual warren and, after a very limited period, casts them off entirely.

Commercial Value of the Rabbit

At the present time there are many breeds of Rabbit kept in captivity for the fur. The fur of the Angora is exceptionally woolly and is used for the lining of gloves and in the manufacture of dainty underwear. The Blue Beavours have fine fur of a woolly texture. After the skin has been cured, the pelt is used for fur

collars and cuffs for ladies' coats, and a large type of Rabbit, the Belgian Hare, is bred almost exclusively for its flesh, although the pelts, after being cured and dyed, are of commercial value.

The Wild Rabbit, although more or less a nuisance to the farmer, is a valuable source of income. In these days the skins have a high commercial value, the flesh being used as food.

The Hare

The Hare, although similar in many respects to the Rabbit, has certain characteristics. It is a much bigger animal, often twenty-seven or more inches in length. Its hind legs are apparently out of proportion to its body, but with these it is enabled to run at a surprising speed and also to make extremely quick turns. It is an exceedingly timid animal and very quick to detect the slightest sound. Its long ears, like those of the Rabbit, can be turned in almost any direction to catch sound. In general colour the fur is reddish brown, but the underside is of a much lighter shade, often being white, the underside of the tail being whiter than the rest. Its feet, each having five toes, are covered with fur.

Unlike Rabbits, Hares do not care for each other's company, except in the breeding season. Warrens are not constructed, the Hare preferring to live in a hollow formed by its own weight in grass or clover—the Hare's "form." The young are born with their eyes open, the body being well covered with fur. In four or five hours after birth, the young Hares, or Leverets, are able to run about and nibble grass, etc.

Like the Rabbits, Hares have a split upper lip, sharp chisel-shaped incisors and are herbivorous. Much harm is done to crops by these animals, yet they are protected until the shooting season, when they provide excellent "sport."

As a general rule Hares do not thrive in captivity, their timid nature being unsuitable for companionship. In the wild state, on the slightest sound, they crouch down, ears well back, and are not easily distinguished from the soil, which the fur resembles. Should danger approach, they bound away with marvellous speed, often beating in the chase the fastest greyhound.

Rats and Mice

Rats and Mice are also Rodents, but differ in size and habits from the Rabbit. The Brown Rat is the one most commonly known in this country. His habits vary with his surroundings. When living together in farm buildings the chief diet is corn obtained from the stooks or out of bins, feeding troughs, etc. Eggs of Fowl and Ducks are also consumed. These are taken from the nest and often rolled to the burrow. Sometimes one Rat will secure an egg between its throat and knee joints, being dragged along by another Rat to the entrance of its lair. Young Chickens and Ducks do not come amiss to this animal, and, in fact, he will eat anything.

The Black Rat, often found in sewers, is larger and more savage than the brown type. When in danger from Man or Dog, it becomes very fierce, and will use its only weapons of defence, the incisors, to good advantage. A young Dog, once bitten by a Rat, often shirks his work on a second occasion.

Mice are very common, and hence there is no need to go into details. The Dormouse, however, is worthy of note. He is an elegant little fellow, slightly larger than the House Mouse. His fur is a light reddish tawny colour above, but pale and yellowish on the underside. Like the majority of Rodents, he is nocturnal in habits, sleeping during the day in a nest built in the hedgerows. His food consists almost entirely of seeds, acorns, nuts, etc., but he consumes a number of buds in early spring. During the harvest period and in late autumn he becomes very fat, and presently retires to his warm nest, spending the winter in a dormant condition.

The Squirrel

The Squirrel is another interesting Rodent (Fig. 56). Its reddish-brown coat and bushy tail are familiar to most country dwellers. Generally its food consists of seeds of various kinds, the beech and hazel nuts and acorns being its favourite diet. Like the Dormouse, however, it consumes a large number of buds in the early spring. During the autumn, the Squirrel stores up a great many nuts, several hoards being made. Unlike most of the nut-eaters—the Dormouse, Wood Mouse, etc.—it is impatient when breaking the hard shells of nuts. The Wood Mouse holds the nut in its fore paws and turns it round and round as if in a lathe until the shell will readily break into two halves; the Dormouse makes several small holes or narrow grooves; the Squirrel makes an incision in the shell, and then with its powerful incisors and front paws rips it open.

The Grey Squirrel is not a native of this country. It was introduced from

North America, but is now very common in public parks and well-wooded areas; it is not so common as the Brown Squirrel. Both types build their nests of hay, grass and twigs, high up in trees, pines often being selected.

During the autumn, after making several hoards of fruits and seeds in hollow trees, sometimes in the nests and occasionally under herbage, the Squirrels prepare for the winter. Their nests are enlarged and often reconstructed so that a covering is provided against adverse weather conditions. The interior is lined with grass, hay, and bits of straw. Here, with its bushy tail forming an additional warm protection, the Squirrel sleeps during the cold days of mid-winter, but does not hibernate like the Dormouse. When hungry, even on frosty days, it may often be observed visiting its "store" or ripping to pieces the cones of pines, extracting the seed for its food.

The Water Vole

Other Rodents, such as the Water Voles and Guinea Pigs, should receive consideration. The Water Vole, often wrongly called the Water Rat, is able to swim quite well. Its food consists of fish, occasionally the young of Water Fowl, seeds of water plants, and the bark of trees growing near the water's edge. In various places, dotted about among the rushes, will be found a kind of platform, similar to the nest of the Coot, on which the Water Vole consumes its food. Although it burrows extensively in the banks of streams it does not use its burrow as a dining-room. When nesting, a platform is constructed high above the water level, similar to its feeding

platform, but farther from the bank. Its young have fur from birth and in a few days are able to swim.

Natural enemies of all Rodents are found in the Stoat and Weasel and in other less common members of the Weasel Family, the Polecat and Marten. They belong to the order Carnivora, and are untamable and bloodthirsty animals which, when hunting, will attack animals much larger than themselves.

The Stoat and the Weasel

The Stoat and Weasel can easily be identified, although both have a deep-brown or russet-brown coat; the tip of the Stoat's tail terminates in a bushy brown tuft; the Weasel's tail is much shorter and displays the russet brown of the back throughout. The fully grown Stoat, also, is much larger than the Weasel; its total length may reach eighteen inches, the tail taking up half of this. The Weasel is much shorter in build, seldom more than ten inches from the tip of the nose to the tip of the tail; the tail is usually about one-third of the total length.

The underside and sides of the Stoat are much lighter in colour in winter, often assuming a whitish or pale-yellow colour. The Weasel does not change its colour to any appreciable extent. Some writers state that seasonable changes do occur in the fur of Weasels, but judging from personal observations, the change, if any, is very slight. In certain areas, especially the North, the whole of the body of the Stoat changes to a yellowish white hue, with the exception of the black end of the tail, which does not alter. Neither in Shropshire nor Staffordshire has the author discovered a Stoat with a semi-



SQUIRRELS.

These graceful, impudent little fellows are to be found in almost any place where Hazel, Beech or Pine trees abound. The North American Grey Squirrels are much larger than the common English Squirrel, but are less handsome. The two kinds are seldom found in the same wood.

white coat, but specimens have been seen in Yorkshire. The so-called "ermine" is the fur of a Northern Stoat in his winter coat, the black hairs being the tip of the tail.

Stoats and Weasels are regarded as "vermin" in country districts. This is rather an erroneous appellation, for

both do a certain amount of good, even if harm is done to the keepers' "game." Rabbits breed rapidly, but Stoats and Weasels keep the numbers down by sucking the blood of many young ones early in the spring. At the same period they also suck the eggs of such birds as Partridges and

Pheasants, which nest on the ground. Young birds are also attacked and their life-blood extracted, and hence gamekeepers destroy as many Stoats and Weasels as they possibly can. The value of these animals is apparently ignored. During the winter, Rats, Mice, Voles and Moles have deadly enemies in the Weasel and Stoat. The Weasel is a splendid underground worker, and hunts the burrows of Rats, Moles, Voles, etc., when other food is not easily obtainable.

Rabbits are seldom attacked in the burrows, but should one be attacked when feeding, it loses all sense of direction and dashes away, closely pursued by the Stoat or Weasel. When exhausted, it is bitten at the back of the ears by the pursuer, who enjoys to the full the warm blood of its victim. Even Hares run in absolute fear of these small carnivora and rush madly about when one is near. When the Stoat has tired its intended victim, it stealthily approaches the exhausted Hare; one spring and a bite are sufficient, the Hare apparently having lost all power of movement. In country areas, the pitiful cry of the Hare is sometimes heard; it is similar in many respects to the cry of a child in pain.

It is rather a curious fact that such small creatures as the Stoat and Weasel should be able to overcome powerful animals like the Hare; one kick alone from the hind legs of the Hare would be sufficient to break the back of the largest Stoat.

Even Fowls seem to dread the presence of a Stoat. Often Hens are destroyed wholesale. It would appear that a Stoat often kills for the joy of killing, for in a Fowl pen it always

des roys more than it could possibly consume. It may be that the Stoat dislikes noise, and when the other inhabitants make a noise, its efforts to effect silence result in the death of the clucking birds. The back of the head in the region of the jugular vein is a favourite killing spot. A Fox, the largest wild animal of the Carnivora Order in this country, always bites off the heads of poultry; hence the murderer can easily be identified.

Another peculiar fact with regard to the Carnivora Order, or flesh eaters, is that Man has chosen such types for his companions. Dogs and Cats belong to this order, but through training and breeding, types have been obtained which can exist quite easily on a mixed diet.

Dogs

The Dogs of to-day have practically all developed from the Wolf, the Jackal and the Fox. The different breeds found in the world are a tribute to the care and attention which has been devoted to these animals through generations. The St. Bernard, Great Dane, Bloodhound, Bulldog and Alsatian represent the larger breeds, such types as the Maltese and Japanese Spaniels, Pekingese, etc., which are only a few inches high, representing the "toy" Dogs.

Between these two extremes are many varieties, some of which are the real servants of Man. The Collie and its near relation, the Welsh Sheep Dog, show considerable intelligence, and readily respond to training. Setters, Pointers, Retrievers and Spaniels are types trained especially for sport. The smaller Terriers are perhaps the best

known, and their value in destroying vermin such as Rats, etc., their faithfulness and companionable nature render them valuable assets to their owners. In the wild state, Dogs hunt in packs; even now a number of Dogs together will do considerable harm to a flock of Sheep.

The Fox

The Fox is the largest wild representative of the Dog Family in this country. As a rule it lives alone in a hole in the ground known as an "Earth." Like all members of the Dog Family, its sense of smell is very highly developed. Its food consists entirely of carrion; Rabbits, Hares, Rats, Partridges and Birds of all descriptions form the usual diet, but it also pays periodical visits to farm-yards, especially during hard weather. Its teeth are very strong, and, like all the Dogs, it tears the flesh to pieces. This animal provides the English sport known as Fox Hunting. Often the chase lasts for several hours and generally results in a "kill." Keen competition exists among the Hunters to be first in at the death, the Brush (tail) or head being thereby secured. The Dogs are trained to follow the Fox by "scent," and the hunt is arranged on natural lines, the Dogs hunting in packs.

Cats

Cats are well-known pets, and hence little attention will be paid to them. The Wild Cat of the North of Scotland is probably the type from which the pussy of the fireside has evolved. As with the Dog, carrion is the natural food, but the domesticated Cat is quite contented with milk and cooked meat. Her wild instincts, however, show up when a Mouse is near. The growling is, no doubt, a relic of the wild state, warning other Cats to keep away from her legitimate prey. The eyes of the Cat are extremely sensitive. When dusk approaches, the pupils enlarge, giving the animal keen sight even in comparative darkness. The claws are retractile, or capable of being drawn into a sheath—a feature absent from Dogs. The tongue is rough, having on it hard, sharp, pointed bodies which give it the appearance of a rasp. When seizing its prey, the sharp claws penetrate the flesh, the sharp front teeth disabling or killing the victim by a well-directed grip of the jaws. Cats live alone and hunt alone. The pads on the feet enable them to creep along noiselessly; they wait in some suitable spot and suddenly spring upon their victims.

Animals such as Rabbits, Rats, Mice and Guinea Pigs are often kept as pets, and further information will be found in a later chapter.

CHAPTER VIII

AGRICULTURE AND HORTICULTURE

THIS chapter is intended primarily for teachers in rural schools.

The parts dealing with Soils and Manure, however, should be found useful by the teachers of Gardening. In a later chapter dealing with the School Garden, certain parts of this section will be referred to.

Origins and Properties of Soils

Everything a farmer or agriculturist has to deal with can be traced back to two primary sources, the soil and the atmosphere. Vegetable products such as Potatoes, Grass and Wheat contain no chemical elements which cannot also be found in the soil or the air. Equally true is the fact that animals and their products—milk, butter, mutton, beef, leather, etc.—are obtained as the result of feeding animals on plant substances.

The Soil is the name given to the earthy matter found on the surface of the land, and is sometimes spoken of as "mould," "earth" or "dirt." It is nowhere of great depth and in some places is very shallow. Underlying the true soil is earth, or mould, something like the material on the surface but varying in colour and texture. This is termed the subsoil, and when exposed assumes the appearance of the true soil—the agencies effecting the change being the atmosphere, moisture and temperature.

The teacher should not attempt to

trace the origin of soils to their source. To take the present planet as a starting point needs a good knowledge of Geology and of Astronomy. Even regarding soils as already existent, they are of incalculable ages, and hence it is advisable to keep the study within practical limits. The materials which now constitute the sedimentary rocks bear evidence of having been repeatedly reduced and again hardened into compact masses. The present soils have been brought about by the degradation of previously existing rocks through the action of running water, solutions effected by moisture and carbon dioxide, glacial action, temperature, vegetation and in recent generations by cultivation. Such forces, acting through the ages and still acting, are responsible for all soils.

That there are different kinds of soils is a fact easily discovered; the differences are visible to the eye when portions are taken up and handled, and when they are walked upon; they also show themselves by the kind of vegetation which grows naturally upon them.

Red soils may be seen in South Shropshire, Herefordshire and Gloucestershire; greyish soils in the Thames Valley and in Kent; black soils in North Shropshire, Staffordshire, Lincolnshire and in most cultivated gardens; yellow soils in parts of Northumberland, etc.

Much can be learned about a soil by handling it ; a dry, loose soil passes easily between the fingers. Even moistening such a soil does not make it cohere for any length of time. Other soils, especially those of a clayey nature, are so tenacious that they can be moulded quite easily. When walking on such a soil the tenacity is easily seen by the amount which clings to the boots. A sandy soil, when rubbed between the fingers, gives a characteristic "gritty" feeling, whereas a clayey, or tenacious, soil feels soapy and greasy. The plants native to a soil always indicate its character. Heather, Bracken, Larch, etc., are the natural produce of poor sandy soils which form the heaths and moors. Oak trees flourish upon heavy or clay soils found in the heart of Kent and in the Thames Valley ; Cowslips also favour this type of soil. The Beech and Yew may be found on the chalky soils of the South of England. Sedges, Sundews, Cotton Grasses and Rushes are found growing in localities where the land is wet or marshy.

The foregoing are indications of the observational work which can be accomplished without the aid of apparatus.

Going deeper into the subject, it may be stated that, although soils were formed by certain disintegrating agencies, the latter were assisted by transporting and mixing forces. Running water, for example, not only wears away particles of rock in its forward rush, but carries with it mineral fragments of varying sizes. A sorting of materials is also effected when lower levels are reached, the larger particles being left behind and the finer particles carried forward until the stream be-

comes sluggish, when they are laid down in the form of mud.

The soil as we see it to-day is the result of a long series of changes. Often underneath the soils and subsoils, rock surfaces very different in character are to be found. In many of the Midland Counties such as Gloucestershire, Oxfordshire, etc., it is a stiff bluish clay. In parts of South Staffordshire, Worcestershire and Herefordshire a red sandstone forms the underlying strata. On the Downs, the Chilterns and in parts of the counties of Northumberland, Durham and Yorkshire, the underlying rock is chalk. On either side of the Pennines the stratum consists of a hard limestone. In parts of North Wales the underlying rocks are slate. An ordinary geological map of the country will indicate stratas of varying types in other districts.

Some soils, by the colour and texture, are easily identified with the underlying rock formation. These are described as sedimentary, good examples of which are found in the Wiltshire Downs. Other surface soils show no connection whatever with the rocks beneath ; these are known as transported or erratic soils, and are very common in the country. Excellent examples of transported soils are to be found in Norfolk and Suffolk and in the border clay of the Northern Counties.

The effect in bygone ages of moving ice in the form of glaciers has no doubt helped in the formation of transported soil. As a glacier flows along the surface of the land it scratches grooves and crushes the underlying rocks. In its course also it carries with it the material resulting from the destruction of rocks, and this, after being taken

some considerable distance, helps to form a soil in a spot far removed from its place of origin.

The mechanical action of water is an important factor. Soils near the mouths of rivers have been accumulated almost entirely by the action of water. Bordering the estuaries of the Thames, Severn, Humber and several other rivers, the soil, rightly called alluvial, has been formed of the material derived from the wear and tear of rocks, etc., brought down by the river water. Even the clearest stream contains sediment, and this may be seen if a glass of the water is allowed to stand for a few hours, when the bottom of the glass will show a deposit. This sediment is carried in suspension by the moving water, the amount varying with the rapidity of the stream.

Apart from the mechanical action of moving water, there is also a chemical action to be considered. Certain constituents of rocks are soluble in pure water; for example, rock salt, gypsum and, to a lesser degree, silica. Rain water, in falling through the atmosphere, dissolves some of the carbonic acid gas or carbon dioxide, and water thus changed is capable of dissolving certain substances which are insoluble in pure water. The most important substance acted upon by rain water is carbonate of lime, and this is the main constituent of limestone, chalk and marble. Silica or quartz is a common rock-forming material; it is hard and is only slightly soluble in water containing carbon dioxide. For this reason it is usually found in comparatively large angular fragments. Sand is composed almost entirely of grains of quartz, which form

also a large proportion of the mineral matter in sandy soils.

The rock-forming materials which give rise to silicates of alumina, are known as feldspars and are widely distributed in rocks. Feldspars are compounds of aluminium oxide combined with soda, potash or lime. They change easily when acted upon by air and water: the quartz and harder materials are set free, chemical changes take place and ultimately as silicates of alumina combined with soda, potash, iron or lime they form the firmer material of soil and become the chief mineral constituents of clay.

Soil, therefore, may be considered as "rotted rock." The subsoil also consists of mineral fragments formed by the disintegration of rocks, but the changes through which it has passed have not gone far enough for the production of the true soil.

Rocks are composed of a large number of mineral substances consolidated into a compact mass. These masses may have been formed from minerals, such as granite and basalt—so-called Igneous Rocks—which have cooled down from a molten state. Others which have been formed under water, such as clays, sandstones, limestones and rock salts, are called Aqueous Rocks. The latter generally are stratified or arranged in layers; Igneous Rocks are not. Aqueous Rocks often enclose the remains of animals and plants in a fossilised form and are granular in texture. Igneous Rocks never contain fossils and are, commonly, crystalline in structure.

The conversion of rocks to soil under the action of the weather—alterations of temperature, frost and rain—is assisted by chemical changes in some

of the minerals which dissolve in water, so that the solid mass crumbles or disintegrates. The products of this action, or *weathering*, may either collect on the surface of the rocks, or be carried away by wind and water and eventually deposited in some other place. The weathering agents do not cease their activity when a soil is formed. Usually, on account of the loose condition of soils, they are more easily acted upon by frost, rain, oxygen and carbon dioxide.

Other agents, also, in the form of plants and animals, work upon the soil constituents. No sooner is a surface of solid rock exposed to the air than it becomes covered with a growth, first of lichen, then of mosses and finally of grass and shrubs. This irrepressible invasion of vegetation removes the bizarre appearance of new buildings in a few years; it is this which gives their picturesque appearance to old houses and ruins and produces the rich and varied colour and softness of outline of the hillsides. Vegetation penetrates and derives nourishment from almost any material. Even glass becomes coated with green, and *Funaria* soon changes the colour of newly constructed walls, etc.

On the hillsides the early generation of plants is succeeded by others, and gradually a soil is formed consisting of partly organic and partly inorganic matter, until a higher class of vegetation becomes possible. Vegetation is assisted by atmospheric changes until finally the continuity of the rock gives way and a thin soil is produced.

Soils as we know them to-day are the net result of atmospheric and chemical changes together with the

action of vegetation through unlimited time.

Composition of Soils

The origin and formation of soils leads up to the consideration of their composition. From the agricultural and horticultural point of view, the solid bulk of the soil may be considered as consisting mainly of four kinds of matter, silica (sand), silicates of alumina (clay), chalk, which is derived from calcareous rocks such as limestone, and humus. The latter consists chiefly of decayed and decaying vegetable matter mixed with a greater or less proportion of animal substance. If the superficial layer of dead leaves, etc., is removed from beneath trees in a wood, the material found underneath gives a good idea of the meaning of the term. Year by year the leaves fall and slowly decay, giving rise to a dark "mould" consisting of the organic matter derived from leaves of previous years together with pieces of twigs and roots, and often the remains of animals. These substances form complex chemical compounds containing carbon, hydrogen, oxygen and nitrogen, and represent various stages in the decomposition of animal and vegetable tissue. Each successive year fresh organic materials are added, the processes of decomposition are continually going on, and hence the term humus is used to describe the variable mixture thus produced.

Various names are applied to soils which contain a large proportion of one or other of the four minerals mentioned. Therefore, if the proportion of sand, as compared with clay, is high, such are described as sands or sandy soils; in clays and clayey

soils the percentage of silicate of alumina is high. Soils of an intermediate type are termed loams, and the names "clayey loams" or "sandy loams" are used as the proportion of sand or clay increases. When chalk forms a large proportion of the soil (over 10 per cent.), it is described as "calcareous soil." Should a clayey soil contain a large percentage of chalk, it is called "marl." Similarly when a soil contains a large proportion of humus, it is described as an "organic soil." Such soils are rare, those of this nature being described as "peat" or "fen."

Other chemical elements present in soils are potash, soda, oxide of iron, magnesia, phosphoric acid, sulphuric acid and chlorine. These substances are seldom found in the free state, but form oxides or compounds of oxygen with some other element. Potash, soda and magnesia are compounds of oxygen with the elements potassium, sodium and magnesium respectively. Phosphoric and sulphuric acid contain phosphorus and sulphur in combination with oxygen and hydrogen. Oxides of iron vary very much in colour, and although they do not occur in the soils in large quantities, the red and yellow sands and clays owe their colour to the hues of the oxides present. Carbonates of lime and magnesia occur in many soils; phosphates and sulphates are also generally present.

The soil should not be considered as an inert mass consisting of varying amounts of the four kinds of matter. It is the scene of endless changes brought about, not only by chemical action but by living organisms. The Earthworms and Moles are very important and active agents in the

soil, and nitrifying bacteria, fungi and algæ (lowly forms of vegetable life) assist in preparing the food of higher plants. The study of these lowly organisms has of recent years greatly assisted the agriculturist. It has shown that when Squitch, hedge-clippings, etc., have been burned on the fields, not only do the ashes help fertility, but also the heat destroys the harmful organisms such as protozoa, and ultimately increases the growth of the useful bacteria.

The substances most useful to plant life are nitrogen, phosphoric acid, potash and lime. Soils often become deficient in one or other of these, and the cultivator should know how to make up the loss.

Farm yard Manure

Nitrogen is derived from the decay of organic matter in the soil, in addition to which small quantities are brought down by the rain. Farm-yard manure contains a large amount of nitrogenous matter and the addition of this material to the soil may be considered the chief method of restoring lost or used nitrogen. Farm-yard manure consists of the remains of vegetable matter either in the form of litter or of food residue. It is usually a mixture of animal excrements with straw, or other material supplied as litter, in varying proportions, the latter being saturated with urine.

Such manure contains all the constituents which the land requires for the nourishment of plants. The inorganic materials present are potash, soda, magnesia, lime, oxide of iron, silica, chlorine, phosphoric and carbonic acids, all of which are found in plant

ash. Organic constituents are represented by various nitrogenous compounds which give rise to ammonia and humic acids ; from the latter, when acted upon by bacteria (nitrification), nitrogen is supplied to growing crops. Hence the complexity of its composition helps to render farm-yard manure a perfect as well as a general manure.

The most valuable constituents of the manure are those contained in the urine of live stock. Straw or other litter absorbs the liquid, though some of it may drain away. Further loss may occur through fermentation, and especially if a dark-brown liquid is allowed to escape from the mass. This liquid contains not only the constituents of urine, but valuable portions of the more solid excretion which has become soluble.

Modern farmers recognise the value of covered yards for the winter feeding of cattle. In such covered yards the manure can accumulate to a considerable depth and become of uniform texture and quality. The gutters are so arranged that the liquid flows into a tank, from which it can be used when required ; further, fermentation is diminished to a great extent. When manures are allowed to lie "open," oxidation of the excretion rapidly takes place, resulting in the loss of valuable plant food in the form of a volatile gas, "carbonate of ammonia."

Dryness is also a reason for loss ; in this case free nitrogen often passes from the mass. Hence, to keep the valuable contents of farm-yard manure until such can be applied to the fields, compression and moistening of the heap are advisable. Often the liquid collected in tanks is pumped back again on to the accumulating mass of

manure in covered yards in order to prevent the wasteful effects of fermentation. A well-kept farm-yard manure is of great value. When applied to the soil, the nitrogen in the liquid excretion of animals becomes the first plant food. The residue slowly becomes available, the finely divided matter of the more solid excreta first, then the constituents of the straw provide valuable soluble salts which the roots can absorb.

The physical effect of farm-yard manure is also important. When fresh manure is applied to clayey soils, it helps to break down the cohesive nature of the particles ; the fresh straw and litter provide air channels, thus promoting oxidation in the lower recesses of the soil. The fresher the condition of the manure, the less available are the food contents. Clayey soils are well adapted to retain such materials until the chemical and bacterial actions have taken place.

Well-rotted manure in which the constituents are more or less available should be applied to sandy and loamy soils. Spring is the best season to manure such types of soils, for as the plant foods become readily available, they can be taken up by the growing crops. If applied in the winter, most of the nutrient ingredients will be washed out and carried away in the drainage water, long before the crops are ready to make use of them.

The amount of farm-yard manure produced even on a well-managed large farm is insufficient to supply the needs of the arable and pasture land. Many farmers overcome the difficulty by a rotation of crops. The study of crops in their relation to the soil has resulted in a four-year system of cropping. Previous to the introduction

of the four-course system, several types of rotation were in vogue. Wheat and Beans were grown alternate years; this was a two-year system. Again, Wheat and Beans were grown, followed by a fallow year; a three-year system.

Some years no manure appears necessary, especially after a root crop has been fed upon the land by Sheep, or possibly after Beans or Clover, which leave the land rich in nitrogen.

In the four-course, or Norfolk Rotation, it is found that the land is in its greatest stage of exhaustion after Wheat. For this reason a heavy dressing of manure, at the rate of 12 to 20 tons per acre, is applied for the next crop of roots; the latter may be considered as starting a new rotation. The second crop in the four-course system would be either Oats or Barley, Clover and Grass seeds being sown at the same time; if the roots are eaten on the land, the "droppings" from the Sheep will replace the loss and no further addition is required. The third year's crop will be Clover, followed in the fourth year by Wheat. When possible it is advisable to manure at the end of the third year, that is, before the land is prepared for the Wheat crop.

Modifications of the Norfolk system are often found; a five-course system is made by leaving the Grass and Clover for a second year. Sometimes an additional Corn crop follows Wheat, the five courses being Roots, Barley, Clover, Wheat and Oats. The four-course system is still the guiding principle in farming, but modifications are made to meet the needs of particular districts. When variety is introduced in cropping, the four-year system

may be extended to cover a number of years; for example, Turnips, Barley, Clover, Wheat; Carrots, Wheat, Potatoes, Wheat; Cabbage, Wheat, Clover, Mangolds.

The eight course, or Wiltshire system, is useful in counties in the South. In this case, Catch Crops such as Vetches, etc., are introduced before the root crops, and thus, in many cases, two crops are produced in the same year. Such a system is only workable in Sheep-rearing areas. It enables farmers, especially in Hampshire and Wiltshire, to keep large flocks of Sheep and, by feeding them on Catch Crops, etc., to enrich the soil at the same time.

Artificial manures are now largely used to make up for the insufficiency of farm-yard manure and to replace the essentials, such as nitrogen, phosphoric acid and potash. Such manures have the advantage of presenting a large amount of fertilising material in a small bulk. Many of them contain only one of the valuable ingredients and are then spoken of as nitrogenous, phosphatic or potash manure as the case may be.

Nitrogenous Manures

The manures under this name are usually nitrate of soda, sulphate of ammonia, nitrate of lime, nitrolin or calcium cyanamide, nitrate of ammonia, blood meal, rape dust and shoddy. It is essential that such manures should be applied to the land in finely ground condition. Sulphate of ammonia and nitrate of soda are apt to become caked, and lumps which will not pass through a $\frac{1}{4}$ -in. sieve are harmful to growing crops.

Phosphatic Manures

The chief source of phosphatic manures is superphosphates and basic slag. Steamed bone flour may be regarded as a phosphatic manure, although it contains a small amount of nitrogen. Bone meal, made from ground bones, free from grease, contains approximately 50 per cent. of phosphates and about 4 per cent. of nitrogen. Such manure is valuable for fruit-growing. The meal contains particles of bone about $\frac{1}{4}$ in. or more in size, from which the phosphates become available very slowly. Fish meal and guano are often used; like bone meal, such manures contain a certain amount of nitrogen in addition to their phosphatic contents.

Potash Manures

Sulphate and muriate of potash are the usual sources of supply. Kainit, of which two types are imported, contains a large proportion of common salt and is useful on land where salt and potash are required.

Lime

This material is often spoken of as a manure; strictly speaking this is incorrect, although it is an essential plant food. Lime has several direct uses, all of which are of value to the farmer and gardener. In the first place it improves the nature and drainage of clay or heavy soils, making them more open and friable. Reserves of nitrogenous material in the soil are acted upon and made available to the growing crops. It is of great value in checking the disease known as Club Root. Most crops respond to liming, especially leguminous and root crops,

but for Potatoes, Rye and Oats it should not be applied at the time of planting.

Manures for Special Crops

There is room for the exercise of considerable skill in the application of artificial manures. A knowledge of the requirements of various crops, as well as the properties of the manures themselves, is essential. In this respect, much experimental work can be carried out in country schools. It must be remembered that artificial manures are applied not to enrich the ground, but to feed the crops. When the needs of particular crops are known, the time and the method of applying the fertiliser become deciding factors. For example, nitrate of soda becomes a plant food when applied to the soil. Hence this manure and those of a soluble and rapidly acting nature should be applied in the spring. Bones, basic slag, guano, etc., are slow-acting fertilisers and may safely be applied to the land in the autumn.

Wheat occupies the land for a long time; for this crop it is usual to apply superphosphates at the rate of 2 cwt. per acre at the time of sowing in autumn. As a top dressing in spring, nitrate of soda, applied at the rate of 1 to $1\frac{1}{2}$ cwt. per acre, is beneficial.

Barley and Oats should receive a dressing of superphosphates on a soil rich in lime; a phosphatic guano or bone meal on soils deficient in lime at the time of sowing. A top dressing of nitrate is unnecessary in the case of Barley, but is often useful for Oats.

Turnips and Swedes respond to a top dressing of phosphates. In districts affected by the Turnip Fly, it is advisable to apply phosphates. Man-

golds do not usually respond to phosphatic manures.

Basic slag is, perhaps, the most beneficial on land poor in lime, but when the land has received a good dressing of farm-yard manure, no artificials are needed.

In districts near the sea, Seaweeds such as *Fucus*, *Ulva*, *Laminaria*, etc., are used in addition to farm-yard manure. Most of these plants decay rapidly in the soil, rendering available the nitrogenous contents. The authorities on the subject recommend an addition of superphosphates or basic slag, since the phosphatic content is about half that of farm-yard manure.

For the gardener, other natural manures are available, Poultry and Pigeon manure containing a large percentage of nitrogen and, in smaller amounts, phosphates and potash. The nitrogenous content is in an easily fermentable form and care must be taken to prevent loss. From the Fowl pens and coops the manure should be removed and stored in a dry shed, a layer of dry soil alternating with a layer of manure. The heap should be turned occasionally until the whole of the mixture is dry and friable. In this form it can be used as a top dressing for any growing crop at the rate of six to eight ounces per square yard; fresh manure should not be used. Owing to its rapid evolution of ammonia it is harmful to young roots—the rule-of-thumb gardener speaks of “burning.”

To make the “dry” manure of some value, artificial manure can be added. For Potatoes, muriate of potash at the rate of $1\frac{1}{2}$ ounces to 6 ounces of Poultry manure. As an addition for Turnips, Onions and Celery, phosphates are useful, mixed up with the earth-

dry manure, 5 lb. of the latter to 1 lb. superphosphate or basic slag.

When a liquid manure is required, 14 lb. of Poultry dung, placed in forty gallons of water and allowed to stand for 48 hours, will supply the need. For fruit and the vegetable crops, this should be applied at the rate of 2 gallons per square yard.

Green Manuring

On clay soils it is advisable to grow and dig in Catch Crops such as Vetches, Rape or White Mustard. This process not only supplies the organic matter necessary, but helps considerably in breaking up the heavy nature of such.

The same process with light soils is an advantage; the decaying vegetable matter has a tendency to render such soils more retentive.

Cabbage leaves, stems, lawn clippings, fallen leaves, in fact any green matter, should be buried in order to enrich the organic matter.

Soot

This is also of value as a manure and as a soil improver. After being stored for at least a month in a dry shed, it can be used instead of sulphate of ammonia at the rate of 9 lb. per rod. Its nitrogenous content becomes available slowly, and hence it should be applied some time before sowing or planting.

Ashes

Ashes from the burning of waste vegetable matter, hedge clippings, etc., should be stored in a dry shed until required. The potash content is in an available form, and hence for Carrots, Onions, Potatoes, Parsnips, etc., a top dressing of 2 lb. per rod is of value.

Cultivation

Both the farmer and gardener apply the same principles to the art of cultivation. The spade and the plough turn the upper layer of the soil over; the cultivator and fork break up the large lumps of earth and remove weeds; the harrow and rake reduce the surface of the soil to a degree of fineness—the tilth. The sowing of seeds is carried on in one case by hand and in the other by the aid of machines. What the farmer does on a large scale, assisted by animals and machines, the gardener does almost entirely by the use of small tools and his hands. The deep digging or double digging of the gardener has, to a certain extent, its counterpart in the deep ploughing and “cultivating” of the farmer. Manuring and rotation of crops are similarly treated by both, but the gardener restricts his activity to the production of food for Man, while the farmer produces food for animals and

also food for the community at large. In a garden the aim is to produce as much as possible in a limited space; a more intensive system is the result.

In country schools much useful work can be done if the types of farm animals are dealt with in outline. The various breeds of Horses, Cattle, Sheep, Pigs, etc., should receive consideration, together with the main features of Poultry-rearing. Unfortunately the present volume is limited in size, and much information on these points is necessarily omitted. Useful details can be obtained from the Journal of Agriculture published monthly by the Ministry of Agriculture and Fisheries, and in this periodical the teacher should find the most up-to-date information. In the succeeding chapter on the School Garden, information will be given on the most common diseases and pests of cultivated plants, and it is hoped this will be found useful to teachers in country districts as well as to the teachers of gardening.

CHAPTER IX

SCHOOL GARDENS

Aim of School Gardening

FROM many points of view gardening may be considered as a practical subject. Apart from the growing of vegetables, or the purely theoretical side, the subject is closely allied with Practical Arithmetic and Elementary Science. The time spent on this subject is insufficient to make gardeners of the scholars, and such is not the aim, but, if properly taught, the principles underlying common

gardening practice should be inculcated.

Further, School Gardening is an extension or practical application of Nature Study, and should develop the “seeing eye,” the “understanding heart” and encourage the scholars to look upon Nature as an ally in their endeavour to cultivate plants. Again, gardening is a subject which fosters a sense of the beautiful, makes the scholars self-reliant, neat and tidy, and gives scope for gaining knowledge

through observation and activity which no class teaching could render so valuable. The purely economic aspect should not be overlooked. Skill in the use of tools, the amount of seed required for a certain area, the time of planting and the right methods are valuable assets to anyone, and especially to those who, in time, may possess gardens and allotments of their own.

The gardening scheme should be continuous throughout the year. Outdoor work is generally possible, and through the winter many operations essential to good cultivation can be carried out. The general lay-out of the garden may need a slight alteration, the paths renovated, hedges cleaned, etc., and, when the weather is mild, bastard trenching or double digging and manuring can be carried out. When outdoor work is impossible, lessons on general principles can be given and a Winter Scheme in use at the present time is appended.

The teacher should be a member of the ordinary staff whenever possible. However capable and well-qualified a visiting teacher may be, the work is not so effective, nor does it arouse such keen interest as when taken as an integral part of the curriculum. Correlation with other subjects is extremely useful and can, of course, be carried out best by the class teacher who not only knows his scholars, but is able to link up the practical work in the garden with theoretical work in the classroom. Many visiting instructors are excellent practical men, yet from the point of view of discipline, correlation of school subjects, and value of the garden to the scholars in general, the class teacher with a fair knowledge of gardening, is much to be preferred.

Should there be no member of a staff capable and desirous of taking gardening, then the subject should not be included in the curriculum. Some authorities, however, employ visiting Instructors; it is advisable in this case for the class teacher to be present during the period of instruction and thus form a link between the classroom and garden.

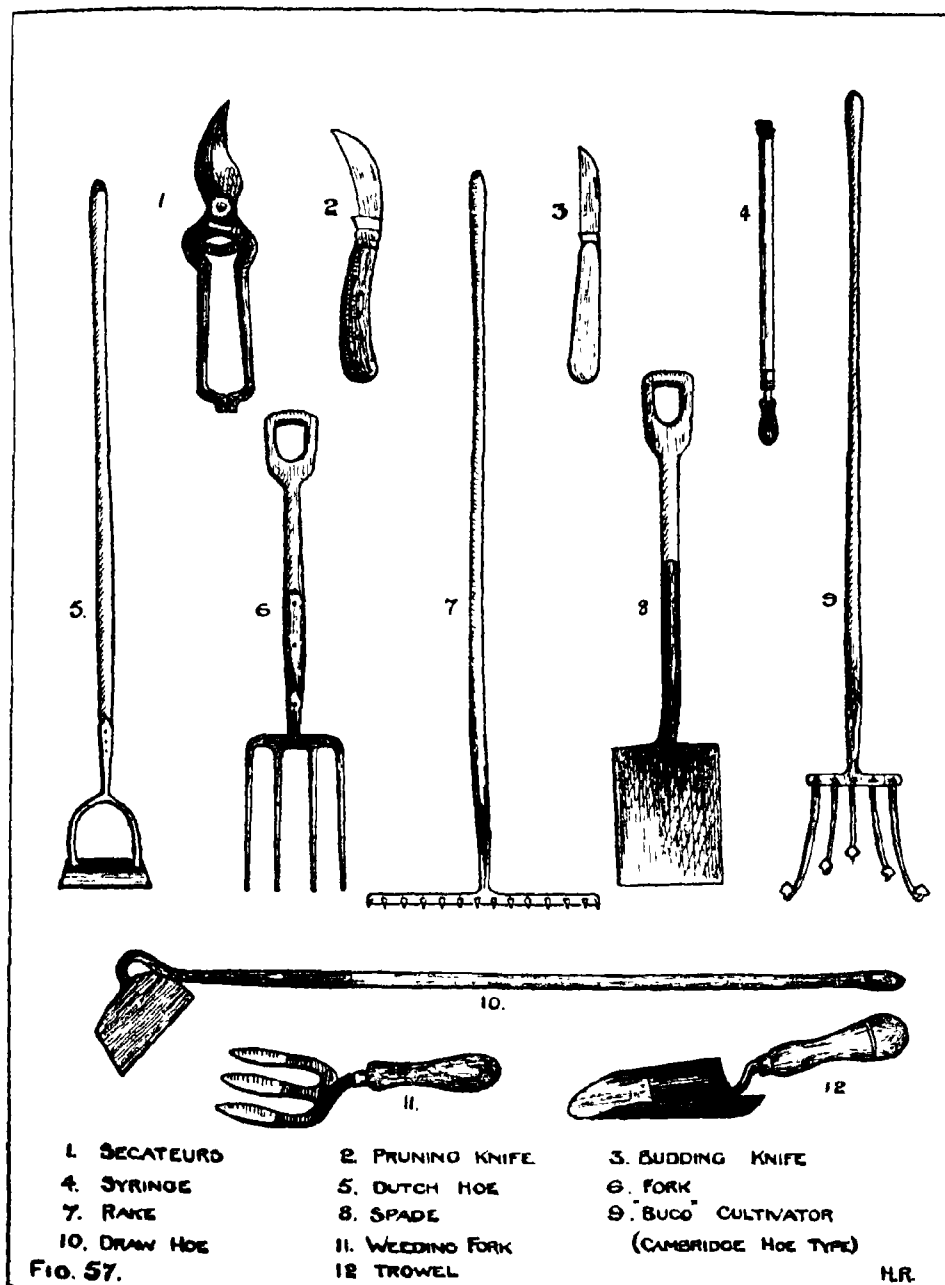
Where possible the school garden should be within easy distance of the school. The practice in many country districts is to apportion a part of the Head Teacher's garden for this purpose; in others to extend the playground to meet the requirements. In many towns, allotments are obtained, and, when these are within five minutes' walk of the school, they suit the purpose admirably.

Land Required

At least two rods of land should be allowed for each scholar, that is a 28-rod garden will allow for a class of 14 scholars, one rod each and sufficient land for a demonstration plot, nursery beds, fruit and flower border, space for tool shed and manure heaps, etc. For a class of 20 scholars, 1,200 square yards are essential, 4 allotments of 5 rods each. In many counties, areas are given special names; for instance, in parts of Staffordshire and Shropshire, a rood is 64 square yards or an 8-yards run.

Tools (Fig. 57)

This is rather a vexed question from the teacher's point of view. The supply is often limited and has to be supplemented by tools brought by the children. The minimum for effective work should consist of half as many spades,



TOOLS FOR THE SCHOOL GARDEN.

A "set of tools" as represented should be provided for every two boys of a gardening class with the exception of those numbered 1, 2, 3 and 4. Of these, one of each is sufficient for each class. A watering-can is often considered essential—the Dutch Hoe is far more valuable.

forks, Dutch hoes, draw hoes (swan-neck type), rakes, dibbers, garden lines, trowels, hand forks and measuring sticks a yard long marked off in inches, as there are members in the class. If a Woodwork class is also run in connection with the school, the dibbers, line holders and measuring sticks might be obtained from this centre. A wheelbarrow, water-can, syringe, sécateurs, pruning knife and budding knife are also necessary. If possible, a small cold frame should form part of the equipment. A shed large enough to accommodate all the tools, wheelbarrow, etc., is essential, and this should, whenever possible, be erected on the garden site.

General Lay-out of Gardens

Much can be said for either of the types of School Gardens as arranged at the present time. The "Single," "Dual" and "Common" Plot Systems have their advantages and disadvantages. From experience the dual plot is, perhaps, the best for the less-experienced teachers. Under this system the boys should have two years in the class and then each plot can be in charge of a senior and junior boy. The Single Plot system, each boy having charge of at least one rod of garden, is excellent in many respects, but it is not advisable to attempt this system unless the scholars have some slight knowledge of garden operations. With the Common Plot system, the garden can be worked on model lines. In country districts it may well take the form of a cottage garden, and in towns a model allotment is worth attempting.

Where land is obtainable and two classes can be taken, ideal conditions for School Gardens and for practical

and moral training present themselves. The one part of the garden should be worked on the Common Plot system by juniors or first-year scholars, the remaining part, arranged in single plots, to be cultivated by senior or second-year scholars. Such an arrangement is very effective, and rivalry of a friendly nature shows itself during the second year, the best efforts of the boys being put forward in keeping their gardens spick and span. The above method was instituted some six years back by the writer; 2,000 square yards of land were utilised, and up to the present time there has been no necessity to modify the scheme.

There is no reason why a modification of one or other of the schemes should not be adapted to meet the needs of a particular district.

At the present time the writer has the following in operation. The school of 360 boys, in an industrial area, can at present only hold one gardening class, and hence the scholars are changed each year. Three allotments, each 320 square yards in area, are being used. One is being cultivated as a model allotment, and is in charge of eight boys. The other two are cut up into fourteen plots, twelve of which are used as single plots for boys, one as a nursery bed and the other as a demonstration section. Running between the two gardens is a flower border, each boy having his own section to look after. The Common Plot is used for experiments with manures, these being worked in conjunction with the ordinary cropping arrangements.

The Teacher of Gardening

Before dealing with the methods employed in teaching the art of culti-

vation, a word of warning is necessary. The teacher must bear in mind that he is training boys in the right use of tools and the correct method of sowing and planting, raising plants in the cold frame, etc. Many errors will be made, but often such mistakes are more valuable than hours of instruction.

For example, when getting out a trench for small seeds, the line slips and is neglected by an unthinking boy; the result of his neglect is apparent when the plants are above ground. In planting Potatoes, failure to mark the correct distance between the rows results in a difficulty when the time comes for earthing up.

The teacher of gardening, in an attempt to obviate untidiness, which he knows will occur, often does the work himself; this practice is not commendable. The Demonstration Plot is the teacher's domain, and if full use is made of it for practice by the boys, the errors made will be of a slight nature only. Teachers often do too much of the practical work themselves, mainly because they know that Inspectors and County Instructors are critical.

However, if Gardening is worth taking as a school subject, then, like all other subjects, perfection cannot be obtained with only two hours each week available. Moreover, the technical skill of a gardener is the result of years of experience, and this should be taken into consideration when dealing with the practical work of the boys. If proper use is made of the Demonstration Plot by teacher and scholars, and the teacher insists on the right use of tools, and sees all drills and trenches before seeds are sown, the gardens will present a satisfactory appearance to any reasonable Inspector.

Gardening Operations

From the foregoing remarks, it may be thought that the teacher of gardening needs several pairs of hands and eyes. This is, however, not the case; his method of tackling the work is the essential and dominating factor. Many of the operations necessary can be taught during the Winter, and for this reason new Gardening Classes should begin in November. At this period the gardens will be clear of produce, except for the Winter greens, and a start can be made with Digging, Double Digging, Bastard Trenching and Full Trenching. This work provides ample opportunity for the teacher to demonstrate the correct method of using the spade and fork.

Digging

This operation is, perhaps, the easiest to perform, and is often the only one carried out by allotment holders. In all operations with the spade the object is to displace the soil. A trench should be made, one spit or one spade in depth, and 2 ft. in width, across one end of the plot or garden, the soil being removed by the aid of the wheelbarrow to the other end, or the plot should be divided longitudinally, the removed soil being placed on the path opposite to the other half of the plot. In the trench thus formed, weeds, grass, cabbage leaves, grass clippings or manure can be placed, spread evenly over the surface, care being taken that no Couch Grass, Coltsfoot or Creeping Crowfoot is included. The soil from a similar width of the garden can be used to fill up the first trench, its removal forming a second trench one spit deep. These operations are continuous until the whole of the ground

has been dug, the last trench being filled in with the soil removed in the first place from the opposite side or end of the plot.

In this operation it is imperative that the spade is properly used. The blade should be inserted in the ground to its full depth at an angle not greater than 60° . Boys are apt to attempt to remove too much soil at a time, a spit 8 in. deep by 3 in. wide is quite sufficient for the average boy of twelve years. For beginners, it is advisable to run a line across the plot, marking the amount to be removed. By first pressing downwards, a spadeful of soil can be lifted, and, on being thrown forward, should be completely turned over. When this is done, the soil is more evenly turned and the fully dug plot should present a fairly level appearance.

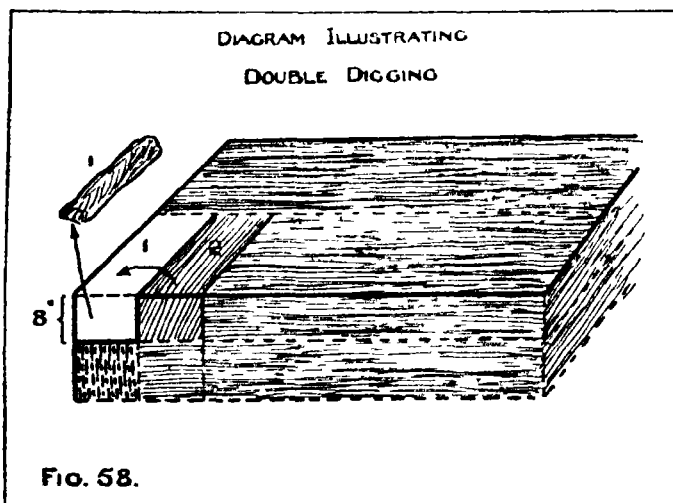
Double Digging (Fig. 58)

This type of work necessarily takes

up more time, but is more effective than digging. The garden, or plot, should be divided longitudinally into two equal parts; a trench 1 yard wide should be made, the soil being removed to a depth of 8 in. and wheeled to the opposite side of the plot. The bottom of the trench should be forked to a depth of 8 in., leaving this in a rough condition. After forking, leaves, grass and ephemeral weeds can be placed in the trench, and then the soil from the second yard of ground thrown on the top. These operations are continued throughout the plot, the last trench being filled up with the soil previously removed from the first.

Double digging is the most suitable treatment for maiden land, or when grass land is being converted to a garden. In the latter case the turf should be removed, followed by the first 8 in. of soil. The bottom of the trench should be forked or broken up with a mattock or pick. The turf from the second

section should be cut up and placed face downward in the trench, the soil thrown over and the second trench thus formed, treated in the same manner as the first. Similar operations should be carried out until the whole plot has been dug, the last trench being filled in with the turf and soil removed at the beginning of the operations.



DOUBLE DIGGING.

This is a simple yet effective gardening operation. The subsoil in this case is broken up, thus allowing the oxygen of the air to act on the soil particles.

Bastard or False

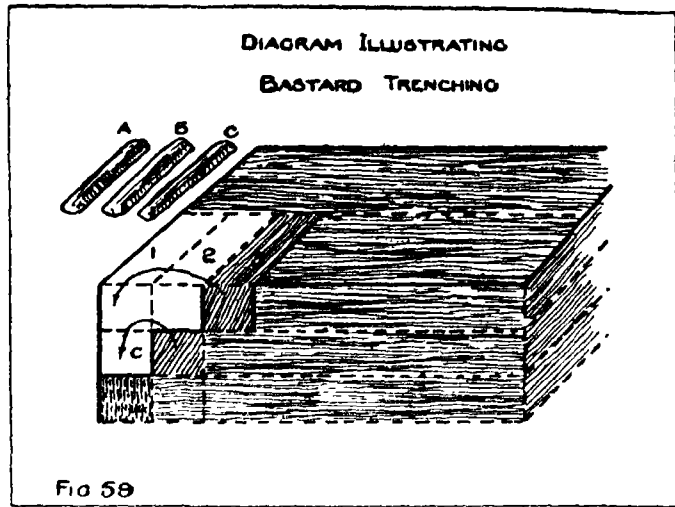
Trenching (Fig. 59)

In the operation of Double Digging, it will

be noticed that the subsoil, although disturbed, remains in situ, the position of the top soil being changed. Bastard Trenching should be carried out on land only when the subsoil has been disturbed by Double Digging, for in this type of cultivation the position of both soil and subsoil is changed.

A trench similar to that recommended for Double Digging should be formed (Section 1, Fig. 59), the soil being placed in a convenient position on the opposite side of the plot (Fig. 59a). From the second yard of the plot (Section 2, Fig. 59) the top spit should also be removed and placed near that removed from the first section (Fig. 59b). The subsoil from Section 1 should be removed to 8 in., the material being placed in a third heap as shown in Fig. 59c. The third spit of Section 1 should then be broken up with either a mattock, pick or fork. The second spit from Section 2 (the subsoil) should then be thrown on to the third spit of Section 1 and the top spit of Section 3 by means of the spade placed also on the top of Section 1.

This operation leaves Section 1 complete, Section 2 with the top soil and subsoil removed, Section 3 with the top soil removed. When the bottom spit of Section 2 has been broken up, the subsoil from Section 3 is placed on the top, the operation being completed by removing the top spit from Section 4. The work is carried on in a



BASTARD TRENCHING.

Bastard Trenching is a most difficult operation to carry out successfully. Care must be taken to ensure that the subsoil is not brought to the surface.

similar manner throughout the plot, the last trench but one being filled in with the soil from the second section, the last trench receiving the subsoil and soil which were removed from Section 1.

Some writers recommend a trench 2 ft. wide for Bastard Trenching. After twenty years' experience in the teaching of gardening, the writer is of the opinion, without hesitation, that the yard trench is preferable. Care must be taken in removing the soil from Section 3 to Section 1, but if a boy is taught to remove a spit of soil commensurate with his strength, no difficulty will be experienced. The smaller trench is quite sufficient for experienced gardeners, but for effective work with boys working together space is required, and the larger space lessens the risk of danger to their partners.

True or Full Trenching (Fig. 60)

The gardening operations which come under this heading should only

be carried out on gardens which have been thoroughly cultivated and those which have been Bastard Trenched on several occasions. In this case the positions of the soil and subsoil are reversed, the subsoil becoming the upper layer. As in Bastard Trenching, the soil and subsoil are removed from a section of the plot 1 yard wide. The bottom of the section is broken up with a fork or, when the third spit is very hard or clayey, the use of a mattock is perhaps advisable. On heavy soils, vegetable refuse should be mixed up with the bottom layer to assist drainage. When this has been done the top spit of Section 2 is removed to Section 1, the subsoil of Section 2 becoming the top layer of Section 1.

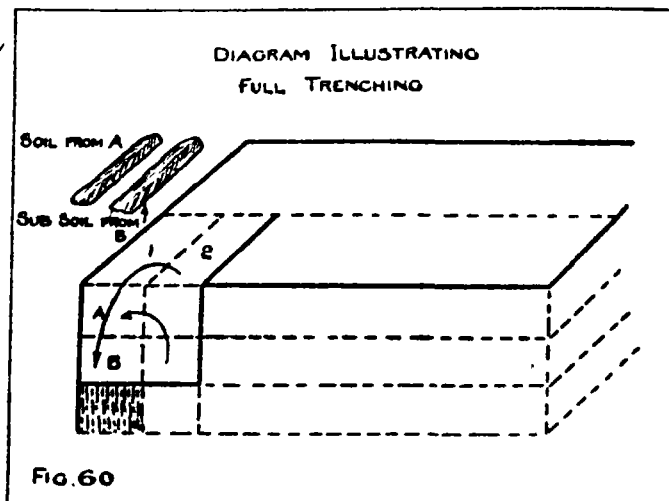
It is often advisable, especially when cultivating the Common Plot, to divide the whole into four parts, five boys (three with spades and two with forks) being responsible for a section. The garden should also be divided longi-

tudinally, and in this case the sections can be worked in opposite directions. Fig. 61 represents a Common Plot divided as suggested.

For Double Digging, Bastard and Full Trenching, Sections 2 and 4, remove the soil from the first trench (A) of the respective plots and place same in Sections 1b and 3b. When the first trench has been completed, Sections 1 and 3, commence operations, removing the soil from their respective trenches to Sections 2a and 4a. Sections 1 and 3 will work from north to south, the other two divisions working in the opposite direction. It is obvious that certain boys are waiting to start operations for some time. During this time, other work can be attended to, such as the cleaning of paths, forking between fruit trees or clearing the plot of weeds.

Drainage

Heavy soils are sometimes more or less waterlogged. Deep cultivation, such as Bastard Trenching, will do much to remove this defect. With School Gardens, this is, perhaps, the only method of dealing with the problem, for land drainage is rather an expensive process. Beneficial results are obtained if the paths are constructed to act as drains, and, where necessary, the work can be carried out in Winter. The soil forming the paths should be removed to form a trench 3 ft. deep by



FULL TRENCHING.

Full Trenching should not be attempted until the condition of the subsoil has been improved by Bastard Trenching.

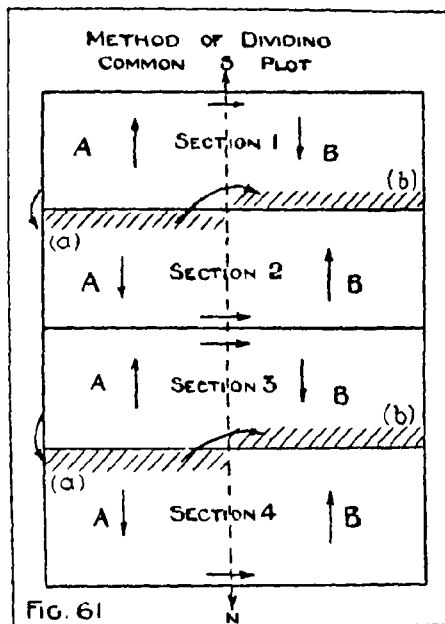
1 ft. wide. In the bottom stones, brick ends, builders' rubbish, ashes, tin cans, etc., should be thrown to a depth of 6 in., this rubble being covered with ashes and then with the original soil. Where this is done the paths will be comparatively dry throughout the year, and when Bastard Trenching and path draining are in operation, the heavy nature of the land is greatly improved.

Ridging

On very heavy soils it is often very difficult to get surface water away unless special methods are adopted. With such soils, Bastard Trenching should be carried out, and early in winter the land should be "ridged." This process is similar to the "earthing up" of Potatoes, and the Draw Hoe or, better still, the Cambridge Hoe can be used for the purpose. The soil should be laid up to form ridges and furrows, the distance from the crown of one ridge to that of the next being approximately 3 ft. Such an arrangement not only assists in getting rid of surface water but presents a greater surface for the beneficial action of frost.

Surface Cultivation

However efficiently the digging or trenching has been done, much more work is necessary in spring in order to prepare the soil for the reception of seeds. As soon as the weather permits, the whole of the plots should be forked over and the larger lumps of soil broken down. When the surface is in a dry and friable condition, the rakes can be brought into use to secure a level surface of fine soil. Raking to produce a good "tilth" is a difficult



THE COMMON PLOT.

The illustration shows a convenient method of dividing the plot for the winter work—digging or trenching.

operation and the Demonstration Plot should be utilised for practice purposes. The greatest difficulty is experienced by boys in keeping the soil on the plot, and at the same time obtaining an even surface.

Rotation of Crops

Although gardens must, to a great extent, show the personality and also the ability of the teacher, certain general principles can now be given. Even with a rich soil it is necessary to have a rotation of crops, and the following is an arrangement which experience has proved to be of value.

The garden, or plot, should be divided into four sections. In the first division Potatoes, Peas and Beans should be planted; Section 2 should be reserved

for green crops such as Cabbages, Brussels Sprouts, Broccoli, Cauliflower, etc.; Section 3, for Beet, Carrots, Parsnips, Radishes, etc., and the fourth section for Onions, Leeks, Turnips and Celery. (*N.B.*—The cultivation of Celery on Single or Dual Plots is not recommended.) The basis of the foregoing rotation is the food mainly required by the various plants. Those in Section 1 require phosphates and potash. The green plants are greedy feeders and utilise a large amount of nitrogen and phosphates. Section 3 contains the tap-rooted vegetables, which require chiefly nitrogen and potash; those in the fourth group require potash, nitrogen and phosphates in more or less equal proportions.

By using a rotation such as that indicated, the constituents will be kept in a well-balanced condition. The vegetables are so arranged that each group of plants makes a somewhat different demand on the soil and leaves it in a better condition for the next crop. For example, the roots of Peas and Beans, when left in the soil, enrich the nitrogen content. The following crop, members of the Cabbage family, require a large amount of nitrogen;

the third crop requires potash; very little of this constituent is required by the previous crop.

Again, if farm-yard manure is only obtainable in small quantities, this should be used for the crops in Section 1, and applied during trenching between the first and second layer. Artificial manure can then be used for the other sections, supplying the crops with the special foods they require. In such a system, farm-yard manure is applied to the whole of the garden once in four years, and, with proper cultivation, this is sufficient. Lime is often necessary, and hence, before the planting in the second year, unslaked lime should be applied to Section 1 at the rate of 6 to 10 oz. per square yard.

Cultivation

It is impossible, in this volume, to give details of the methods employed in cultivation of individual vegetables. With correct cultivation of soil and a reasonable system of rotation and manuring, the following table will provide the details necessary for successful efforts:

Seeds.	Time of Planting.	Depth in Soil.	Distance.		Recommended Varieties.
			Apart.	Between Rows.	
Beans, Broad	Feb. or March	2½ to 3 in.	10 in.	3 ft.	Bunyard's Exhibition, Green Windsor, Harrington Windsor.
Beans, French	May	2 to 2½ in.	12 in.	2 ft.	Canadian Wonder, Ne Plus Ultra, Negro Longpodded.
Beans, Kidney	May	3 in.	12 in.	4 ft.	Scarlet Emperor, Painted Lady, The Czar.
Peas . . .	Feb. to May	1½ to 2 in.	Dwarf, 3 in. Tall, 6 in.	2 ft. 3 ft.	The Sherwood (1½ ft.). The Daisy, The Pilot, Duke of Albany (4½ ft.), Ne Plus Ultra, Veitch's Perfection.

Seeds.	Time of Planting.	Depth in Soil.	Distance.		Recommended Varieties.
			Apart.	Between Rows	
Beet . . .	April and May	1 in.	6 to 8 in.	9 in.	Dell's Crimson, Cheltenham Green Top, Crimson Globe.
Turnips . . .	Feb. to Sept.	$\frac{1}{2}$ in.	6 to 8 in.	9 in.	Early Green Top Stone, Snowball, Veitch's Red Globe.
Radishes . . .	Feb. to July	$\frac{1}{2}$ in.	Broadcast		Scarlet Tulip, French Breakfast, Long Scarlet, Short Top.
Parsnips . . .	Feb. to March	1 in.	10 in.	10 in.	The Student, Tender and True, Hollow Crown.
Carrots . . .	Feb. and March	1 in.	8 in.	9 in.	James's Scarlet Intermediate, Altringham, Long Red Surrey.
Onions . . .	Feb., March and August	1 in.	6 in.	9 in.	Ailsa Craig, James's Keeping, Cranston's Excelsior, Giant Rocca, White Lisbon, Flat Red Tripoli.
Leeks . . .	March	1 in.	10 in.	12 in.	The Lyon, Musselburg, London Flag.
Shallots . . .	March	(Just below the surface)	9 in.	9 in.	Red or White.
Onion Sets . . .	April		15 to 18 in.	2 to 3 ft	Dargill Early or Whitchell Early (1st Early), The Ally or Abundance (2nd Early), Majestic or The Bishop (Late).
Potatoes . . .	March to May	4 to 6 in.			Flower of Spring, Elam's Early, Enfield Market, (Red Dwarf Dutch for pickling).
Cabbage . . .	August	$\frac{1}{2}$ in.	16 in.	2 $\frac{1}{2}$ ft.	Early Offenham, Christmas Drumhead, Early York
Cabbage . . .	March	$\frac{1}{2}$ in.	18 in.	2 $\frac{1}{2}$ ft.	Snowball, Veitch's Autumn Giant, Early London.
Cauliflower . . .	March	$\frac{1}{2}$ in.	18 in.	2 $\frac{1}{2}$ ft.	Veitch's Self-Protecting, Snow's Winter White, Purple Sprouting.
Broccoli . . .	March	$\frac{1}{2}$ in.	24 in.	2 $\frac{1}{2}$ ft.	Cambridge Champion, The Wroxton, Scrymger's Giant.
Brussels Sprouts . . .	April or May	$\frac{1}{2}$ in.	24 in.	2 $\frac{1}{2}$ ft.	Drumhead, Early Ulm, Ormskirk.
Cabbage Savoy . . .	March	$\frac{1}{2}$ in.	24 in.	2 $\frac{1}{2}$ ft.	Wonderful (Cabbage) Tom Thumb (Dwarf)
Lettuce . . .	March and April	$\frac{1}{2}$ in.	9 in.	9 in.	Nuneham Park (Cos).
Vegetable Marrow . . .	March and April	1 to 1 $\frac{1}{2}$ in.	24 in.	2 or 3 plants only required	Moore's Cream Custard, Green Striped.

The above table will undoubtedly be found useful to beginners. In the end column will be found a list of varieties suitable for the School Garden, the selection being based on personal experience.

A few hints on the sowing of Peas and Beans may be helpful. The dwarf varieties of Peas are, in the most cases, the better to use; many districts experience difficulty in obtaining Peasticks.

Assuming the suggested rotation is being carried out and that the section for Peas, Beans and Potatoes has been manured at the time of trenching, the following method of planting Peas should be successful. Where possible a top dressing of wood ashes, applied after trenching, forms additional food material for the crops.

Early in February, or as soon as weather conditions are suitable, the ground should be well worked with a fork and all hard lumps broken down to a fine tilth. Drills 3 in. deep should be made with a draw hoe; the bottom of the trench should be flat (Fig. 62). The seeds should be sown in eights, as indicated in the diagram, and then covered over lightly by forking the previously removed soil.

On very light soils it is often advisable to make the trench 6 in. deep, covering over the seeds with 3 in. of soil. For late Peas, this is always a good plan, and especially serviceable, should watering become necessary.

Broad Beans

Beans do not crop well in loose soils, therefore it is not advisable to disturb the soil with the fork or spade. Break the rough lumps with the back of the fork, draw out a trench 3 in. deep, placing the seeds, black scar (hilum), downwards, in two rows 9 or 10 in. apart diagonally (Fig. 62), and then cover over with soil and tread firmly.

Kidney Beans

Prepare the soil in the same manner as for Peas; draw out the trench with

a draw hoe and cover seeds over by using the fork. The cotyledons in this case come above the ground and form the first foliage leaves—the loose covering of soil facilitates an easy development.

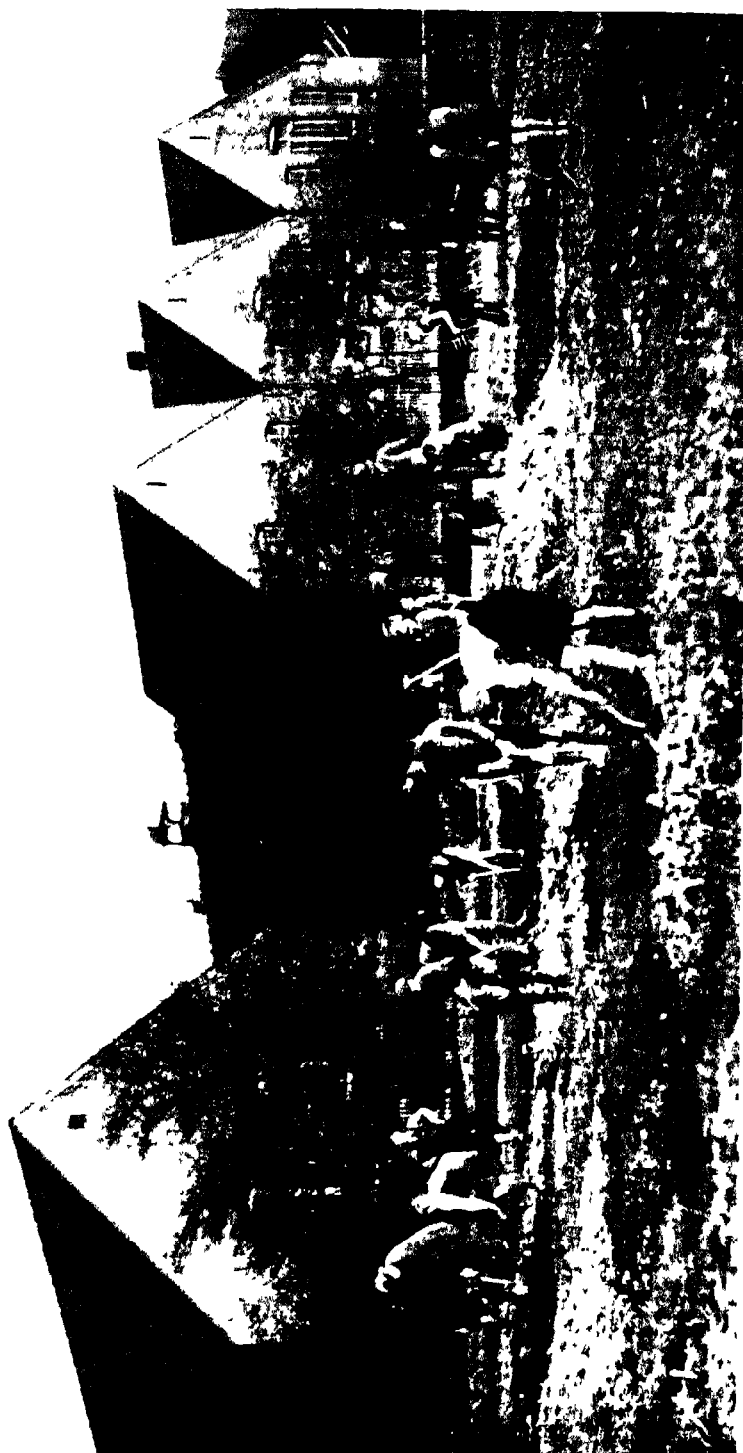
Potatoes

The "seed" Potatoes should be greened and sprouted in boxes. By this means defective "sets" can be discovered, the risk of damage by frost is lessened, and the crop reaches an earlier maturity and a larger size. After forking over the plot, trenches should be made 4 to 6 in. deep and 24 to 36 in. apart. The Potatoes should be planted "rose" end upwards, 15 to 18 in. apart in the rows. To cover over the "sets" the fork or the Cambridge Hoe should be used. When the haulms, or stems, are about 2 in. high, the soil between the rows should be forked, weeds between the plants having previously been cut down with the Dutch hoe. Commence earthing up as soon as the height of the haulms permits, and do this in two or three operations, at intervals.

Vegetable Marrows

For the cultivation of these plants a special bed is required. This can be made during Autumn by collecting fallen leaves, soil in small quantities being added as each layer of leaves is obtained. A mild hot-bed is the result.

The plants can be raised in the classroom during March, the seeds being sown in flower-pots. In May the plants should be hardened off and planted in their permanent quarters early in June. If hand pollination is resorted to excellent berries will be obtained.



THE GARDENING CLASS

[illegible]

Fruit Culture

The cultivation of fruit trees in towns is often a difficult problem owing to the limited space available; country schools should, however, find no difficulty. Where possible Crab and Quince stocks should be obtained; three of each will be sufficient. Failing these, maiden trees, Apple and Pear, should be procured from a Nursery. When established, the art of grafting can be demonstrated. If land is available, bush trees such as Currants (black and red), Gooseberries, Raspberries, Pears, Apples and Plums should be obtained. It is obviously undesirable to cultivate standard trees on School Gardens, but when ground is unlimited half-standards could be utilised.

When beginning the growing of fruit it is a good plan to purchase one good tree of each type required, from a nursery. At the end of the second year, "cuttings" can be taken, and these will, by careful treatment, eventually increase and become useful trees. Although this is a somewhat lengthy process, the method suggested has its educational advantages. The pruning of the purchased stocks and the care essential for the training of "cuttings"

have a lasting effect on the scholars concerned. Even if space is limited, bush trees such as Currants, Gooseberries and Raspberries can be cultivated on either side of the main path. This course is advisable, for the majority of people are under the impression that for trees a large garden is required.

Preparing the Soil

Where a fruit plot is to be constructed it is essential that the soil should be well prepared. The plot should be Bastard Trenched and heavily manured with farm-yard manure during autumn. Early in spring

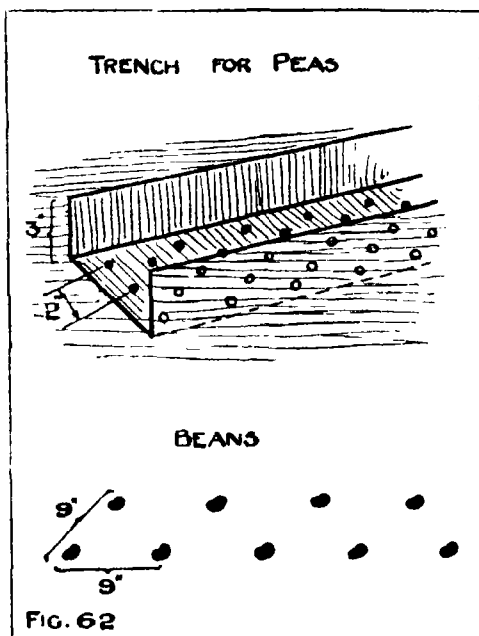
the trees should be obtained from a nursery and planted out as early as possible after delivery. A hole for each tree should be dug sufficiently large to take the roots. For bush Apples and Pears it is advisable to drive in stakes for support before planting the trees. The following are suggested varieties:

Apples, half-standard

Newton Wonder,
Lord Derby (culinary),
Beauty of Bath (dessert).

Apples, bush

Lane's Prince
Albert (culinary),



HOW TO SOW PEAS AND BEANS.

The above diagrams indicate satisfactory methods of sowing Peas and Beans. Light is able to reach all the plants.

	Worcester Pear- main, Cox's Orange Pippin (dessert).
Pears, bush	Jargonelle, Marie Louise and Hessle.
Black Currants ..	Boskoop Giant.
Red Currants ..	Houghton Castle.
Gooseberries ..	Whinham's Indus- try and Crown Bob.
Plums ..	Victoria, Shrop- shire Damson, Pond's Seedling.
Raspberries ..	Superlative or Lloyd George.

The number of each kind of fruit tree depends on the available space. If two rods can be utilised, two half-standard Apples, three bush Apples, three bush Pears, two Plums, three Gooseberries, two Black Currants, one Red Currant and three Raspberries will provide variety.

Along the sides of the main garden, Raspberries can be planted every 6 ft. The Loganberry should also receive attention. One good plant is sufficient; this is best at the end of the fruit plot and trained towards either side.

In country districts, instruction should be given in grafting and budding; both these processes aim at similar results—the union of two parts of plants, a short piece of shoot being united with a well-rooted plant or stock. Little was known of the art until fruit culture became fashionable in Tudor times. In 1572, Pippin, Pear and Cherry slips (scions) were brought from France and grafted on native stocks. In the classroom, grafting can

be carried out on Geraniums and in the garden with all trees of the same Natural Order. Although it is possible to graft Plums and Cherries, the results are not satisfactory. For stone fruits, budding is the better method. Both processes are carried out for similar reasons:

1. To increase the number of a particular variety. This point is of importance; it is impossible to raise varieties from seed; propagation by "cuttings" or layering is not satisfactory.

2. When a standard tree is required, a straight stock should be obtained and a drooping scion united with it.

3. Sometimes it is necessary to increase the rate of growth. This is done by grafting a quick-growing scion on a slow-growing stock. Whenever stock and scion are very different, an enlargement takes place at the place of union.

Success in the art of grafting or budding depends on the ability of the Instructor to recognise the position of the layer of actively dividing tissue—the cambium. It is the union of these meristematic cells which results in subsequent growth. The cambium lies immediately above the woody tissue, or between the wood and bark; hence it is important that the cambium of the stock and scion shall be in direct contact.

Methods of Grafting

There are two methods of grafting which can be taught in the School Garden: (a) Whip or Tongue; (b) Crown or Rind grafting. The former is the better method when the stock and scion are about the same size, the latter being used for the improvement of old trees. Generally grafting is carried out at the

end of March or early in April, when the sap is rising. The growth of the stock should be in advance of the scion. For this reason scions should be obtained in autumn and put in the soil, or moist sand, to prevent their drying up and to keep them in a dormant condition until March or April.

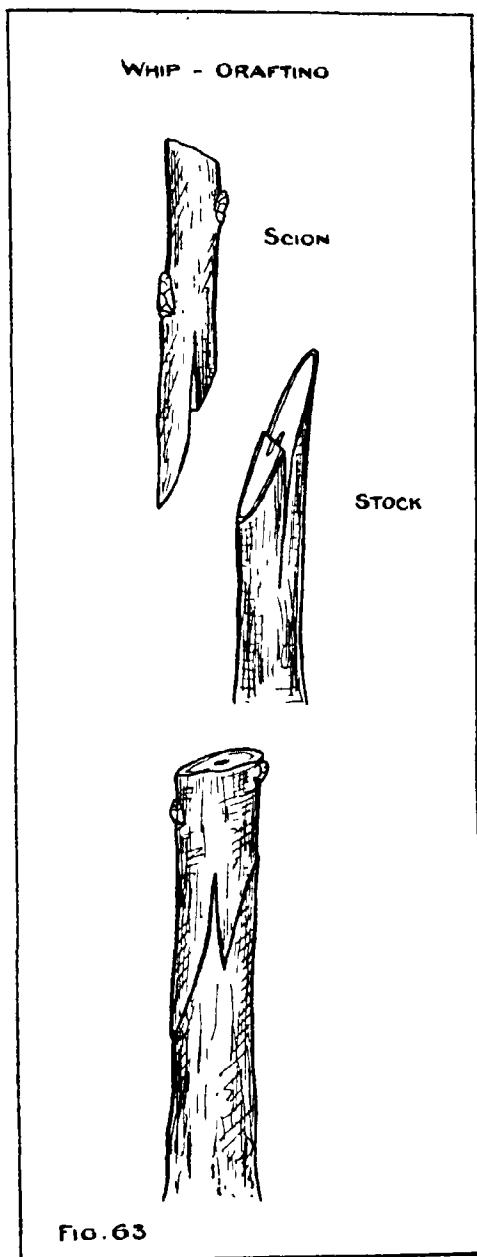
Whip Grafting (Fig. 63)

A long oblique cut should be made through the stem and a corresponding one through the scion as near the same slope as possible. A wedge-shaped portion should then be removed from the stock and as near as possible a similar portion removed from the scion. The "tongue" formed in the scion should fit into the wedge-shaped cut of the stock, care being taken to place the cambium of one side of the scion in close contact with that of the stock. The scion should then be securely tied to the stock by means of raffia or bast, clay or grafting wax being placed round the cut portion to exclude air. Two or four buds only should be left on the scion. Successful results can be obtained without the "tongue," but more skill is required in binding the graft with raffia.

Practice in this type of grafting can be carried out with twigs of the Willow; the stocks will grow quite well in water. The scions should be planted in soil a week before attempts are made. For indoor work it is not necessary to cover the union with clay; bind well with raffia, however.

Crown or Rind Grafting (Fig. 64)

For this type of grafting the upper part or head of the tree or stock is cut off completely at a point a little above where the scion is to be grafted.



WHIP GRAFTING.

After the scion has been placed in position on the stock, the union should be secured by means of raffia. A covering of grafting-wax or clay should then be applied.

This preparation of the stock must be done before growth begins, the best time being the early part of February. One or more scions are prepared with long sloping cuts and then inserted into longitudinal slits, 2 in. long, cut into the bark of the stock. The united parts should be bound firmly with raffia and then covered completely with clay or grafting wax to exclude air and rain.

With both types of grafting it is necessary to remove carefully the clay or wax and raffia as soon as the buds on the scions have grown 6 or 8 in. Often a supporting stake is advisable; this should be bound tightly to the stock in such a position that the scion can also be fastened to it.

Budding (Fig. 65)

The process of budding is more intricate than that of grafting. In this country the most common method employed is that known as "shield-budding," and is usually performed in July and August, when the bark can readily be separated from the cambium ring. Newly formed wood buds should be selected for insertion and taken from the middle part of shoots produced the same year. The bud to be used is taken from the shoot by removing a shield-shaped portion of the bark and wood as indicated (Fig. 65a). The wood must be carefully pulled from the bark and thrown away. This is the most difficult part to perform. If the rudimentary vascular cylinder of the bud comes away with the wood, leaving a hollow when viewed from the inside, the bud will not develop; the vascular cylinder, if intact, will stand out as a slight prominence from the bark.

In the stock a T-shaped incision

should be made (Fig. 65b). The sides should be carefully raised and the prepared bud inserted in the slit (Fig. 65c), the wound being carefully bound with raffia or bast, leaving only the bud exposed—the leaf in the axil of which the bud is growing being severed so as to leave about $\frac{1}{2}$ in. of petiole attached to the bark. Three weeks or a month later the binding should be removed, and during the autumn the upper part of the stock, above the insertion of the bud, should be cut away. In spring no growth but that from the bud should be allowed; dormant buds should be rubbed out as soon as they appear.

In budding operations the healing tissue, or callus, formed by the cambium of the transplanted bud, becomes united with that formed by the cambium of the stock, and as the cambial surfaces brought together are large, a good union is readily made.

Budding is the best method of propagating Roses, exactly the same process being carried out as that recommended for fruit trees.

Layering

The process of "layering" consists of bending and pegging down a shoot of a plant into the soil. From the bent portion in the soil, sooner or later, adventitious buds arise, after which the "layers" may be severed from the parent plant. In this manner the Apple Paradise Stock is obtained. In order to induce the formation of adventitious roots the shoots to be pegged down are often "ringed," the bark being cut completely through or "tongued"—a wedge-shaped piece being cut out of the underside. Carnations and Currants are readily propagated by layering.

Cuttings

The term "cutting" is applied to any part of a plant which may be used for propagation. The leaves of Gloxinias and Begonias, when cut through their mid-ribs and fastened down or even laid on damp sand, produce buds and roots, which develop into new plants. For School Garden work, however, shoots are selected for cuttings. Generally good results are obtained if the shoots are cut through just below a node, for, in most cases, adventitious roots only arise at the latter points. Woody cuttings such as Gooseberries and Currants 8 to 10 in. long should be obtained in Autumn after leaf-fall. The buds from about half the length of the shoot should be removed and this portion placed in the soil.

For Apples and Pears the cutting should include a "heel" or small piece of wood from the older branch on which the selected shoot grew. This method is generally successful; unheeled cuttings often fail to produce adventitious roots.

Cuttings of herbaceous plants must be placed in loose loamy soil to induce a rapid formation of roots. When a frame is available it is advisable to keep the air inside close and damp to prevent a too rapid loss of water during the time the shoots are without roots.

Flower Culture

No School Garden is complete without a flower border. Herbaceous perennials such as Phlox, Asters (Michaelmas Daisies) and Chrysanthemums might with advantage be used, and such biennials as the Wallflower, Sweet William and Canterbury Bell should also be cultivated. Where space is limited, annuals should be grown, a

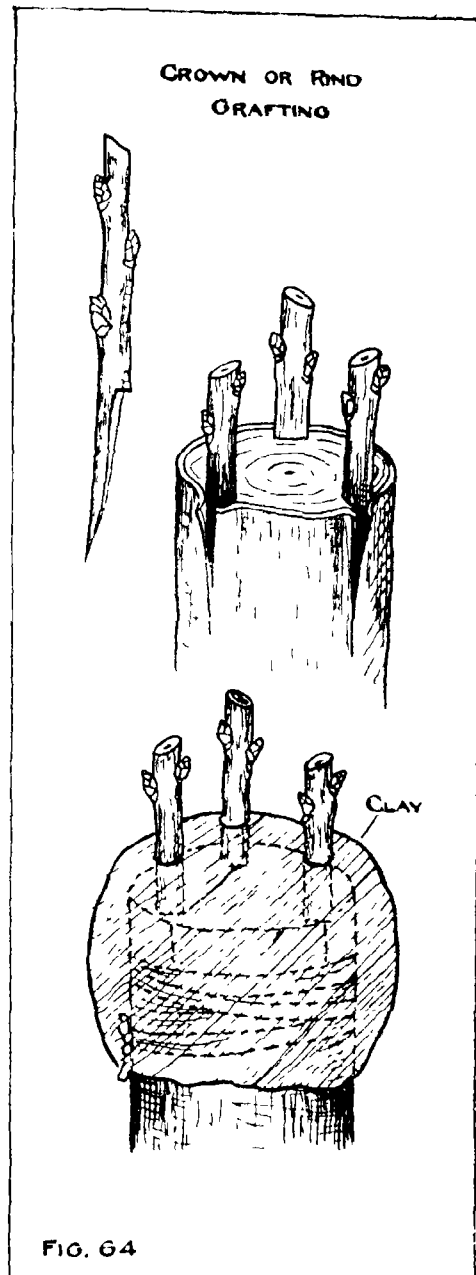


FIG. 64

CROWN OR RIND GRAFTING.

This is the best system of grafting for old trees. Any number of scions can be inserted in the crown. See that the cambiums are in contact.

suitable selection being Sunflowers, Sweet Peas, Nasturtiums, Shirley Pop-

pies, Linum, Lupins, Candytuft and Mignonette. Sweet Peas need deep cultivation and often grow best when sown in groups of 6 to 8, with 4 ft. between the groups, along the sides of the main path. When alternated with Sunflowers along paths, a pleasing effect is produced. The flowers grown should be labelled, names being given, together with the Natural Order.

Grasses

In country districts, one part of the School Garden should be devoted to the cultivation of agricultural grasses, a patch 1 ft. square being allowed for each variety. The manner in which such grasses are mixed to form temporary and permanent pastures, their rapidity of growth, durability and feeding properties might receive attention during the Winter season. Such types as the following will provide useful comparative work on the lines suggested: Italian Rye Grass, Cocksfoot, Timothy, Meadow Foxtail, Red Clover, Alsike Clover (tall-growing kinds), and Crested Dogstail, Perennial Rye Grass, Sheep's Fescue, Hard Fescue, Fiorin, White Clover, Bird's-foot Trefoil and Black Medick (shorter kinds).

Herbs

Most gardens can find space for the cultivation of the more common herbs. Thyme, Mint, Sage, Rue (useful for chickens), Lavender and Marjoram are suitable varieties for the majority of gardens. Many others such as Horehound, Sweet Basil, Balm, Coriander, Caraway, Rosemary and Wormwood are valuable to the farmer.

Pests and Diseases

Many of the insects troublesome to the gardener have been dealt with in

the chapter on Insect Life. The Cabbage Butterfly can be studied under natural conditions in the School Garden and the best method of preventing damage by the caterpillars discovered. Obviously the destruction of the eggs is the most humane method, and in the School Garden this should be done. Should small holes be discovered in the leaves, then a thorough search must be made for the caterpillars. Spraying with a solution of common salt, 2 oz. to a gallon of water, is often effective; it is necessary, however, to drench the plants thoroughly. Once the caterpillars have burrowed into the heart of the cabbage they are inaccessible, and hence the aim should be to destroy the larvæ at the earliest possible opportunity.

The eggs of the Cabbage Moth are laid singly and are often overlooked. The caterpillars are generally the same colour as the leaves, and hence careful observation is necessary to prevent the ravages of this pest.

The Carrot Fly

Most gardens and allotments are troubled with the larvæ of this pest, which bores into and feeds upon the roots of Carrots, Parsnips and sometimes Celery. The plants attacked turn brown in patches and finally become rotten. Carrots attacked by the larvæ can be easily recognised by their foliage. In the early stage the leaves turn red, finally become yellow and wither away.

The Carrot Fly is about $\frac{1}{2}$ in. in length and of a black or dark greenish-black colour. She appears in May or early June and lays her eggs in clusters near the top of the Carrot and just under the ground. On hatching out, the

larva wriggles through the soil to the tip of the root where it gains an entry. Gaining strength, it eats its way upwards, making frequent holes to the outside, and often the larvæ may be found protruding from such holes. When fully fed, the larvæ leave the plants and pupate in the soil. Carrots badly infected often show horizontal cracks, by which other pests such as Woodlice and Millipedes are able to cause further damage to the crops.

Much can be done to prevent attacks if precautions are taken. In the first place seeds should be sown very thinly; secondly, thin out as early as possible—as soon as the plants have their first foliage leaves—destroying at once the small plants removed. In the School Garden the soil can be consolidated by hand at the time of thinning, and this helps to prevent the visits of the Fly. After this operation is completed the bed should be sprayed with a Paraffin Emulsion. This is made as follows: Dissolve $\frac{1}{4}$ lb. soft soap in 1 quart of boiling soft water and while still hot add $\frac{1}{2}$ pint of paraffin. When required for use, mix $\frac{1}{2}$ pint of the emulsion with $\frac{1}{2}$ gallon of rain water, the spraying being repeated on three occasions at weekly intervals.

The above has been successfully carried out for several years. Rotation of crops together with careful sowing and thinning seem to be the main points in preventing attacks. It will be noticed that under the system of rotation suggested, Carrots and Parsnips are planted on the same ground every fifth year.

The Black Aphid

This troublesome pest calls for special consideration. Most parts of

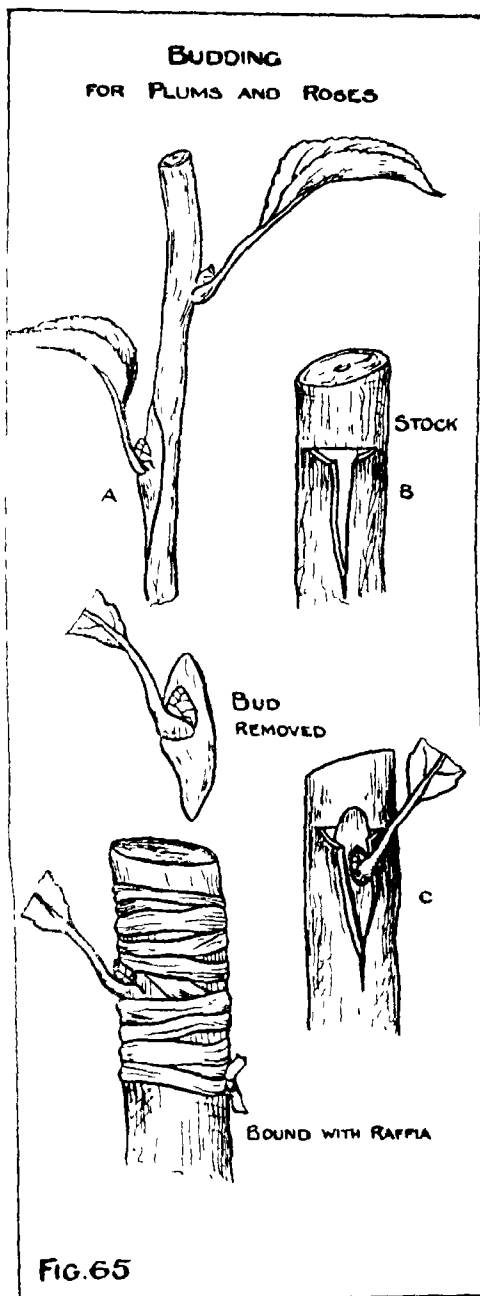


FIG. 65

BUDDING.

A certain amount of skill is necessary for this operation. The wood from the inside of the bud should be removed, care being taken not to destroy the vascular bundles

the country receive annual visits, and hence various names are used to describe it—e.g. Black Blight, Black Dolphin, Black Army, etc. Practically everyone recognises the Blight on Broad Beans. The congregation of individuals at the top gives the plant a dirty appearance and renders the infestation evident even to the most casual observer.

The life-history of the Black Aphid and the Green Fly found on Roses and fruit trees is very similar. In late autumn winged females and males are produced. These leave the plants and fly to certain trees, such as the Spindle tree. Wingless females are produced, and after being fertilised by the winged males lay eggs in the bark of the tree; these do not hatch out until spring. All the adult Aphides are killed off as winter approaches.

Early in Spring the eggs on the Spindle tree, and possibly other shrubs, hatch out into female Aphides, which develop the power of reproducing others. Winged types are produced which fly to other plants and reproduce in a similar manner, but giving rise to other winged and wingless types. The winged form is the type which spreads infestation, for a single Aphid is capable of giving rise to thousands of others.

In the School Garden it is often possible to prevent the spread of the pest. Broad Beans should be planted early and, as soon as flowers develop, the tops of the Beans should be pinched out and buried. Lateral shoots which develop low down on the stems should be removed. Spraying with a Paraffin Emulsion as recommended for the Carrot Fly is a good preventive, but

is of very little use when once the Aphides have been allowed to take possession. In using the Paraffin Emulsion on Beans or Rose Trees it is essential that no drops of paraffin float on the surface of the dilute wash, otherwise burning of the leaves will occur.

In dry weather Kidney and Runner Beans are often attacked. Spraying with a contact insecticide is necessary. The most effective is one made up of soft soap, nicotine and soft water. The following proportions will make a concentrated solution: $\frac{1}{4}$ oz. nicotine, $\frac{1}{4}$ lb. soft soap and 1 pint boiling water. Store the mixture in a tightly corked bottle in a place of safety—nicotine is poisonous and must be handled with the greatest possible care. When required for use, $\frac{1}{4}$ pint of the solution to 1 gallon of water will produce a suitable spray fluid.

Onion Fly

The remarks made on the planting of Carrots are equally applicable to the Onion. The greatest possible care is necessary when thinning out. It is generally after this process that the Onion Fly lays her eggs, and hence, if the thinning is carelessly done, the aroma of the bruised Onions becomes an attraction. After thinning, the bed should be sprayed with the Paraffin Soft Soap Emulsion.

Many other pests are met with in School Garden practice, such as Snails, Slugs, Mice and Rats.

For those teachers who are able to cultivate fruit a lesson on the Winter Moth will be given in a later section.

SECTION II

CHAPTER I

GENERAL SCIENCE IN THE ELEMENTARY SCHOOL

THE chief aim in science teaching in the elementary school should be to create a permanent interest in the subject. One can scarcely hope to inculcate scientific habits of thought, even if this is considered desirable. The child should be afforded an opportunity of reasoning about knowledge obtained ; he should be acquainted with a few scientific principles and their operation in the service of mankind ; he should also be able to distinguish the essential features of an experiment. But the energy of the teacher should be directed to the task of giving the child an interest which will survive, and therefore abstruse scientific reasoning, which is beyond the capacity of the pupil, should not be imposed on him. The primary school teacher should not hesitate to remove from his scheme that which, after reasonable experiment, is found to have no appeal to the child. Do not attempt to impose a matriculation syllabus on a child twelve years of age.

Apparatus

The vexed question of apparatus has now to be considered. There are some teachers who manage with practically no apparatus, but they must, at times, be severely handicapped. If science deserves a place in the curriculum, it should emerge from the slate-pencil stage. A few pounds can buy a

generous supply of the less costly apparatus. If there is nothing but home-made apparatus, the harassed science teacher may be unable to lay his hands on that small, elusive, but necessary part of the apparatus, which, if not forthcoming, may make his lesson a dismal failure. The science apparatus of a school may take several years to bring to completion, but, once obtained, will be a great boon to the teacher ; breakages can be made good from time to time and the stock replenished by small purchases. There is no need to buy expensive apparatus.

It is desirable to have the co-operation of the handwork instructor, who will be able to have many articles made, the prices of which would otherwise be prohibitive. Elaborate apparatus is unnecessary, in fact, with young children, the principle may be obscured if the apparatus is too refined. The manufacture of electrical apparatus provides excellent instruction in the handwork room.

Group Work

If possible the children should work in groups, but the tasks set should be simple. If questions are set relative to the experiment, they should be couched in simple language. It is excellent practice in English for chil-

dren to furnish written answers to questions in science. It must, of course, be remembered that science has developed for itself a characteristic mode of expression, so that such statements as the "action of dilute sulphuric acid on zinc" may not be intelligible. To teach a child to express himself in a way which is intelligible is often no easy task, and it will, as a rule, be found more difficult in science than in any other subject.

In science one must avoid attempting too much and must bear in mind the limitations of the child. As John Dewey says, "It is he (the child) and not the subject-matter, which determines both quality and quantity of learning."

Note-making

Young children must not be expected to make their own notes without assistance. The teacher, as a general rule, will make the notes on the board, along with a sketch, of course, and the children should copy this into their books, which should be of a suitable size. The notes should be in composition form and should be made with the assistance of the children; the sketch should be in pencil, and should not be too small. Notes should not be dictated. Older scholars will be able to make their own notes if the teacher has sufficient time to mark them, for the average teacher is forced to keep marking within reasonable bounds.

CHAPTER II

SIMPLE EXPERIMENTS IN GENERAL SCIENCE

PRIMARILY this work is intended for schools in large towns and cities where great difficulty is experienced in obtaining the necessary material for more advanced Nature Study, and hence the three upper standards, V, VI and VII, are provided with experiments in science which can be easily carried out. Nevertheless, Nature Study should be included whenever possible.

Volumes

1. Use the measuring jar to find the volume of an irregular piece of glass.

2. To find the volume of a marble, find the total volume of, say, a dozen, and then by division find the volume of one.

3. Find the volume of a hollow cylinder by means of the burette. Also repeat, finding the volume of any hollow prism. The surface of the liquid in a burette is known as the meniscus. Always read the lowest point of the meniscus, except when the liquid used is mercury. Use a funnel to pour the coloured water into the burette. Be careful to read the meniscus at your eye level (Fig. 1).

Enter results like this :

2nd reading : 47.2

1st reading : 10.1

$\therefore$ Volume of cylinder = 37.1 c.c.

Now check the result by calculation.
Volume of prism = area of base by height.

It is a good opportunity at this stage to realise what a cubic centimetre of water is. It is a very small quantity, and weighs 1 gramme. If possible obtain a small tin, hollow cube, each side of which, measured internally, is 1 cm. You have now 1 c.c. of water. Now use a pipette, made to hold 1 c.c., and by means of it measure 1 c.c. of water into a small beaker. Use a 25-c.c. pipette and by means of it put 25 c.c. of water into another beaker.

Now examine a small weight marked 1 gramme (or 1 grm. for short). Place it on a scale pan attached to a spring balance and observe the movement of the pointer. Use other weights on the scale pan and again notice the movement of the pointer. How accurately can you measure the weight of an object by means of the spring balance you are using? Obtain the weights of a variety of small objects—a pocket knife or a penny, for instance. To find the weight of a penny it may be a good plan to weigh six pennies, and by division find the weight of one.

If you have a suitable spring balance, weigh a beaker, add 25 c.c. of water by means of a pipette and find the weight of the water. What should you expect it to be?

Water and Filtration

Sometimes it is necessary, especially in the case of spring water, to filter it, and so separate from it the grains of sand. Filter some water on a small scale. Mix a small amount of sand in clean water. Obtain a filter paper and a filter funnel. Fold the filter paper up, make it into a small pocket and place it into the funnel (Fig. 2). Carefully pour the mixture into the

funnel and notice the clear water collecting in the beaker.

Obtain a solution of salt and water and repeat the experiment. Is the salt separated from the water? To separate the water we must distil the solution. Fig. 3 shows a convenient form of apparatus. Pure water will be collected in the test tube, where the steam is condensed by the cold water of the trough. Now pour the remaining solution from the flask in an evaporating dish and carefully evaporate to dryness. Do not overheat the dish during the last stages. A deposit of salt will be obtained in the evaporating dish.

Repeat the experiment, using sodium nitrate, alum or sugar instead of salt.

Water in small quantities is colourless, but in large quantities is of a bluish colour. It may also be regarded as tasteless, although distilled water is unpleasant to drink.

Artesian Wells

Let us consider the artesian well, which is a free-flowing well. To make possible an artesian well, it is necessary to have porous rocks containing water, overlaid by impervious rocks. If the impervious cover is pierced by borings, water will naturally rise to the surface (Fig. 4). Such a condition exists in the London Basin, where the London clay lies on porous rocks. As so many wells have been sunk, the water now only rises to within about 100 feet of the surface.

The Bunsen Flame

The bunsen burner can produce two flames, the luminous and the non-luminous. In order to get the non-luminous flames, open the holes at the

bottom of the burner and you will then be able to distinguish the different coloured cones (Fig. 5a). The cone A consists of completely burnt gas, the cone B of partly burnt gas and the cone C of unburnt gas.

To prove that cone C is unburnt gas, place in it a glass tube of the shape shown in the sketch (Fig. 5b). Put a light to the end of the tube and note the small flame. What does this prove? When the holes at the base of the burner are open, air is drawn in with a rush and the mixture of air and gas is ignited at the mouth of the tube.

The luminosity of the luminous flame is due to some extent at least to the particles of carbon which are separated, becoming incandescent. If particles of iron, i.e. iron filings, are dropped into the non-luminous flame, it becomes luminous to some extent. Heat an incandescent gas mantle with the non-luminous flame.

Examine the candle flame and try to distinguish two well-marked zones (Fig. 5c). Test the lower one for unburnt vapour.

Sulphur-mixtures and Compounds

Sulphur is very often found in the neighbourhood of volcanoes, as in Italy and Sicily, and many rocks contain sulphur, for example, iron pyrites and zinc blende.

Heat some sulphur in a test-tube and notice the changes. At 115°C . it melts and is yellow, but at 250°C . it is viscous and nearly black. Further heating makes it more mobile, till at 440°C . it boils. Before it boils pour it into a beaker of water, and you will have made plastic sulphur. You must notice, however, that it is still sulphur;

its physical appearance may have changed, but chemically it is still the same substance—sulphur.

Now mix some roll sulphur with iron filings. You have what is known as a mixture, and the iron filings can be separated from the sulphur by means of a magnet. You may separate the sulphur away by adding carbon bisulphide to the mixture. Place some of the mixture in an iron tray and heat for some time. Now try to separate the iron filings by means of a magnet. You cannot, for you now have, not a mixture, but a new compound, i.e. an entirely new substance, although this substance contains sulphur and iron chemically combined. This new substance is iron sulphide.

Take the compound red lead, which consists of lead and oxygen. You cannot withdraw the lead by ordinary means—by attempting to dissolve in water for instance. We can, however, obtain the lead from red lead.

Obtain a charcoal block and scrape a hole in it. Mix some red lead with ground sodium carbonate and put the mixture in the hole, scraping some particles of carbon over the mixture. Heat the mixture by means of a blowpipe flame, keeping the cheeks well inflated throughout the process. Do not allow breathing to disturb your blowing through the blowpipe (Fig. 6). Eventually you will observe small globules of lead appear in the hole. When cool draw the globules over a white paper and notice the dark line made. Use a pestle and mortar to grind the sodium carbonate.

The Volcano (Fig. 7)

It will be interesting at this stage to say a few words about volcanicity,

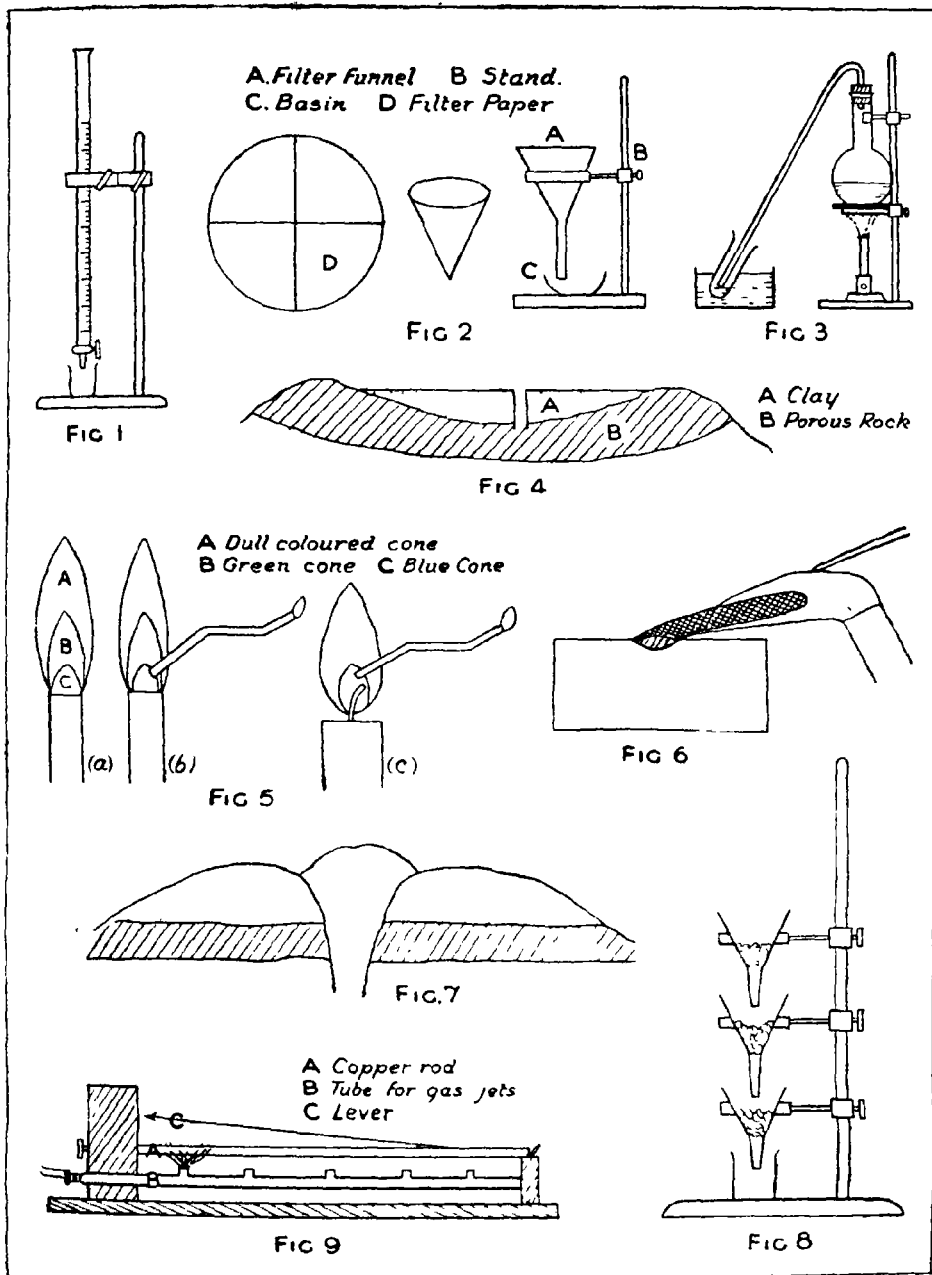


Fig. 1.—BURETTE AND STAND.

Fig. 2.—METHOD OF FOLDING FILTER PAPER. FUNNEL AND STAND.

Fig. 3.—DISTILLATION OF WATER.

Fig. 4.—ARTESIAN WELL.

Fig. 5.—ZONES IN GAS AND CANDLE FLAMES.

Fig. 6.—THE BLOWPIPE.

Fig. 7.—FORMATION OF VOLCANO.

Fig. 8 FILTERS IN SERIES.

Fig. 9.—APPARATUS FOR EXPANSION OF METAL ROD.

as sulphur, as has already been mentioned, is often found in the neighbourhood of volcanoes. When a volcanic eruption is about to take place there are usually, though not always, preliminary warnings. The atmosphere is very oppressive; an unwonted calm steals over the countryside, birds cease their melodies and animals become uneasy. For a few days ashes are flung into the air from the volcano, and then the great catastrophe comes. Following the ashes, dense volumes of steam rise in the sky and sometimes lava pours forth from the neck of the volcano down the mountainside. If the flow is rapid there

may be an enormous loss of life, besides destruction of property.

Everyone has read of the destruction of Pompeii by the eruption of Vesuvius in A.D. 79, and the destruction of the neighbouring town of Herculaneum by the sea of mud, in which it was buried. No lava was emitted on this occasion. There are, of course, eruptions which are not so destructive; Stromboli vomits forth steam and ashes about every hour, and it is a strange sight when seen from the sea—it is a natural lighthouse.

The Kimberley diamond field of South Africa occurs in an old volcanic neck or pipe.

CHAPTER III

TWO ELEMENTS

CARBON exists in the form of the diamond, graphite and charcoal.

The Diamond is crystalline and is generally colourless, although occasionally it is yellow, brown or blue. It is found in India, Brazil, Sumatra and Australia, but the largest stones come from Kimberley in South Africa, where the diamonds are found in old volcanic vents. The biggest diamond is the famous South African Cullinan Diamond, the largest dimension of which is over 3 inches. The diamond is practically pure carbon, and is the hardest substance known; when strongly heated in air it will burn.

Artificial diamonds were first prepared by Moissan, a French chemist, in 1893 by dissolving charcoal in molten iron heated in an electric

furnace and suddenly cooling the iron by plunging it into water or molten lead. The force of the interior expanding and the outer crust contracting turned the charcoal into diamond. On dissolving away the metal with acid, very small diamonds were found, together with some graphite.

Graphite may be regarded as semi-crystalline. It occurs in scales disseminated through other rocks, and it also occurs massive. It is soft, grey-black in colour and has a metallic lustre. It is found in quantity in Siberia, Ceylon, Bohemia, India and California and is also found in the British Isles in Borrowdale, near Keswick. At the present day graphite is manufactured on a large scale at the Acheson Works, Niagara, by

means of the electric furnace. It is used :

(a) In the manufacture of lead pencils, when it is ground into a fine powder, washed free from grit, mixed with fine washed clay, and forced through fine holes.

(b) As a lubricant.

(c) As a coating for iron to prevent rusting.

Amorphous Carbon

1. Wood charcoal is prepared by the destructive distillation of wood. The old wasteful way of making wood charcoal was to build the logs into a heap, cover with turf so as to leave a hole at the base and at the top, and then ignite the heap. Combustion took place very slowly.

Make a small supply of charcoal by heating a few splinters of wood in a test-tube.

Wood charcoal absorbs gases and is used to pack the ventilators of sewers. It is also used in the creation of a vacuum.

2. Animal charcoal is made by heating bones in a confined space. It has the power of absorbing the colouring matter from solutions. Warm litmus solution or brown-sugar solution with animal charcoal and observe how the colour disappears. Animal charcoal is used for decolorising sugar. Heat some brown-sugar solution or litmus solution and pass through a succession of filter funnels containing animal charcoal (Fig. 8). •

3. Gas carbon is a good conductor of electricity and is used for making carbon rods for the electric arc light.

4. Sugar charcoal, lamp-black, soot, and many other substances contain carbon. Coal may consist of 75 to

90 per cent. of carbon ; coke, 90 per cent. The chief constituent of petroleum is carbon, and by fractional distillation petroleum can be separated into heavy lubricating oils, light oils and spirits.

Phosphorus

Phosphorus is mainly obtained from bone ash. Yellow phosphorus is kept under water, as it smoulders in the atmosphere. Cut a piece of yellow phosphorus, about the size of a pea ; place it on a metal tray (a sand tray), touch it with a heated wire and note what occurs.

At 0° C. it is brittle.

At 15° C. it is soft and can be cut with a knife.

At 30° C. it melts.

At 34° C. it takes fire.

At 43° C. it melts under water.

Obtain a test-tube and pour some carbon bisulphide into it ; add a small piece of phosphorus. When the phosphorus has dissolved, pour the solution on to a filter paper and place the filter paper on a tripod. Note what occurs when the paper is dry.

Very finely divided phosphorus takes fire spontaneously.

Phosphorus is very poisonous, and it is exceedingly unhealthy to work in a match factory, as the fumes of the phosphorus attack the bones of the jaw and nose. It is phosphorescent in the dark.

There is another variety of phosphorus, known as red phosphorus, which is not poisonous, and is a powder. It is obtained by heating yellow phosphorus in a closed test-tube containing carbon dioxide ; only gentle heat is required.

Scarlet phosphorus is obtained by

boiling a solution of yellow phosphorus in phosphorus tribromide for some hours.

The Manufacture of Matches

Matches are supposed to have been first accidentally manufactured many years ago by a schoolmaster who taught chemistry to his boys. New discoveries are rarely purely accidental, however, and are, as a rule, the result of careful thought and experiment.

The use of yellow phosphorus in the manufacture of matches is forbidden

by law ; thus scarlet phosphorus, being non-poisonous, is used. Lucifer matches are sometimes made by dipping wooden splints into melted paraffin wax and then into a paste of scarlet phosphorus, potassium chlorate, glue and red lead. The potassium chlorate provides the oxygen for the ignition of the phosphorus. "Safety" matches are tipped with a mixture of antimony sulphide and potassium chlorate, and the match is ignited by rubbing on a surface of scarlet phosphorus, red lead and powdered glass.

CHAPTER IV

HEAT

Effect of Heat

FIT up some adaptation of the apparatus (Fig. 9), heat the copper rod and note the movement of the lever, which can be arranged to magnify the expansion. Most substances expand on heating, though there are exceptions.

Obtain a ball and ring, so that the ball just passes through the ring. Now heat the ball and you will find it no longer passes through the ring. Allow the heated ball to rest on the ring, and after a time it will fall through; the ring has now expanded, having been heated by the ball.

In industry, expansion has to be taken into account in :

- (1) Fixing the iron tyres on cart or truck wheels.
- (2) In the manufacture of big guns.
- (3) In fixing rivets.
- (4) In the construction of a railway.

(5) In the erection of bridges and steel towers.

(6) In casting.

It should be noted that ice floats in water, so that volume for volume ice is lighter than water. If ice is heated it contracts, contrary to the usual law. This accounts for many leaking pipes after a severe spell of winter. Water reaches its maximum density at 4°C. , i.e. volume for volume water weighs heavier at 4°C. than at any other temperature.

The Water Thermometer and the Air Thermometer

Water Thermometer (Fig. 10a).—Place this in warm water and notice the rise up the tube.

Air Thermometer (Fig. 10b).—Warm the flask by means of the hands and note the movement of the blob of ink in the bent portion of the tube.



Figure 10. Science Room equipment.

GROUP WORK IN SCIENCE

The photograph shows part of a classroom arranged for group work in science, as suggested in the text. It will be seen that one group is engaged in the study of electricity, another on the composition of matter, and a third group on the magnetic field.

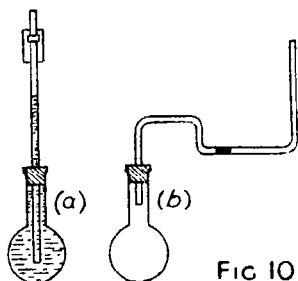


FIG 10

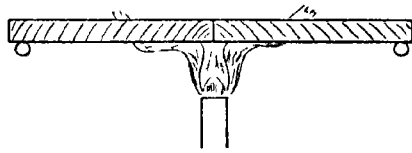


FIG. 11

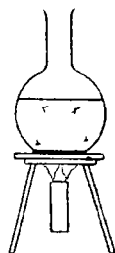


FIG 13

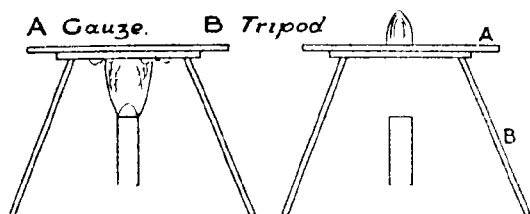


FIG 12

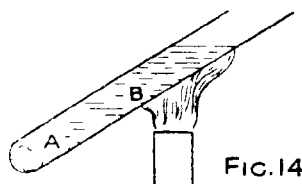


FIG. 14

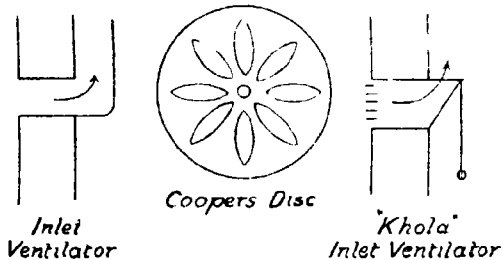


FIG. 15

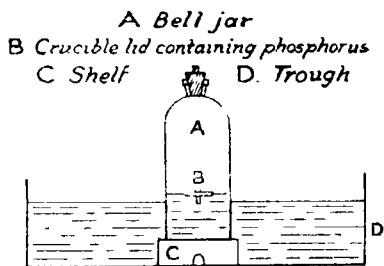


FIG. 16

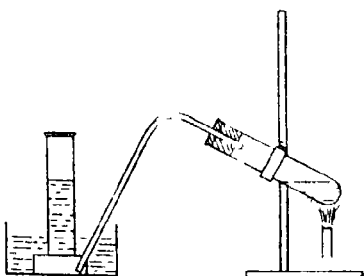


FIG. 17

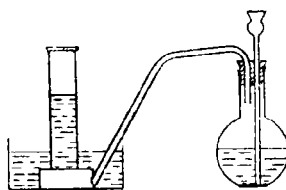


FIG. 18

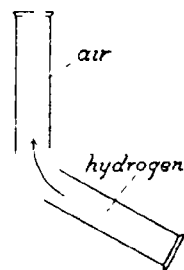


FIG. 19

Fig. 10.—SIMPLE THERMOMETERS.

Fig. 11.—CONDUCTION OF METALS.

Fig. 12.—CONDUCTION OF WIRE GAUZE.

Fig. 13.—CONVECTION IN A LIQUID.

Fig. 14.—WATER, A BAD CONDUCTOR OF HEAT
—(A) ICE, (B) WATER.

Fig. 15.—VENTILATORS.

Fig. 16.—OXYGEN IN THE AIR.

Fig. 17.—PREPARATION OF OXYGEN.

Fig. 18.—PREPARATION OF HYDROGEN.

Fig. 19.—HYDROGEN DISPLACING AIR.

These thermometers, while they show that water and air expand when heated, are of very little practical utility because they are not sensitive enough. A thermometer must indicate the slightest change in temperature. The thermometer we are about to describe contains neither air nor water, but mercury. Mercury is used because :

1. It does not freeze under ordinary conditions.
2. It does not boil under ordinary conditions.
3. It does not wet the tube.
4. It is very sensitive to changes of temperature.

Examine mercury in a dish.

Sometimes alcohol is used in the manufacture of the household thermometer.

The Construction of a Thermometer

Obtain a thermometer tube consisting of a tube of narrow bore with a bulb at one end and a funnel at the other. Such a tube can be obtained from firms supplying chemical and physical apparatus. Pour mercury into the funnel and gently heat the tube. By alternate heating and cooling the tube, and finally by boiling the mercury in the bulb, fill the tube with mercury. Place the bulb in steam or boiling water and seal the tube below the funnel.

To graduate according to the centigrade system, place the bulb in ice shavings and scratch a mark on the glass to indicate the level of the mercury at freezing-point. Now place the thermometer in steam (not boiling water) and make a second mark. This point is the boiling-point. Complete the graduation by the most suitable method for your purpose.

The boiling-point of the centigrade thermometer is 100°C . and the freezing point is 0°C . We may have temperature below freezing-point, for example— 5°C . Now a thermometer used in England for ordinary household purposes is known as the Fahrenheit thermometer and the boiling-point on this is 212° , while the freezing-point is 32° . The number of Fahrenheit degrees between freezing-point and boiling-point is, therefore, 180. Thus we see that 100 divisions on the centigrade scale correspond to 180 on the Fahrenheit scale. Supposing you desire to know what a reading of 60°C . would mean on the Fahrenheit scale.

100°C . mark corresponds to 180°F . plus 32°

$\therefore 1^{\circ}\text{C}$. mark corresponds to $\frac{180^{\circ}}{100}\text{F}$. plus 32°

$\therefore 60^{\circ}\text{C}$. mark corresponds to $\frac{180^{\circ}}{100} \times 60^{\circ}\text{ plus } 32^{\circ}$
 $= 108^{\circ}\text{ plus } 32^{\circ} = 140^{\circ}\text{F}$.

Notice that you must make allowance for the Fahrenheit scale starting at 32° for freezing-point. Now try to convert 60°F . to the centigrade reading.

What is a thermometer used for? It is used to measure the temperature of a body, i.e. to measure the degree of hotness of a body. A thermometer is not used to measure the amount of heat. Take two beakers, one double the size of the other, fill with water and boil. The readings will be the same, but the amount of heat in the larger beaker is obviously more than in the smaller beaker. In this book we shall not discuss the method of finding how much heat there is in a body, but confine ourselves to measuring how hot

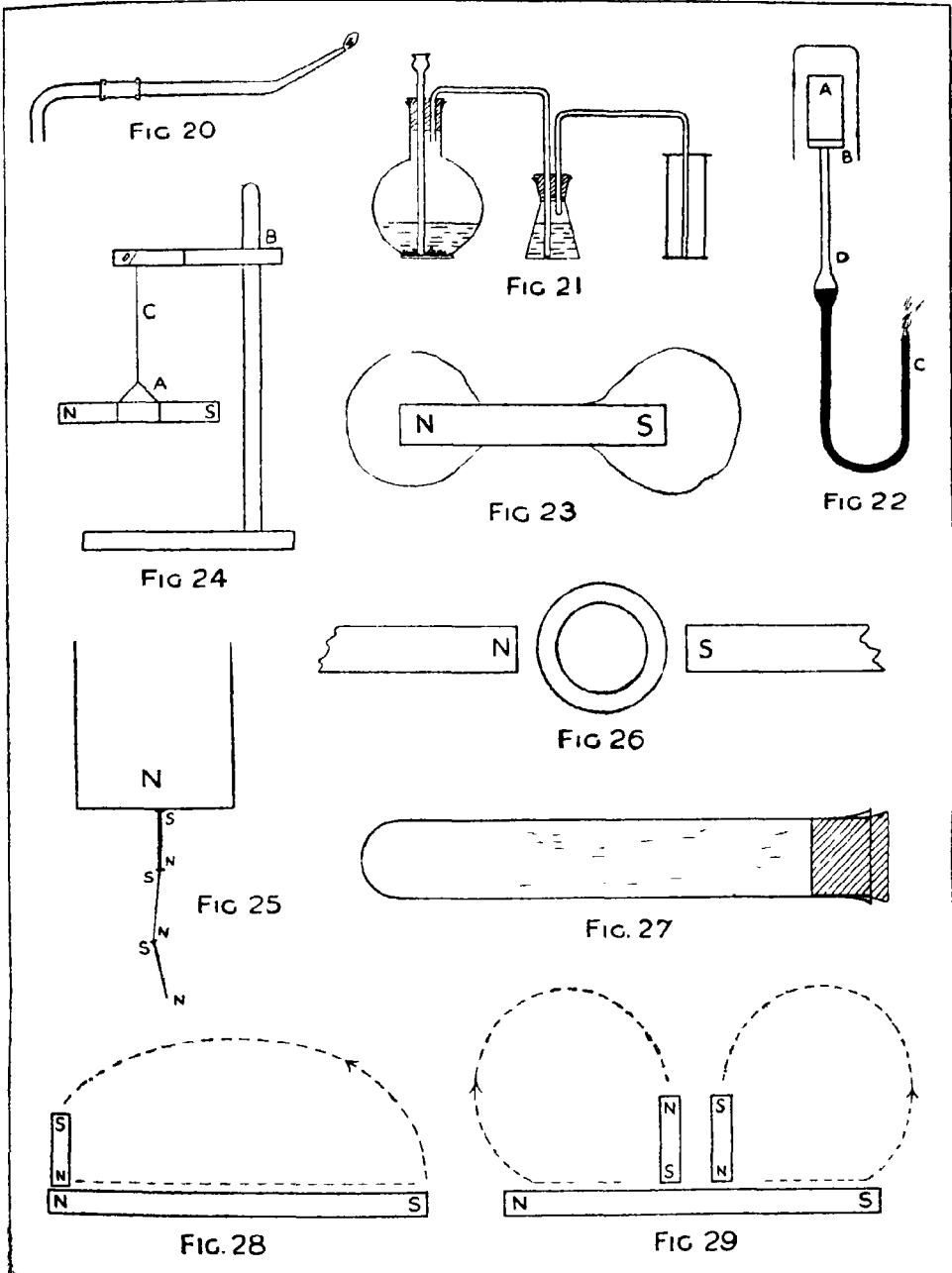


Fig. 20.—JET FOR BURNING HYDROGEN.

Fig. 21.—THE PREPARATION OF CARBON DIOXIDE.

Fig. 22.—DIFFUSION TUBE.

Fig. 23.—FIELD OF FORCE OF BAR MAGNET.

Fig. 24.—BAR MAGNET IN STIRRUP.

Fig. 25.—INDUCED MAGNETISM.

Fig. 26.—THE FIELD OF FORCE.

Fig. 27.—ARRANGEMENT IN TUBE OF MAGNETISED IRON FILINGS.

Fig. 28.—MAGNETISATION BY SINGLE TOUCH.

Fig. 29.—MAGNETISATION BY DOUBLE TOUCH.

a body is. Boil some water in a beaker and then allow to cool; take the temperature every half minute for about ten readings and then every minute. This will take you about half an hour. Now plot a graph, temperatures against time, and draw conclusions from it.

The Melting-point of Wax

Melt some wax and allow some to adhere to the bulb of the thermometer. Place in water and heat the water. Note the degree when the wax melts, and then allow to cool and take the reading when the wax just solidifies again. Take the average of the two, and this will give a rough approximation to the melting-point of wax.

Transference of Heat

Heat may be transferred by conduction, convection and by radiation.

In conduction the actual body does not move as a whole, although the molecules are generally recognised to be in a state of motion. If a poker is placed in a fire the heat travels along the poker and can be felt by the hand holding it. The heat felt through the poker may be much more intense than the heat felt directly from the fire. As the molecules of the poker become heated, they are supposed to bombard each other. Which is the better conductor, copper or steel?

Obtain a bar, one half made of copper, the other half of steel. Fix, by means of wax, a marble at each end, heat in the middle and observe which marble falls first (Fig. 11). You may try this experiment, using several bars of different metals, all heated equally

by the same burner. Use blobs of wax to indicate how quickly the heat travels. Why can a bunsen flame burn above a wire gauze while not being able to burn below it?

Place a gauze on a tripod and a bunsen burner underneath the tripod. Ignite the gas above the gauze without igniting that below it; or again, ignite the gas below the gauze without igniting that above it. Why is this possible? (Fig. 12.) The gauze conducts the heat away so rapidly that the heat is insufficient to cause ignition below or above the gauze as the case may be.

The Davy Lamp.—This is the principle underlying the construction of the Davy lamp. The small oil lamp is surrounded by a gauze the temperature of which is not high enough to cause any gas outside to ignite. The Davy lamp is also an indicator of the condition of the air down a mine. A small blue cone surrounding the flame indicates that dangerous gases are present, and thus the miner is warned.

Convection.—In this process the body itself actually moves. Obtain a flask three-parts filled with water; drop in a small piece of magenta dye (or potassium permanganate), and gradually heat (Fig. 13). Note the convection currents produced. Why does the warm water rise?

It may here be remarked that water is a bad conductor of heat, for water can be boiled at the top of a test-tube while there is ice at the bottom (Fig. 14).

Hot Water Heating Apparatus.—This depends on the convection currents produced in the water. Examine the school heating apparatus.

Convection Currents in the Atmosphere.—Open the door slightly and, by holding a candle flame to the aperture, find the direction of the currents entering and leaving the room. The chimney has a great deal to do with the convection currents. If we had no chimneys in a room, we should have to have efficient ventilators. Electric fires do not need a chimney, but in its absence another form of ventilation must be adopted. There are many kinds of ventilators to assist in the production of convection currents. Still air is an enemy of health, so that the air in a room should be kept in a state of motion, without draughts, of course ; this is sometimes accomplished by means of electric fans. However it be done, it is a necessity.

Sometimes you will see a ventilator in the ceiling of a room, or, if you are in the street, you will observe a tower-like structure above a building ; this may be a ventilator (Fig. 15).

Radiation.—Heat can also be transferred from one body to another by radiation. There is no atmosphere for the greater part of the distance between the earth and the sun, yet heat reaches the earth from the sun. How does it

travel? Not by conduction or convection, as these methods require a definite medium for their heat conveying, but by what is termed radiation. Radiant heat is very similar to light, e.g. it can be reflected and refracted.

All hot bodies lose some of their heat by radiation, if they are placed in cooler surroundings. The rate at which such a body loses heat depends on :

1. The nature of the surface of the body.

2. The difference between the temperatures of the body and its surroundings. The bigger the difference the more quickly is heat lost.

Use a hollow metal cube, of which two faces are blackened by a candle flame and two polished bright with metal polish, to show how much more quickly the blackened faces lose their heat than the bright ones. In this experiment, fix thermometers with their bulbs at equal distances from the black and the bright faces of the cube and note the different readings. Now we can see why so-called “radiators” are painted black. Find other examples of bodies polished or painted black for a particular reason.

CHAPTER V

GASES

Vitiation of the Atmosphere

THE atmosphere may contain certain things injurious to health.

1. *Dust*.—This, especially in large cities, may assist in the carrying of bacteria. It is essential for health that there should be as little dust in the atmosphere as possible. Our streets should be well cleaned and even washed. Many appliances (vacuum sweepers) to collect the dust in the house have recently been placed on the market.

2. *Gases*.—In the neighbourhood of factories there is liable to be obnoxious gas. During the war many factories produced poisonous gas and, as a rule, all foliage and grass near the factories perished.

3. *Smells*.—Harmful smells are often met with in badly ventilated and overcrowded buses. We can often trace a cold back to the time when we travelled inside a bus.

4. *Dark Streets and Slums may contain the Virus of Disease*.—Sunlight is an enemy of disease, so open your windows and let the rays of the sun come directly into your house.

5. *Smoke is Inimical to Health*.—It has a great deal to do with the prevalence of fogs in our great cities, hence the agitation to abolish the open fire grate. If you have the opportunity, stand on an eminence outside a city and notice the pall of smoke that hangs over it.

Having considered what we may call the hygiene of the atmosphere, we

shall now consider it from the point of view of the chemist.

How much of the Atmosphere consists of Oxygen or Active Air?

Obtain a crucible lid and attach a piece of cork to it so that the small handle of the lid fits into the cork. Put a piece of phosphorus into the lid and float on the surface of the water contained in a trough. Obtain a bell-jar with greased stopper. Remove the stopper and place the bell-jar over the crucible lid as shown in Fig. 16. Slightly heat a wire (the rod of a deflagrating spoon will serve) and touch the phosphorus. When the phosphorus is burning vigorously, place the stopper in the bell-jar.

The water gradually rises in the jar. When it has ceased to rise, notice how far it has gone up the bell-jar. Test the remaining portion of air in the bell-jar with a lighted splint and notice what occurs. If the original level of the water in the bell-jar is marked by means of a strip of gummed paper, and the final level is also marked, it will be possible to find, by means of a measuring jar, how much of the air has been used up. What has happened to this air?

This portion of the atmosphere has joined with the phosphorus to form an oxide of phosphorus, fumes of which can be seen during the experiment. Because it is active, and joins with the phosphorus to form a new substance,

it is known as active air. Its usual name is oxygen. The remaining portion of the air in the jar, which would not support burning, is sometimes known as inactive air, though it is usually termed nitrogen.

The atmosphere consists of approximately one part of oxygen to four parts of nitrogen. There are also small quantities of other gases present, such as carbon dioxide, ozone, etc.

Oxygen is a very useful gas in industry, and doctors also occasionally make use of it. We could not exist in the absence of oxygen, and divers need it when they explore the sea bottom; mountaineers need it when they attempt to climb such a mountain as Everest; and the aeroplane pilot needs it when he passes beyond the clouds to very high altitudes.

Prepare oxygen on a small scale.

1. Heat a mixture of manganese dioxide and potassium chlorate in a test-tube and test the gas with a glowing splint.

2. Gently heat a test-tube containing lead peroxide (brown in colour) and concentrated sulphuric acid. Test the gas with a glowing splint.

Nitrogen is used in the manufacture of fertiliser for the use of the farmer. Most plants derive nitrogen from the soil, and hence the need of a fertiliser containing nitrogen. Peas and beans, however, have the power of absorbing nitrogen from the atmosphere, but they are practically the only plants which can do so directly.

The Preparation and Properties of Oxygen

Crush some potassium chlorate in a mortar and add a small quantity of

manganese dioxide. Put the mixture in a hard glass tube. Arrange the apparatus as shown in the sketch (Fig. 17). Heat the mixture, gradually at first: the gas given off will pass down the delivery tube into the gas jar. When the gas jar is full of gas, close the mouth by means of a greased plate and remove the jar from the trough. The gas collected in the jar is known as oxygen, or active air. Collect several jars of the gas and investigate its properties.

Properties of Oxygen

1. Plunge a glowing splint into a jar of the gas and notice what occurs. Repeat this several times.

2. Put some sulphur in a deflagrating spoon, ignite it by means of the bunsen flame, and plunge in a jar of the gas. What occurs?

3. Cut a small piece of phosphorus and place in a deflagrating spoon. Touch it by means of a heated wire and plunge in a jar of the gas.

4. Obtain a piece of wood charcoal and heat it until it glows. Plunge as before in a jar of the gas. Use a deflagrating spoon. Pour lime water in the jar, shake up and note result.

5. Burn a piece of magnesium in air and then in oxygen.

6. Obtain a small piece of iron wire and attach to a deflagrating spoon. Cause some sulphur to adhere to the wire and then ignite the sulphur, and after a few seconds plunge the spoon into a jar of oxygen.

The Preparation and Properties of Hydrogen

Hydrogen is prepared by the action of dilute sulphuric acid on granulated

zinc. Dilute hydrochloric acid may be used instead of dilute sulphuric acid.

Carefully put some zinc into the flask and set up the apparatus as shown (Fig. 18). Pour some acid down the thistle funnel, and after waiting about two minutes collect the gas. If possible use small gas jars; on no account use a cracked jar or bring a flame near the apparatus. The reasons for these precautions will be obvious.

Obtain several gas jars of the gas and place in the order in which they are prepared. Finally collect a jar half full of the gas, allow the water to fall from the gas jar and quickly cover the mouth with a greased plate.

Jar 1. Apply a lighted splint and see what occurs.

Jar 2. Repeat.

Jar 3. Repeat.

Jar 4. Half is air, repeat.

Jar 5. Pour the gas upwards and then test the jar for hydrogen. What do you conclude from this experiment? (Fig. 19.)

Add more acid to the zinc until the gas is coming off very vigorously. Remove the delivery tube quickly and replace by a tube drawn to a fine bore as in sketch (Fig. 20).

Wait a few seconds and then apply a light to the end of the tube. Note the colour of the flame. Why is it necessary to wait?

Hydrogen is a very light gas and is used in balloons and airships, though it may, in the near future, be totally replaced. It is extremely inflammable, and so is highly dangerous, especially when used for military purposes in time of war. The gas is used in industry.

The Preparation and Properties of Carbon Dioxide

Fit up the apparatus as shown in sketch (Fig. 21) and collect the gas by the displacement of air. Cover the marble with water before adding the acid.

Properties

1. Add lime-water to a jar of the gas. Also obtain a test-tube containing lime-water and breathe down a glass tube into the lime-water; note what happens.

2. Drop a soap bubble into an inverted bell-jar containing carbon dioxide. The bubble will float on the surface of the carbon dioxide. What does this show? Note that the carbon dioxide can be prepared in the bell-jar by adding dilute hydrochloric acid to powdered "whiting."

3. Plunge a lighted splint into a jar of the gas.

4. Burn magnesium in the gas. Black specks of carbon will be seen on the jar and magnesium oxide will remain.

5. Pass carbon dioxide through water containing litmus solution. The solution changes colour. Boil and note what occurs.

Carbon dioxide weighs, bulk for bulk, about one and half times as heavy as air. It is not poisonous, but it will not support life—consequently people suffocate in an atmosphere of CO_2 . Formerly it was supposed that the ill effects of bad ventilation were due to the CO_2 in the atmosphere. Normally, there is up to .04 per cent. of CO_2 in the air. Excessive crowding never gives more than .7 per cent., and people exposed to twice that amount show

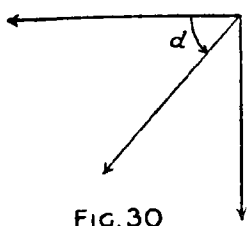


FIG. 30

- A Zinc rod
B. Solution of potassium bi-
chromate & sulphuric acid
C. Carbon rods joined by
copper wire

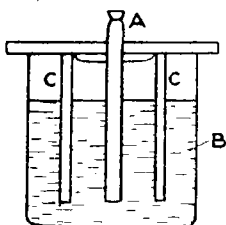


FIG. 33

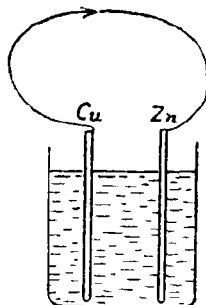


FIG. 31

- A. Copper pot containing copper sulphate
B. Shelf for crystals of copper sulphate
C Porous pot of dilute sulphuric acid
D Zinc rod

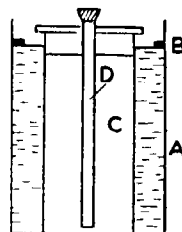


FIG. 32

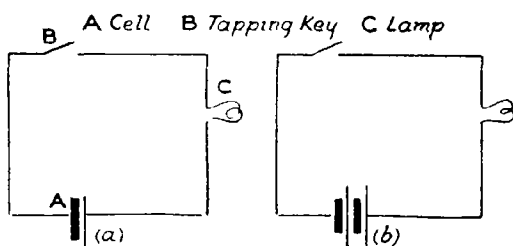


FIG. 34

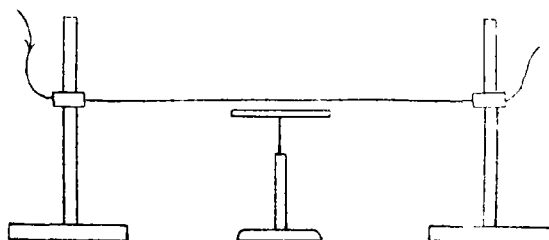


FIG. 35

- A Circular coil of wire
B Terminals of coil
C Magnetised needle

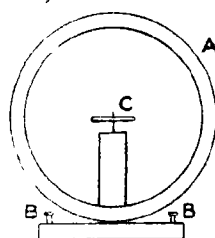


FIG. 36

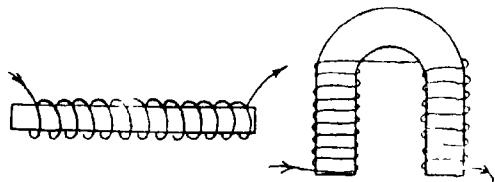


FIG. 37

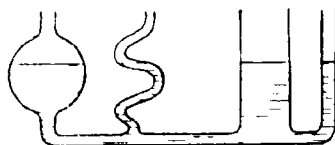


FIG. 38

Fig. 30.—ANGLE OF DIP.

Fig. 31.—SIMPLE CELL.

Fig. 32.—DANIELL CELL.

Fig. 33.—BICHROMATE CELL.

Fig. 34.—EFFECTS OF AN ELECTRIC CURRENT.

Fig. 35.—MAGNETIC EFFECTS OF A CURRENT.

Fig. 36.—GALVANOMETER.

Fig. 37.—ELECTRO MAGNETS.

Fig. 38.—WATER SEEKS ITS OWN LEVEL.

no ill effects if the air be kept in motion, and temperature and moisture are not too high. Thus the old methods of testing the air of a room by measuring the amount of CO_2 present have been given up.

At Naples there is the famous Grotto del Cane, and a dog entering this cave is suffocated by the layer of carbon dioxide on the floor. A man, however, is not affected, as his head is above the carbon dioxide.

When carbon dioxide dissolves in water, carbonic acid is produced. The gas is used in the manufacture of mineral waters and also as a fire extinguisher. It is stored in steel cylinders.

The Diffusion of Hydrogen through a Porous Pot

Examine a porous pot. You will observe that it is unglazed, and if you fill a porous pot with water and allow it to stand for a time, the outside of the pot becomes damp. Fit up the apparatus as shown in the sketch (Fig. 22), where D is a long tube about a metre in length from the top to the bend. In the bend is a quantity of coloured water.

Obtain a bell-jar of hydrogen and

carefully place it over the porous pot, and at the same time notice the movement of the coloured water. There will be a rapid diffusion of gas from the bell-jar to the porous pot and from the porous pot to the bell-jar. Which is the more rapid?

Repeat with coal gas in the bell-jar and also with carbon dioxide if time permits. You will find that a slightly different arrangement will have to be used if the experiment is performed with carbon dioxide, owing to the heaviness of that gas. The tube will have to be bent so that the bell-jar is upright.

You will find that the rapidity of diffusion depends on the heaviness of the gas. The smaller the density of a gas, the more rapidly it diffuses.

Now, a similar thing to this takes place in Nature. A device has also been used in the mines—depending on the diffusion of dangerous gases through a porous pot—to detect the presence of harmful gases, and the miners are warned by a bell, which is operated by an electrical device.

Note.—Air weighs, bulk for bulk, fourteen and a half times, and carbon dioxide twenty-two times, as heavy as hydrogen.

CHAPTER VI

DOES MAGNESIUM GAIN OR LOSE IN WEIGHT WHEN IT IS HEATED IN A CONFINED SPACE?

BEFORE we can attempt to solve this problem we shall have to make ourselves familiar with the chemical balance. If we obtain a lever and support it at its middle point, and also place two scale pans, one at each end, we shall have a very simple balance. Now examine a laboratory chemical balance and note the refinements—the carefully balanced lever, the knife edges, the plumb line and index.

Examine a box of weights; make a sketch of the brass weights and then of the smaller weights—a series of circles containing a number will do, i.e. the number of grammes. You will observe that you can weigh accurately any object within certain limits. Make up from your weights any number taken at random, e.g. 45.73 grm., 69.5 grm.

In weighing it is usual to observe the following rules:

1. Put object to be weighed in left scale pan and weights in right pan.
2. Raise and lower by means of left hand.
3. Remove weights with tweezers, using the right hand only.
4. Lower the central rod before putting on or removing weights.
5. Carefully replace all weights after using them.

The Problem

Clean a piece of magnesium ribbon about a foot in length. Coil it up,

and place in a crucible, then weigh the crucible, lid and magnesium.

Now place on a pipeclay triangle and heat. The crucible lid should not completely cover the crucible at first, but no fumes should be lost. After heating for some time the lid should be placed over the crucible and then the crucible may be further heated for a few minutes.

Allow to cool, and note if there is a gain or loss in weight. You should try to account for this difference in weight and realise that it was impossible to detect any difference before the introduction of the sensitive balance.

What substance is contained in the crucible? Burn some magnesium ribbon in air and note the greyish substance which remains. What is it?

The Spring Balance

Drive a nail into a drawing-board and from this support a steel spring so that the coils of the spring do not actually touch the board. Attach drawing-paper to the board so that the movement of any point of the spring can be indicated (by means of a pencil) on the paper. Fasten suitable weights to the spring and note the stretch for each weight used. Does your result verify the law of the spring balance, viz. "Stretch is proportional to load?"

Remove the equal weights one by one and observe if the spring regains its original stretch. Enter your results in tabular form. If the spring is stretched beyond a certain limit it will not regain its original length on removal of the load. It has stretched beyond its "elastic limit."

CHAPTER VII

MAGNETISM

LODESTONE is the natural magnet. It is a kind of iron ore and was supposed to have been accidentally discovered by a shepherd of Asia Minor named Magnes, whose crook accidentally came in contact with a quantity of lodestone and was attracted by it.

Dip a piece of lodestone into some iron filings and notice how they adhere.

Artificial magnets are usually made by means of an electro magnet which will be described later.

Dip a magnet bodily into iron filings and notice how the filings adhere to it.

Two points near each end (Fig. 23) where the power of attraction seems to be the greatest are known as the poles of the magnet, and because they behave in many respects in a different way from each other are termed N. and S. poles, i.e. north and south.

Obtain a stirrup and let it hang from a burette stand by means of untwisted silk (Fig. 24). Place a magnet in the stirrup and allow to swing freely. It will finally come to rest pointing in a north-south direction.

The Laws of Magnetism

Suspend a magnetic needle and bring the N. pole of a magnet to the N. pole of the needle. Now bring

the S. pole of a magnet near the N. pole of the needle. Completely verify the statement, "Like poles repel, unlike poles attract."

Induced Magnets

Note how a number of steel pins can be made to adhere to a magnet as in sketch (Fig. 25). The steel pins for the time being are induced magnets, and may even retain some of their magnetism on removal from the large magnet.

The Field of Force

A magnet is supposed to be surrounded by what is known as a field of force, and we can get an idea of the direction of the force by a simple experiment. Place a magnet on a table so that it points north-south, and cover with a sheet of drawing-paper. Shower a few iron filings over the paper and gently tap the paper. The filings will arrange themselves in particular directions. Make a sketch of what you see.

Repeat by using waxed paper. When the filings have arranged themselves, heat the waxed paper by means of a bunsen flame and so retain a permanent record of the lines of force.

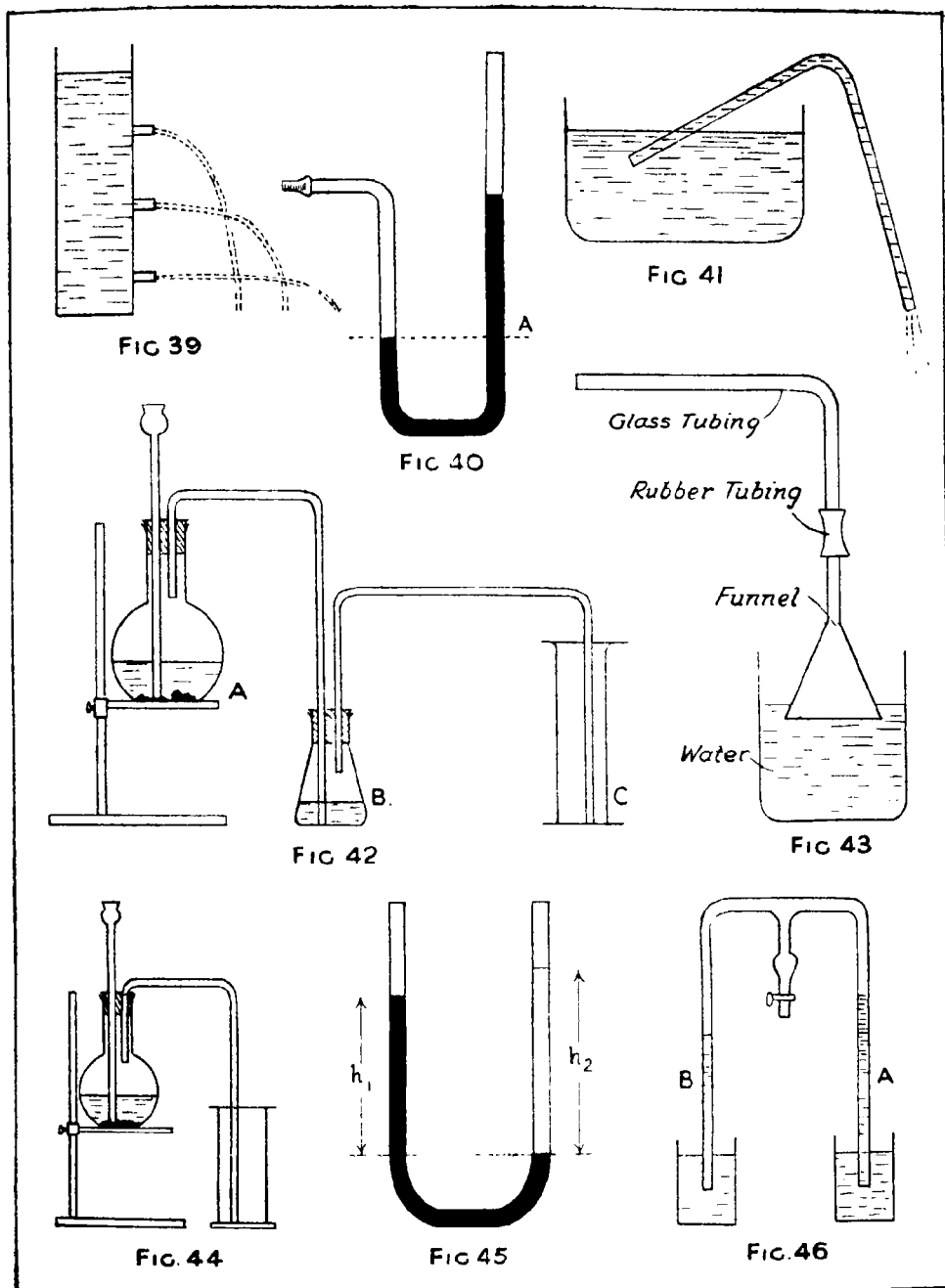


Fig. 39.—PRESSURE IS PROPORTIONAL TO DEPTH.

Fig. 40.—MANOMETER.

Fig. 41.—SYPHON.

Fig. 42.—PROPERTIES OF CHLORINE.

Fig. 43.—METHOD OF DISSOLVING GAS IN WATER.

Fig. 44.—PREPARATION OF SULPHUR DIOXIDE.

Fig. 45.—DENSITIES OF LIQUIDS WHICH DO NOT MIX.

Fig. 46.—HARE'S APPARATUS FOR LIQUIDS WHICH MIX.

Arrange two magnets with a soft iron ring between them. Repeat with iron filings as above and note their arrangement. You will observe that the soft iron ring seems to draw the lines of force into it and so shields the space within it (Fig. 26).

Soft iron will not retain magnetism as does steel, so permanent magnets must be made of hard steel.

Can a Magnet be made to lose its Magnetism?

Obtain a test-tube and fill with iron filings (Fig. 27). Draw a magnet along the tube and examine the filings. The filings arrange themselves and the tube becomes a magnet. Shake the tube well and it loses practically all of its magnetism. A permanent magnet may lose much or all of its magnetism if it be hammered or heated.

How to make a Magnet of a Piece of Steel

1. By the single-touch method (Fig. 28).
2. Double-touch method (Fig. 29).
3. A piece of steel may be slightly magnetised by holding it in the magnetic meridian, pointing half down and tapping the end with a hammer.

The constant hammering in the construction of a ship has a tendency to make the ship a magnet or a number of magnets. Thus soft iron plays an important part in shielding the ship's

compass from the effect of a ship's magnetism. Consult a book for a description of a ship's magnet. How is the ship's compass constrained to revolve in a horizontal plane when the ship is constantly moving up and down and from side to side?

The Dip Needle

An ordinary magnetic needle moves in a horizontal plane, while the dip needle moves in a vertical plane. Point the dip needle due north and read the angle of dip. Which type really points due north, the dip needle or the horizontal needle?

To find the direction north by means of the dip needle, turn the needle so that it is vertical. Now rotate it through 90° and it will point due north.

The dip is the angle between the direction of the lines of force of the earth's field and the horizontal (Fig. 30).

Additional Exercises

1. Arrange two magnets in line pointing in the magnetic meridian. Trace the lines of force, using iron filings.
2. Arrange two magnets in the magnetic meridian and trace the direction of the field of force as before.
3. Magnetise a steel knitting needle. File in the middle, break in half and test each half for north and south poles.

CHAPTER VIII

ELECTRICITY

The Simple Voltaic Cell

OBTAIN a glass jar and place in it two plates, one of zinc (Zn) and the other of copper (Cu). Pour very dilute sulphuric acid into the jar and join the Cu to the Zn by means of a copper wire (Fig. 31). A current will pass from the copper to the zinc. At present you have no means of detecting whether a current is passing, but later on you will be able to do so. Observe bubbles of gas rising from the zinc plate. What gas is produced by the action of dilute sulphuric acid on zinc? [Turn to preparation of gases.]

This type of cell has a great disadvantage; the hydrogen collects on the copper plate and eventually prevents a current from passing; it becomes polarised.

When a current is or is not passing, bubbles still rise from the zinc plate. If pure zinc were used no bubbles would be given off when the plates were not connected. This action (when the current is not passing) in commercial zinc is prevented by amalgamating the Zn plate. To do this, clean the zinc plate with dilute sulphuric acid and then rub it over with mercury.

Can a Cell be made in which Polarisation does not take place?

Set up a Daniell cell as shown in the sketch (Fig. 32). The crystals of copper sulphate on the shelf keep the copper sulphate concentrated.

The hydrogen produced by the action of the acid on the Zn passes through the porous pot and meets the copper sulphate, which absorbs it before it reaches the copper pot. Thus the cell is depolarised.

This cell, however, has a great disadvantage. The liquids diffuse through the porous pot and mix (turn to Preparations of Gases—Diffusion through a Porous Pot). The cell, also, has very little power.

The force which drives a current through a cell is electro-motive force, and it is measured in volts. The E.M.F. of the Daniell cell is about 1.1 volts.

Can a Cell be constructed having a greater E.M.F. and in which only one Fluid is used?

Dissolve potassium bichromate in sulphuric acid and dilute about ten times (Fig. 33).

Join the Zn to one of the carbon rods and a current will flow. After some time the bichromate solution will turn green in colour and need replacing. The cell produces an E.M.F. of about 2 volts. The potassium bichromate is the depolarising agent. Do not leave the Zn in the solution when a current is not passing.

The Dry Battery

Carefully take a dry battery to pieces, and you will see that it consists

of three cells joined together in a particular way. The zincs are joined together and the cells are said to be joined together in series. The E.M.F. of the battery is three times that of a single cell.

Take one cell to pieces. How far may you call it a dry cell? What are the plates used?

How to detect if a Current is passing when the Plates are joined

Include in the circuit a tapping key and a 2-volt lamp (Fig. 34a).

First of all use a bichromate cell, press the key and observe if the filament glows. Repeat with a Daniell cell and a voltaic cell and note the difference.

Put a 4-volt lamp in circuit and use 2 bichromate cells in series and observe the result (Fig. 34b).

None of these cells gives a steady current for long. Recently an excellent cell has been produced which, with very little attention, produces a steady current, lasting for hours at a stretch, and is very suitable for work in "wireless."

Obtain two burette stands and secure a copper wire by means of them so that the wire is horizontal. Place a magnetic needle underneath, as shown. A sensitive needle should be used (Fig. 35). Include the wire in a circuit and also employ a tapping key and note the movement of the north pole of the magnet. A movement of the needle indicates that a current is passing round the circuit.

An instrument, called the galvanometer, can be used to detect a current. It can easily be made by fixing a short magnetised needle in the centre of a vertical coil of wire. When a current passes round the coil, the needle is deflected (Fig. 36).

The Electro Magnet

Obtain a bar of soft iron and wind a dozen or more turns of insulated copper wire round it. Attach the ends of the copper wire to terminals, in order to include in a circuit. A dry battery such as is used in a flash lamp may be used to provide the current. Dip the end in the soft iron filings and note the result (Fig. 37). Now by means of the tapping key break the circuit and again note the result.

If steel is used instead of soft iron a permanent magnet will be obtained. The electro magnet is used in industry, and is particularly suited for loading iron and steel goods. It can be used to separate iron and steel scrap from other metals. The principle of the electro magnet is utilised in the construction of house bells, for when the bell circuit is joined, the electro magnet thus produced attracts an iron rod which moves a lever which in turn rings the bell.

To make a magnet by means of an electro magnet, place a bar of steel across the poles of the electro magnet, pass a strong current and strike the bar several times with a wooden mallet.

CHAPTER IX

PRESSURE

Water seeks the Lowest Level

OBTAIN apparatus similar to that shown in the sketch (Fig. 38).

Pour water down one of the tubes and observe that a common level is obtained.

Pressure increases with Depth

Obtain a tin cylinder, make equal holes at various depths, pour in water and draw an inference from the result (Fig. 39).

The Barometer

Many boys and girls find it difficult to understand the principle of the barometer.

The barometer consists of a glass tube about 80 cm. long, closed at one end and open at the other. It is filled to within an inch of the top with mercury and inverted several times to rid the tube of air. It is then completely filled and inverted in a trough of mercury. The mercury in the tube falls a short distance. The air, pressing down on the mercury in the trough, keeps the mercury up in the tube. Above the mercury in the tube is practically a vacuum, so there is no pressure on its surface. The height of the mercury column varies from day to day according as the pressure of the atmosphere varies, but the height is usually about 760 mm. We therefore say that the atmosphere has a pressure of 760 mm. Mercury has a density of 13.6 grm. per c.c.

IV—13

Would it be possible to make a water barometer? Consider the advantages of using mercury.

The Manometer (Fig. 40)

This is really a pressure gauge. When the mercury levels are equal in height, the pressure in A is that of the atmosphere. An increase in pressure in A will cause a difference in the levels equal to the increase in pressure. Find pressure of water and gas mains.

The Siphon (Fig. 41)

The trough may be emptied of its water by means of a tube as shown. Start the action by sucking water through the tube and water flows until the tank is empty. Can you furnish a possible explanation?

Find out what you can about the diving bell.

Pressure Gauges

There are many different types of pressure recorders. One in extensive use is the Bourdon Gauge, which consists of a tube coiled into a flat spiral. This is connected to the liquid or gas the pressure of which is required, when the spiral attempts to enlarge and become of greater radius, dependent on the pressure. By a suitable arrangement the spiral moves a pointer, which records the accurate pressure.

Other gauges utilise the compressibility of gases for their pressure recording, but the Bourdon is the one in most extensive use.

CHAPTER X

WATER AND WATER SUPPLY

EVERY town needs an ample supply of pure water, and very often water has to be brought to the town from great distances. Liverpool gets its water from Lake Vyrnwy, Glasgow from Loch Katrine and Birmingham from the Elan Valley. Thus water is brought through about seventy-five miles of pipe to Birmingham reservoirs. Water must be pure, and to render it so it is passed over filter beds consisting of layers of rough stone and gravel. Very often the water has to be treated with a gas named chlorine in order to render it free from disease-producing germs. For instance, the water supply of New York City is chlorinated by the largest equipment in the world. A very small quantity of chlorine will render water sterile, but sometimes, when water is highly contaminated, by sewage, for instance, the amount of chlorine added gives the water an unpleasant taste. This is removed by the addition of the gas sulphur dioxide. We shall consider these two gases, chlorine and sulphur dioxide.

Sometimes we complain that the water we use is very hard and so causes us to use a greater amount of soap for cleaning purposes. Obtain some lead piping and allow "soft" water to stand in it for about a month. Now test the water for the presence of lead. Add dilute hydrochloric acid to

the water and pass sulphuretted hydrogen; note the coloration. Sulphuretted hydrogen is produced by the action of dilute hydrochloric acid on iron sulphide. It is necessary for the water to be hard to some extent.

To test Water for Contamination by Sewage

Obtain a beaker of water from a pond and add Nessler's solution. A yellowish discoloration indicates contaminated water.

*Chlorine (Fig. 42)**Properties*

1. Greenish-yellow gas, which irritates mucous membrane.
2. Soluble to some extent in water.
3. Two and a half times as heavy as air bulk for bulk.
4. Drop a piece of blotting-paper soaked in turpentine in a jar of the gas. It immediately takes fire.
5. Light a wax taper and lower into a jar of the gas. It continues to burn.
6. Put a piece of phosphorus into a deflagrating spoon and lower into a jar of chlorine. The phosphorus will ignite.

Bleaching Action

Moisten some leaves, flowers and turkey-red cloth and put into a jar of chlorine. They are bleached. Try

this again with the turkey-red cloth dry.

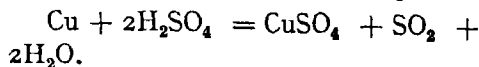
Moisture is necessary. Write a few words with ink on a piece of paper and drop paper in the gas. Now do the same with "dry writing."

Chlorine water may be prepared by using the apparatus shown (Fig. 43).

Sulphur Dioxide (Fig. 44)

Sulphur dioxide is produced when sulphur burns in air. It can be pre-

pared by the action of concentrated sulphuric acid on copper turnings.



Properties of Sulphur Dioxide

1. Heavy.
2. Colourless.
3. Very soluble in water.
4. Extinguishes a lighted taper.
5. Bleaches straw and silk in the presence of water. The gas is a useful disinfectant.

CHAPTER XI

DENSITY

THE density of a substance is its mass per c.c. or per cubic yard or per cubic foot, etc.

Thus it is the $\frac{\text{mass}}{\text{volume}}$ (gram. per c.c.).

If the weight of a body is 6 gram. and its volume is 2 cm., its density is 3 gram. per c.c.

To find the Density of a Glass Stopper

Weigh the glass stopper on a chemical balance. Now find its volume by means of a measuring jar, and so calculate its density.

Find the density of sand in the same way; a fairly large quantity should be taken. Why?

A very convenient method of finding the density of a liquid is by means of a density bottle of known volume. Fill with liquid, find its weight, and hence calculate the density.

Specific Gravity

The specific gravity of a substance is

the weight divided by the weight of an equal volume of water.

The specific gravity is numerically equal to the density of a substance, but is expressed as a number. It is really a number of times. It is a very easy matter to find the specific gravity of a substance like turpentine or methylated spirits by means of the specific gravity bottle.

W_1 = weight of bottle filled with water.

W_2 = weight of bottle filled with spirits.

W_3 = weight of bottle empty.

Then the specific gravity of spirits = $\frac{W_2 - W_3}{W_1 - W_3}$.

To find the Specific Gravity of a Liquid which does not mix with Water

Bend some tubing to the form of a U (Fig. 45). Pour in some water and then some turpentine, for example. Read the heights above the common level

To find the Specific Gravity of a Liquid which mixes with Water

Use the modification of the U-tube as shown (Fig. 46). Measure the heights above the levels in the beakers. The same reasoning applies to calculation using this method.

The Hydrometer

This is an instrument for measuring the specific gravities of liquids. Some instruments give a direct reading and others necessitate calculation. A special form of hydrometer is used in determining the density of milk; another form is used by medical men.

CHAPTER XII

MECHANICS

The Centre of Gravity of a Body

THE centre of gravity of a body is the point at which its weight may be supposed to act. In simple objects we may determine the centre of gravity by determining the point of balance.

Cut out an irregular piece of cardboard and balance it over an edge of a triangular prism, for example. Mark the line of contact. Now place the cardboard in a different position over the edge and again balance; again mark the line of contact. The point at which these lines intersect is the point of balance (Fig. 47).

Find the centre of gravity of a cardboard triangle, square and rectangle.

To find the C.G. of an L-shaped Wire

Suspend from a point by means of a piece of weighted cotton, and tie cotton to the arms when the wire has come to rest. Repeat this for a different position. The cottons cross to the C.G., which is outside the body itself (Fig. 48).

Points to be Considered

1. Where is the C.G. of a rod (uniform) ?
2. Where is the C.G. of a tram-car ? When will it topple over ?
3. Should the C.G. of a vehicle be high or low ?

Levers

1. Arrange a lever as in the sketch (Fig. 49), supporting it in the middle on the edge of a triangular prism. Attach a weight of 50 gm. to any point A and find a point B such that another weight of 50 gm. suspended from B restores the balance. Measure PB.

2. Now vary weights W_1 and W_2 and take distances PA, PB, when balance is restored. Repeat this for various weights and enter your results as shown below (Fig. 50). The point P is the fulcrum of the rod.

Moments (Fig. 51)

The moment of a force about a point is the product of the force and the perpendicular distance of its line of action from the point.

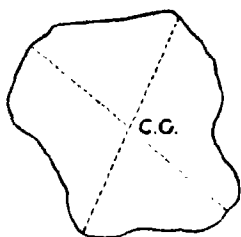


FIG. 47

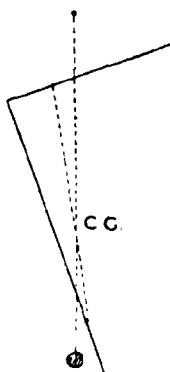


FIG. 48

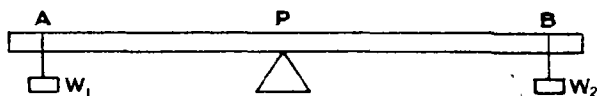


FIG. 49

Exht	W_1	PA	W_2	PB	$W_1 \times PA$	$W_2 \times PB$
1						
2						
3						
4						
5						

FIG. 50

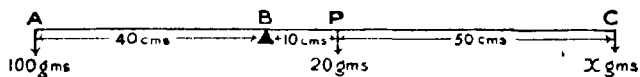


FIG. 52

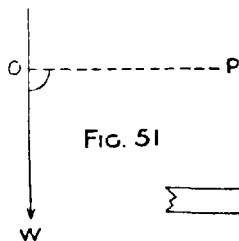


FIG. 51

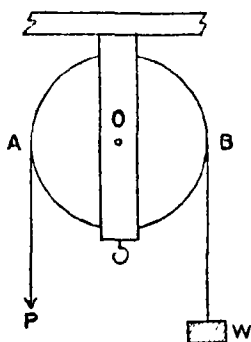


FIG. 53

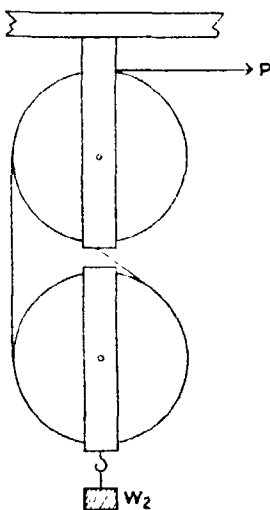


FIG. 54

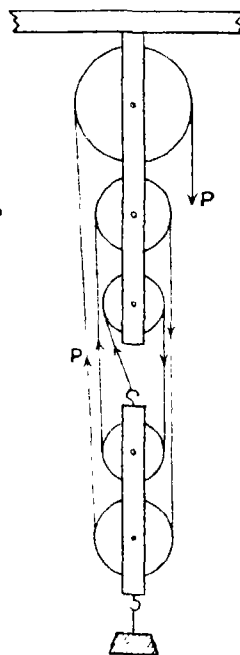


FIG. 55

Fig. 47.—CENTRE OF GRAVITY OF IRREGULAR SURFACE.

Fig. 48.—CENTRE OF GRAVITY OF RIGHT-ANGLED BEND OF WIRE.

Fig. 49.—ILLUSTRATIVE EXAMPLE.

Fig. 50.—METHOD OF RECORDING RESULTS.

Fig. 51.—MOMENT OF A FORCE.

Fig. 52.—ILLUSTRATIVE EXAMPLE.

Fig. 53.—SINGLE FIXED PULLEY.

Fig. 54.—SINGLE MOVABLE PULLEY BLOCK.

Fig. 55.—DOUBLE MOVABLE PULLEY BLOCK.

Suppose we take the fulcrum at any point in the rod between the middle and the end.

Example (Fig. 52)

A uniform rod 1 metre long has a weight of 100 grm. hanging from one end, and is supported 40 cm. from the end. If the rod weighs 20 grm., what weight will be needed at the other end to restore the balance?

Let x be the unknown weight.

Moment of weight x about B = $60 \times x$.

Moment of the rod's weight about B = 20×10 .

These both tend to turn the rod in a clock-wise direction. Now moment of 100 grm. about B = 100×40 .

This tends to turn the rod in an anti-clockwise direction, but as the rod is balanced, the turning effects are equal.

$$\begin{aligned} \therefore 60x + 200 &= 4,000 \\ 6x &= 380 \\ x &= 63.3 \text{ grm.} \end{aligned}$$

Perform an experiment similar to this with the apparatus at your disposal and observe if the theoretical calculation bears out the practical result.

Pulleys

Examine a pulley and distinguish the three parts—pulley, axis and block.

NOTE.—It should be remarked that the figures relating to the Science Section are numbered independently of the other illustrations in the volume.

The Single Fixed Pulley (Fig. 53)

If P is the effort and W the weight, then by taking moments about O

$$P \times OA = W \times OB$$

$$\text{but } OA = OB$$

$$\therefore P = W$$

$$\text{and Mechanical Advantage} = \frac{W}{P} = 1.$$

The Single Movable Pulley (The Crane) (Fig. 54)

If W_1 = weight of lower pulley

W_2 = weight lifted

and $W = W_1 + W_2$,

then $W = 2P$, for W is supported by two strings.

$$\begin{aligned} \therefore \text{Mechanical advantage} &= \frac{W}{P} \\ &= \frac{2P}{P} \\ &= 2 \end{aligned}$$

A System of Pulleys (Fig. 55)

Let the strings be pulled by a force P . Then the tension throughout is P , so that if W is the weight of lower block, pulleys and weight,

$$\text{then } W = 5P$$

(as five strings support lower block) and
Mechanical Advantage = 5.

Then it is possible to devise many systems of pulleys to increase the mechanical advantage.

The sketch as shown is a convenient means of representing the crane in which the pulley block contains several pulleys on the same axis.

SECTION III

SCHEMES OF WORK

NATURE STUDY FOR THE RURAL SCHOOL

OUTLINE SYLLABUS

INFANTS AND STANDARD I

THE same as that recommended for the urban school.

STANDARD II

Spring and Summer

The awakening of life—opening of buds (baby branches) ; plants springing from the ground ; return of Larks, Crows, etc. ; building of nests ; Chickens, Lambs. Insects, e.g. the Fly comes out of sleeping case. The sowing of seeds.

Excursions :

- (1) To the school gardens (April).
- (2) To the ponds and fields (May).

Growth of Grasses, Corn, etc. ; return of the Swallow and other insect-eating birds ; long, sunny days ; activity of birds and insects—Bees, Wasps, Butterflies ; the coming of flowers, e.g. Daisy, Primrose, Willow-herb, Hawkweed, Dandelion, etc.

Autumn

Ripening of seeds ; disappearance of Summer flowers and the taking of their places by seeds. Work carried out in the gardens and allotments. Gathering of migratory birds, e.g. Larks, Swallows, Starlings, etc. Caterpillars become pupæ. Changes in the colour of the landscape, in length of day, in tempera-

ture. Disappearance of the Bat, Toad, Frog, etc.

Excursions same as in summer.

Winter

Leafless and evergreen trees. Pupæ of Moths and other insects. The "sleeping" animals, e.g. Squirrel, Dormouse, Bat, etc. Short days ; snow, frost, etc.

Throughout the year a simple temperature chart should be kept by the teacher, but reading should be made by the children, and from this information a simple record of weather conditions may be compiled and exhibited on the walls of the classroom. The temperature chart should show outside and indoor temperature.

STANDARD III

Spring and Summer

Dissection of seeds of Broad Bean and Maize to show covering, food supply, embryo and cotyledons.

Study of opening buds, e.g. Horsechestnut, Beech, Lime, Syringa. Germination of Beans and Maize in classroom and garden.

Development of Frog spawn. Excursions to show the gradual awakening of life :

- (1) To the school gardens.
- (2) To the ponds and fields.

Further study of the growth of Beans and Maize. Study of flowers—

devices for opening and closing and for attraction, e.g. Dandelion, Tulip, Viola, Daisy, Mignonette. Disposition of leaves on the Ivy, Ash, Horse-chestnut, Primrose, Daisy, etc. Life-history of an insect treated simply, e.g. Cabbage White Butterfly, Silk-worm.

A second excursion covering the same ground, noting changes.

Autumn

Study of fruits and seeds—Orange, Apple, Cherry, Hip, Haw, Plum, Hazel-nut, Ash, Oak, Sycamore, Lime, etc. Dispersal of seeds by wind, animals or birds, e.g. Dandelion, Sycamore, Lime, Burdock, etc.

Caterpillars going into the pupæ stage (examples from the school garden).

Excursions as in spring and summer—harvesting, plant protection, e.g. Hawthorn, Thistle, etc. Autumn tints, fall of leaf.

Winter

Dormant plant life—study of buds of Horse-chestnut and Beech or Sycamore, also rhizomes of Iris, Couchgrass or Mint. Corms and bulbs.

Frost—effect of frost on soil and vegetation. Snow as a protective agent.

Excursions as before.

Temperature and weather charts may gradually become more complicated. Direction of winds, etc., outside and indoor temperature. Effects of temperature on plant and animal life.

STANDARD IV

Spring and Summer

Germination of Kidney Bean, Wheat, Peas, Mustard and Cress. Dissection of

seeds to show embryo and food supply (cotyledons). Continuous study of Wheat, Peas, etc., with plants grown in school and in the school gardens. Study of the opening buds of Horse-chestnut, Ash and Lime. Catkins of the Hazel, Willow and Poplar.

Development of a Frog from spawn; changes to be noted by the children, in no case by the teacher.

Life-history of a bird; chief birds found in the district to be dealt with in outline.

Excursions to observe the gradual awakening of life:

(1) To the school gardens.

(2) To the ponds and fields.

Further study of the growth of Wheat, Peas and Maize. Study of flowers—devices for opening and closing and for insect attraction, e.g. flowers of the Lime, Horse-chestnut, Dandelion, Daisy, Tulip, Viola, Scarlet Pimpernel and Mignonette. Disposition of leaves on trees studied earlier and also of the Daisy, Primrose, Pimpernel, etc., to secure the maximum amount of light.

Life-history of an insect, e.g. Tiger Moth or Cabbage White Butterfly, the Caddis-fly or Water Boatman.

Bird Life.—Summer visitors—the Swallow and Cuckoo; methods of flight, food, interesting details of their life-history.

Excursions as before, attention being directed to the changes—reasons.

Autumn

Study of fruits and seeds—dispersal by wind, animals, birds, etc. Winged seeds of Sycamore, Lime, etc. Seeds of the Thistle, Dandelion, Avens, Goosegrass, Burdock, the Apple, Plum, Walnut, etc.

Excursions as in spring, noting harvesting of crops, autumn tints, fall of leaf, plant protection, e.g. Hawthorn and Thistle.

Winter

Dormant animal and plant life. Study of buds. Rhizomes of the Iris, Couch Grass, Mint, etc. Runners of Creeping Crowfoot, Strawberry. Life-history of a bulb and corm.

Frost and its effects on vegetation.

Birds—winter visitors. Economic value of birds.

Temperature and weather charts should be kept throughout the year showing outdoor and indoor temperature at stated times in the day—direction of the winds and general observations on the weather.

STANDARD V

Spring and Summer

Seed structure and germination; conditions necessary for germination. Function of root and shoot. Special study of Catkins, Coltsfoot and Butterbur.

Development of Caddis-fly and Water Beetle.

Detailed study of the Potato—grown in school and in the garden. Experiments in disbudding (removing the eyes).

Excursions to the fields and pools to observe the awakening of life—to the school gardens.

Co-relation of plants and insects—parts of a flower and their uses (protection, attraction and seed production). Experiments in plant nutrition.

Life-history of the Frog, House-fly, Cabbage Butterfly.

Bird Life.—Beak formation and food. Economic value of birds briefly and simply stated.

Further excursions—special note of the struggle for existence in the ponds and hedgerows.

Autumn

Seeds and their dispersal; special mechanism of shooting seeds, e.g. Broom, Violet, Herb-Robert, etc.

Modification of epidermal hairs and leaf branches, etc., to provide means of climbing or protection, e.g. Pea, Bramble, Ivy.

Penknife sections to show structure of stem. Simple experiments in transpiration, respiration and assimilation. Starch and sugar.

Experiments in protective colouring (Frog and Stickleback).

Experiments to prove the resting stage of seeds.

Excursions as in spring, changes noted.

Winter

Experiments to show :

- (1) How a soil is formed.
- (2) Movement of water in soil.
- (3) Drainage and aeration.
- (4) Water as a solvent and food carrier.

(5) Composition of air, shown by rusting, burning (phosphorus or candle over water under an inverted jar) and breathing.

Excursions to school gardens to observe differences in soil and subsoil.

Pupils in this division should be encouraged to keep weather and temperature charts for themselves, noting the prevailing winds, etc., using make-shift apparatus fixed by themselves

in the playground or in some easily accessible place in the vicinity of the school.

STANDARDS VI AND VII—GIRLS

Spring and Summer

Plant Life.—Examination of:

- (1) Seedling Bean and Wallflower.
- (2) The stems of Sunflower, Sweet Pea, Oak, Bamboo, Wheat, Onion and Crocus.
- (3) Roots of Grasses, Dahlia, Bean, Carrot and Turnip.
- (4) Underground stem of Solomon's Seal, Iris, Primrose, Mint and Willow-Herb.

Experiments in germination—water cultures.

Buds.—Origin and position on a stem. Adventitious buds; means of protection from cold. Apical growth, cf. root cap.

Animal Life.—Life-history of the Frog or Toad. Life-history of the Earthworm.

The Flowering Plant.—General features, root and shoot. Various forms of roots; root cap. Stem structures—underground stems. Hair structures. Leaf stipules; scale leaves; buds; flowers. Essential differences between root and stem (external). Nodes and leaf arrangement. The leaf; various forms of leaf; chlorophyll; function of leaves, etc. Transpiration and respiration. Arrangement of tissue in the leaf (penknife sections and also microscopical sections). Experiments to show the action of chlorophyll in sunlight. Nutrition—carbon dioxide; assimilation of carbon dioxide by green parts. Dissection of flowers of the Natural Orders Coniferæ, Liliaceæ, Primulaceæ and Compositæ.

Autumn and Winter

Syllabus of Lessons on Live Stock, Poultry, etc.—A brief account of various breeds of Cattle, Sheep, Horses and Pigs; their origin and suitability to various soils, climates and localities.

The management of the various breeds of live stock. The feeding and management of Dairy Cattle; the secretion of milk and its management.

Farm crops and Grasses; their distinctive characters and uses.

The rearing and general management of poultry.

Bird Life.—Economic value of birds treated simply and generally.

STANDARDS VI AND VII—BOYS

Spring and Summer

Soils.—The obvious constituents of soil—stones, roots and earth; stones of different kinds and sizes; microscopic particles; air and water in soils; separation of particles of different sizes; sand, clay, humus, limestone. Sour soils. Plant food—conditions of growth; constituents of plants.

Fruit Trees.—The distinguishing characters of the various kinds of fruits; the methods of propagation; methods of pruning and training; soil and planting; gathering and packing of small fruits.

Common Diseases and Pests of Fruit Trees.—Identification of various diseases and pests; brief life-history; conditions conducive to disease and vice versa. Preventive and remedial measures.

Vegetables.—The identification and characteristics of the more important vegetable seeds. The identification and grouping of vegetables; methods of cultivating; recognition and treatment of diseases and pests.

A demonstration on the simple implements of agriculture; the plough, harrow, etc., together with a brief account of modern agriculture and its development from early times.

Autumn and Winter

Live Stock, Poultry, etc.—A brief account of the various breeds of Cattle, Sheep, Horses and Pigs; their origin and suitability to various soils,

climates and localities. The management of the various breeds of live stock. The feeding and management of Dairy Cattle; the secretion of milk and its management.

Farm crops and Grasses; their distinctive characters and uses.

The rearing and general management of Poultry.

Bird Life.—Economic value of birds treated simply and generally.

DETAILED SCHEME OF WORK FOR THE URBAN SCHOOL

The following Scheme of Work contains not only a Syllabus, but a practical plan for carrying out Nature Study Work in an Urban or a large Country School. In some cases details of experiments are given, but in the parts dealing with subject-matter to be found earlier in this volume, bare outlines only are given. The whole scheme closely follows the latest "Suggestions" of the Board of Education.

The subject-matter has been arranged so that even the inexperienced teacher should be able to make a success of the lessons. Practical teaching experience has been combined with the "Suggestions," and every experiment given has been personally carried out in Elementary Schools by the Author.

Where gardening is taught, every opportunity should be taken to combine class work with outdoor work. The garden should be regarded as an outdoor laboratory.

EDUCATIONAL YEAR BEGINNING APRIL 1ST

INFANTS 5 TO 8 YEARS

In the Infants' Department all lessons on Nature Study should be of

either a conversational or an expressional type. They should afford opportunities for appreciation of Nature and for interesting expression of ideas in speech, writing, drawing, colourings or other forms of handwork. Only the broader and simpler aspects of each topic should be dealt with in this department, the aim being to provide material on which the innate curiosity of the children can have full play. The idea "to see and admire, not harm and destroy," should be firmly fixed in the children's minds at this period of school life; most cruelty arises through ignorance.

In the early stages the lessons should satisfy the interest in living things, no attempt being made to formulate reasons, or to give any. Any explanations should be simple.

The growing of bulbs and corms in flower-pots and water glasses; the development of buds of twigs in water; the feeding and care of the inhabitants of an aquarium; the attention necessary for the keeping of a Flower Table, so arranged that it is in itself a record of seasonal changes; the Bird Table and its visitors; all these help to stimulate the interest of the children.

The following indicates, in a general manner, the topics which will prepare the scholars for more detailed work in the upper departments.

Spring and Summer

Nature awakening ; longer days and warmer weather ; Hazel and Willow Catkins ; opening of buds and the coming of leaves ; the budding and blossoming of flowers ; the singing and mating of birds ; the coming of Lambs and other young animals ; the return of Bees, Butterflies, etc.

The work in the gardens ; preparing the soil, sowing the seeds ; the care of plants in the classroom and in flower borders.

The growing of seeds such as Broad Beans and Peas in sawdust and soil.

Changes in outdoor activities ; more games played, marbles, spinning tops, etc.

More warmth from the sun, not much need for large fires ; less artificial light needed.

Development of Frog spawn.

Flowers of various kinds observed ; the seeds they form.

A Nature Walk is a necessity for young children. Where possible, the school garden should be visited frequently.

Autumn Term—September to Christmas

Shorter days and cooler weather ; Autumn tints, leaf-fall ; trees, flowers and insects preparing for winter.

Harvest time—the gathering of Apples, Pears, Wheat, Barley, Blackberries, etc.

Need for more clothes ; elementary ideas as to sources of supply ; kinds of clothes—the Sheep.

Families of animals such as Rabbits, Mice and Rats ; their work and play ; preparation for winter.

Birds—not so many singing ; collecting together of birds ; disappearance of Swallows and Martins.

Winter Term—Christmas to March

Weather much colder ; shorter days ; withered plants, leafless trees, evergreen trees, the Mistletoe ; frost, snow and ice ; warm coats of animals.

Effects of the wintry weather on the blacksmith, plumber, shoemaker and tailor.

Kinds of fruit available.

Visitors to the Bird Table ; some fresh kinds ; food of birds.

STANDARD II

Spring and Summer Term—April to July

The signs of the coming of spring ; an introduction made to the thermometer ; temperature outside and inside the classroom. Effect of temperature on the known trees and animals. The identification of one or more trees by the bud arrangement, branching, colour and characteristics of the bark ; development of twigs in the classroom. Work in gardens and allotments. Where possible, a visit should be paid to a garden. The growing of seeds, such as the Broad Bean, Pea, Mustard and Cress in sawdust, fibre or on damp flannel or blotting-paper. If a small garden is not available, the larger seeds should be grown in flower-pots. (Pollination in the latter case may be carried out artificially.)

The simple flowers should receive attention, and the technical terms,

sepals, petals, anthers and seed boxes applied, e.g. the Primrose, Polyanthus and Wallflower. The study of Frog spawn should be more detailed than in the Infants' Department; this should be individual observational work, the children observing the changes which take place, the names spawn, or eggs, and Tadpole, being given by the teacher.

Conversational lessons on the developing spawn should be taken occasionally in order to guide the observations into correct channels.

If an aquarium is available, the Water Boatman, Water Snail and the Caddis-fly larva will provide a source of interest.

The life-history of a Butterfly or Moth might also be dealt with. A terrarium is a necessity for this work; a soap box with a glass front is quite efficient. Caterpillars can be secured by the children and their subsequent changes noted.

Bird Life.—Observational work on one or more common birds can be carried out in this standard. The main features of the Sparrow, Robin and Blackbird can be observed.

Animal Life.—The external characteristics of the Cat, Dog, Rat, Rabbit and Mouse can be taken in this class. This should form the outdoor activity of the scholars working in teams. Occasional lessons should be taken in order to test observations or ensure that such work is being done.

Autumn Term—September to Christmas

Ripening of fruits, dry and succulent fruits compared, e.g. Nuts (Hazel and Beech) and Blackberries, Apples and Pears. Dispersal of winged fruits of

the Sycamore, Maple and Ash. Harvest time—the gathering in of Wheat, Barley, Oats, Rye; storing of Potatoes, Swedes and Mangolds.

Preparation for Winter.—Thick coats of animals; more clothes required by man; departure of the migratory birds.

General change in the character of the landscape. Autumn tints and leaf-fall treated in a simple manner. Changes noted in the terrarium; Caterpillars forming chrysalides; cocoons formed by a few types; others burying in the soil.

The food supplied to man by animals, insects and plants.

Winter—Christmas to March

Effect of frost on vegetation—on the soil—on bird and animal life.

Elementary study of water in its three states. Ice and snow considered as solid water, crystals compared. Steam from the kettle—water vapour.

During this term when outdoor work is prevented, Nature Stories should be told to the scholars. They delight in hearing of the lands from which Oranges, Dates, Brazil Nuts, Coconuts and such fruits are obtained, and in this case, Geography and Nature Study are intimately associated. The care bestowed on farm animals during winter forms an interesting topic. The lives of wild animals such as the Rabbit, Mouse, Rat, Squirrel, Dormouse and Hedgehog provide further interesting informative lesson material.

Bird life during this season should be studied by the aid of a Bird Table. The food of the various kinds can be observed and the characteristics of one or more kinds, such as the Robin, Sparrow, Thrush and Blackbird, noted.

The winter condition of one or two common trees of the district should be considered. Specific work on the identification and appreciation of trees in the vicinity of the school should be given as "Team" or group work.

STANDARD III

Spring Term—April to July

General signs of spring; development of buds; Hazel, Willow and Alder Catkins. Spring flowers, the Daffodil, Tulip and Hyacinth.

Germination.—The conditions necessary for this process, treated experimentally. The general structure of a seed discovered—a seed being considered as a small plant packed closely inside a case or seed coat. Three types of seed selected from the Broad Bean, Pea, Vegetable Marrow, Gourd, Lupin, Acorn, Sunflower, Horse-chestnut and Beech to be considered in detail. Experiments to show that air, moisture and warmth are necessary for germination; others to show that neither light nor soil is essential.

Experiment 1.—Seeds in dry sawdust or fibre in the classroom.

Experiment 2.—Seeds in moist sawdust or fibre in the classroom.

Experiment 3.—Seeds in moist sawdust or fibre containing ice.

Experiment 4.—Seeds in moist sawdust or fibre kept in the dark.

Experiment 5.—Seeds in soil surrounded with ice.

Experiment 6.—Seeds in dry soil.

Experiment 7.—Seeds in moist soil in the classroom.

Experiment 8.—Seeds in moist soil outside the classroom.

Experiment 9.—Seeds suspended over water in a glass jam jar.

Experiment 10.—Seeds suspended over water, without access to air.

Experiment 11.—Seeds in water with access to air.

Experiment 12.—Seeds in water without access to air.

Nos. 2, 7, 9 and 11 to demonstrate that moisture, air and warmth are essential.

Nos. 3, 5 and 8 to demonstrate that warmth is necessary.

Nos. 10 and 12 to demonstrate that air is necessary.

Nos. 1 and 6 to demonstrate that moisture is essential.

No. 4 to prove that light is not necessary in the early stages (cf. seed sowing in the gardens).

The development of the seeds in sawdust and soil should be carefully recorded; the cotyledons of some are epigeal and others hypogeal.

Outdoor Activities.—The cultivation of the school garden or an allotment; the implements used by the gardener, such as the spade, fork and rake. An attempt should be made to discover the reason for breaking up the soil.

The life-history of a simple plant such as the Primrose, Chickweed or Meadow Cranebill should be studied, attention being paid to:

(1) Rooting system—tap root, fibrous root or rhizome.

(2) Leaves—size and shape.

(3) Flowers—colour and number of petals, anthers, etc.

(4) Fruit.

A real or an imaginary visit to a farm; the recognition of fields, animals, implements, fruits and grain; the two great classes of food which come from the farm—animal and vegetable. An elementary notion of the town reactions towards problems of food, clothing and

shelter as compared with those in the country. Much of the work can be regarded as the individual observational work of the scholars. In these days of cheap motor excursions, the majority of children visit country districts during the late Spring or early Summer.

Bird Life.—A more detailed study of a resident bird than was possible in Standard II. The Blue Tit and Hedge-sparrow are familiar types; the Black-bird, Thrush and Starling can be considered as alternatives.

Pond Life.—A visit to a pond should be arranged if possible. Various specimens can be secured in May, such as the Brown Beetle larvæ and the Caddis-fly larvæ; the adult Water Beetle should also be obtained. Particular attention should be called to the respiration of the specimens observed through the agency of an aquarium. The inhabitants of an aquarium should be returned to a pond before the summer vacation.

Autumn

A continuation of broad general appreciative interest in Nature. Fruits of various kinds should be studied and an introduction made to dispersal.

The fruits of a few trees, such as the Sycamore, Maple, Ash and Lime, should be taken as indicating wind dispersal.

Small plants having parachute mechanism, the Dandelion, Groundsel and Thistle. (N.B.—With Standard III it is advisable to keep to one method of fruit dispersal.) Selected examples of fruits should be mounted on cardboard, the names and a few particulars being written by the side, and placed in a position where they can be studied by the children. An attempt can be

made at this stage to distinguish a "fruit" from a "seed."

Harvest Time.—Early in the Autumn term, a Nature Walk to the outskirts of the town is advisable. The gathering in of crops such as Wheat, Barley and Oats; the storage of Potatoes, Apples and Pears; the gathering of Blackberries, Raspberries, Damsons and Plums should be observed, and the methods employed for preserving fruits for use later on might be dealt with in a simple manner.

Insect Life.—A small collection of Caterpillars should be made and fed in a terrarium. The Cabbage White Butterfly larvæ and the Woolly Bear (caterpillar of the Tiger Moth) are useful types for work of this description. In school the change to the pupal stage is reached much earlier than under natural conditions.

Bird Life.—This should be regarded as a continuation of the Spring term. Note should be taken, however, of the gathering together of the migratory birds, e.g. Swallows and Martins.

This section can be regarded as the outdoor activities of the scholars in districts where a Nature Walk cannot be arranged. Autumn tints and leaf-fall should be treated in a simple manner; leaves collected and comparisons made.

Drawing and painting should be closely correlated at this period of the Nature Study Scheme.

Winter

The resting stage in plant life. Further consideration of the roots of plants studied in the spring, e.g. Primrose. Other types examined for comparative purposes, such as the Iris,

Dandelion, Daisy, Michaelmas Daisy (Aster), Coltsfoot, Wild Carrot, Hogweed, Couch Grass, Parsnip and Turnip. The class should reach the conclusion that there are several ways by which plants "rest" during the winter.

(1) Trees, having thin leaves, cast them off during the Autumn.

(2) Some plants die, leaving "seed" to carry on the race.

(3) Other plants have food stored in the roots and remain dormant during the cold weather.

Animal Life.—The care taken with farm animals provides an interesting topic. Informative lessons might be given on the dormant condition of the Frog, Toad, Snails and the Dormouse.

Goldfish could be kept in the aquarium throughout the winter. Water Snails also form an interesting study.

Bird Life.—The identification of the various birds by the general build, methods of flight, characteristic movements, etc., will provide outdoor observational activity. The food supply of the resident birds should receive detailed consideration, an attempt being made to find out the order in which fruits are used. Hedgerow fruits, such as Blackberries, Hips, Haws, Honey-suckle berries and the small fruits of the Dead-nettle, Thistle, Plantain, Groundsel and Ragwort are used by the majority of birds, the order varying somewhat with the kind of bird considered.

Frost and its Effect on Vegetation.—Water in its various forms—rain, snow, sleet, ice, vapour, surface and ground water; springs and wells; evaporation and consequent purification; formation of clouds.

During this term informative lessons

giving a simple idea of the way in which man has made advance in using the gifts and forces of Nature might usefully be taken. Correlate the knowledge gained through history lessons of the habits and customs of the early inhabitants of this country and compare with the conditions at the present time. The cultivation in fields of grasses such as Wheat and Barley provides bread; the keeping of animals in flocks and herds, such as cattle, to supply milk (butter, cheese), flesh food and leather; sheep to supply warm clothes as well as meat; the uses made of birds for the supply of eggs, feathers for cushions, beds, and the flesh for food; domesticated animals such as the Dog and Cat, regarded as the servants of man.

STANDARD IV

Spring Term

What is soil? This might be an underlying consideration for Standard IV and Standard V. Man's work with the soil; elementary ideas on soil formation and its constituents—sand, clay and humus. Experiments to show the size of the various particles, mechanical analysis of soil and subsoil. Movement of water in the soil—capillarity. Elementary ideas of the materials dissolved in soil water. The inside of a kettle becomes coated with "fur." Why is this? Well-known substances which will dissolve or remain suspended in water might be examined, e.g. common salt, nitrate of soda, saltpetre, alum, sand and clay. The difference between substances in suspension and soluble substances. Starch and sugar compared. The iodine test might be intro-

duced. Rhizomes of the Iris, Solomon's Seal, the Crocus corm, Wheat and Barley and the Potato examined and tested for starch.

The main features of the Standard IV Syllabus are the linking up of the elementary work carried out in the lower part of the school and a preparation for the more intensive study of the plants in relationship with the soil; the friends and enemies of man found in the insect and animal world, which will be dealt with in the upper classes.

Germination.—Seeds selected from the Sycamore, Horse-chestnut, Peas and Acorns, might be examined and the iodine test applied. This test is best accomplished by soaking the seeds in water, pounding in a mortar and placing a little in a test-tube with water, and then adding iodine.

Effect of Light on Germination and Growth.—Germinate the selected seeds under conditions similar to those given for Standard III. In addition, the following will be useful:

(a) Keep one set of seeds in flower-pots, continually in the dark; keep moist with distilled or boiled rain water. Examine from time to time. Use a similar set of seeds, but kept in the light.

(b) Suspend other seeds over distilled water.

(c) Similar seeds over tap or well water.

The class will not be expected to understand the reasons for the results of these experiments, but a valuable line of study will be opened out.

(a) The leaves and stems of the plants grown in the dark will be a sickly yellow. Growth soon ceases. (Compare with the ones grown in the light.)

(b) Over distilled water, germination

continues until the reserve food material of the seeds is exhausted; the plants ultimately turn a sickly yellow colour and die.

(c) Over tap or well water, the plant will grow well and continuously.

Germinate Wheat or Barley in a flower-pot. When about 3 inches high, place the pot at one end of a long closed box having a hole about $\frac{1}{2}$ inch in diameter at the opposite end, the only aperture for light to pass through. Examine plants on the fourth morning. Turn the pot completely round and compare the results after three days.

Flower Study.—A more detailed study of hypogynous flowers should be undertaken in this class. The members of the Natural Order Ranunculaceæ will provide sufficient variety, or members of the Cruciferæ, such as the Wallflower, Arabis, Shepherd's-purse, Jack-by-the-hedge, Hedge-mustard and Charlock. Keeping to the latter order, several interesting features can be found by observation: technically the Shepherd's Purse and Charlock are annuals, the Wallflower a biennial, the Arabis a perennial.

Alternately, members of the Buttercup Family, Ranunculaceæ, will provide useful work (Lesson Notes).

Bird Life.—This should form the outdoor observational activity of the class throughout the year. Teams or groups should study the form, structure and habits of particular birds. Lessons collating the observational work might be taken monthly, or composition based on bird life given occasionally.

Pond Life.—The carnivorous larvæ should receive attention. Early in June a "fishing" expedition to a pond should be arranged and specimens of the Brown Beetle (*Dytiscus marginalis*)

secured. The methods of breathing and feeding can be studied in an aquarium, tadpoles and small fish or small pieces of meat being used for food. Specimens should be returned to the pond before the vacation.

Autumn

Poisonous fruits should receive special attention. Fruits and fruit dispersal can be taken in more detail, selections being made to illustrate :

(1) Wind dispersal—Thistle, Dandelion.

(2) Animal dispersal—Burdock, Cleavers.

(3) Mechanical devices :

(a) Laburnum, Gorse—twisting of the pods.

(b) Meadow Cranebill and Herb-Robert—catapult mechanism.

(c) Violet and Pansy—drying of the capsule.

(4) Dispersal by birds—Strawberry, Hip, Raspberry, etc.

Harvesting.—The methods of storing grain crops ; threshing, winnowing, milling, might be considered as material for informative lessons.

Leaf-fall and autumn tints. Why do the leaves fall from the trees ?

Animal Life.—The life-histories of wild animals, such as the Squirrel, Rabbit, Hare, Rat and Mouse, treated if possible as observational work. General structure of the Rabbit and Rat taken in class, using a tame live specimen. Position of the eyes noted ; special adaptation of teeth for gnawing ; legs and feet suitable for quick running and scratching ; covering, etc. Simple information lessons on value to the community or otherwise.

Insect Life.—The life-history of larvæ

to be considered. Specimen Caterpillars of the Hart and Dart Moth, Leather-jacket and Cabbage Moth should be secured and placed in a terrarium, the subsequent changes being noted.

Bird Life.—The resident birds, such as the Wood-pigeon, Starling, Crow, Red Grouse and Sparrow-hawk, might be considered at this period ; the kind will vary greatly with the district. The general structure of a bird should be considered as a class subject, the ordinary domestic fowl being used for demonstration purposes. When available, the Bantam is an easily handled subject, or a Pigeon will serve the purpose equally well. A feather from a dead specimen should be examined. Towards Christmas no difficulty should be experienced in securing the necessary examples.

Winter

The dormant condition of plant life. Examination and dissection of the buds of the Horse-chestnut, Beech and Willow. The arrangement of the buds on the twigs and identification of the trees dealt with by the shape, size and structure of the buds and the bud arrangement. Forced growth of buds of Syringa (Lilac), Horse-chestnut and Willow in water in the classroom.

Dissection of the Onion bulb ; forced growth in school to discover the functions of the various parts.

The Atmosphere.—Its existence, weight and compressibility. The Barometer and Boyle's tube. Experiments to prove that air occupies space, has weight, expands when heated ; cold air is heavier than warm air. The constituent gases of the air—oxygen,

hydrogen, a small amount of carbon dioxide and nitrogen. Carbon dioxide from the lungs turns lime water milky. Similarly when a candle is burned in a closed jar, CO_2 is evolved.

Simple lessons on carbon, as a constituent of wood, coal, peat, starch, charcoal and graphite. Produce CO_2 from shells, chalk, etc.

STANDARD V

Spring Term

Revision and extension of the study of the air. The formation of oxides when metals are heated in air. A candle burnt in air over water uses up one-fifth of it; use the lime-water test to prove the presence of CO_2 . Germinate seeds in a closed jar containing a test-tube of lime water; carbon dioxide is evolved and turns the lime water milky. Set up an experiment to show that in sunlight oxygen is given off by the leaves of plants. The common Water Weed, *Elodea canadensis* (Canadian Pond Weed), is the most suitable for the purpose. Place a few healthy branches in a large jar of water; insert over them a glass funnel and over the latter a test-tube filled with water. Stand the apparatus in the sunlight and notice that bubbles of gas are given off and collect in the test-tube. What is this gas? Repeat the experiment, but place the apparatus in the dark—no action takes place.

The Change during Germination (starch to a soluble substance).—Germinate Barley or Wheat on damp blotting-paper and allow to grow until the plumule is $\frac{1}{2}$ –1 inch in length.

(1) Pound soaked grains in water, filter and test filtrate for starch.

(2) Pound the grains which have been allowed to germinate, in water, and test a portion for starch.

(3) Use Fehling's Solution (obtained commercially) on a portion of the filtrate, for sugar.

Repeat experiments several times, using various starchy seeds. The conclusion for the class to arrive at is: That in growth the reserve insoluble starch in seeds, under favourable conditions, is changed to a soluble substance giving a sugar reaction.

The further study of plant life should be carried out—root and shoot system, leaves, shape of leaves, flowers, special attention being paid to the Natural Order Compositæ—Dandelion, Groundsel, Daisy, Ragwort; or the Rosaceæ—the Plum, Buckthorn, Wild Rose, Strawberry, Bullace, Crab, Apple and Pear. Pollination and the agencies effecting this can be studied at the same time.

The study of Bees and Wasps regarded as outdoor activities.

Autumn

Fruits and seeds—classification of fruits into:

- (1) Succulent fruits.
- (2) Dry indehiscent.
- (3) Dry dehiscent.

One or two varieties dealt with in detail, special attention being paid to the fruits resulting from the flowers studied in the summer.

Animal Life.—A detailed study of the Dog. Kinds of Dogs, uses, etc. The Wild Dogs, the Fox being specially considered. The study of the Cow and Sheep (ruminants); general structure, value to the community, etc.

Snails and slugs studied by means

of a terrarium. Hibernation may not take place under artificial conditions.

Insect Life.—By means of a second terrarium, the life-history of one or more pests might be studied. The Codlin Moth or the Winter Moth provides excellent work at this period. As outdoor observation, the class might try to discover why "grease bands" are placed round the trunks of fruit trees.

Bird Life.—The gathering together of migratory birds; dates of departure; value of such birds to the country. The resident birds which are protected by law and rare birds of the district to receive consideration.

Further study of the anatomical structure of birds and an elementary idea given of the classification:

- Perchers.
- Runners.
- Waders.
- Insect eaters.
- Seed eaters.
- Flesh eaters.

Winter

The effect of frost on soil, vegetation, animals and man; the weathering of rocks. Further work on soils; light, heavy and loamy soils compared for water-holding capacity. Humus in soils and its value. Winter treatment of soils and the manuring of gardens and allotments.

Resting condition of plant and animal life. The dormant condition of seeds (this varies considerably; Wheat and Barley will germinate immediately after ripening; Hawthorn berries two to three years after production).

The composition of the atmosphere and water revised.

The interaction of plant, animal,

insect and bird life treated in accordance with the knowledge possessed by the children.

Man's use of the gifts of Nature; the care bestowed on animals and birds; the protection of birds; their value to the community; useful and harmful insects.

The value of the farmer and gardener to the people in cities.

A general revision of the year's work, correlating as far as possible the work carried out in the lower standards.

Throughout the year, temperature and weather notebooks should be kept by the scholars. These should show outdoor and indoor temperatures, maximum and minimum heights of barometer, direction of wind, type of weather and any personal observations on plant, animal or insect life individual scholars care to make. Records of bird migration or details noted in the life-history of resident birds should also be kept.

STANDARD VI

Spring Term

The further study of trees should include those which are of high commercial value, e.g. the Oak, Elm, Beech. The study of these three should be regarded as team work, and information sought in various quarters as to the value and use of the wood; the woodwork centre might usefully co-operate. The general winter appearance; bud and bud arrangement; bark; type of branching, etc., will be known. A study of the flowers, which appear before the leaves, will form interesting class work.

Germination Continued.—In this class it is possible to carry out simple experi-

ments dealing with respiration, transpiration, heliotropism, etiolation and hydrotropism.

Heliotropism.—The growth of stems towards the light and roots from the light can be discovered by the following experiments :

(1) Sow Mustard seeds in two 3-inch pots. When about $1\frac{1}{2}$ inches high, place one pot in total darkness ; cover the second pot with a box having a hole bored in one side about level with the top of the seedlings. Leave for three days and then compare the direction of growth.

(2) Germinate Mustard seeds in sawdust. When the primary roots are about an inch long, take one or two seedlings, passing the roots through holes in a strip of cardboard ; plug the holes gently with cotton-wool to prevent slipping. Place the cardboard with the roots dipping into tap or well water in a glass jar or beaker. Cover the whole with a darkened box with a hole in the side as in Experiment 1. Examine at the end of three days, noting the position of the roots (these will have moved away from the light).

Etiolation.—Germinate Peas, Beans and Wheat in 3-inch pots in total darkness. Such seedlings differ from plants grown in the light. Show by repeating experiment on heliotropism how much more sensitive to light such etiolated seedlings are than normal plants.

Hydrotropism.—At the bottom of a clear glass jar place a small damp sponge. Lay the jar on its side and a short distance from the sponge place on a piece of cotton-wool a Bean seedling with a well-developed tap root, the growing point of which should be about an inch from the sponge. Leave

for a few days, and then notice that the root has a tendency to grow towards the moisture.

In Nature, two forces act on the roots, gravity and hydrotropism ; the direct influence of water on a main root frequently overcomes the directive influence of gravity if the two influences are not working together.

Respiration.—The respiratory process of man should, at this stage, be taken in the hygiene lessons. In any case, the children should know that carbon dioxide is exhaled. Plants have no respiratory organs, yet they need oxygen to develop. Revise the earlier lessons on carbon dioxide. Proceed as follows :

(1) Soak a handful of Peas in water for twelve hours ; allow to germinate on damp blotting-paper for twenty-four hours ; place in a wide-necked bottle and cork tightly. As a "control," cork a similar bottle. Place both bottles in a warm, dark cupboard for twenty-four hours, after which time test for the presence of CO_2 by introducing a lighted taper into the bottles.

(2) By inserting a test-tube of lime-water into the bottle containing the Peas, the presence of CO_2 can also be demonstrated.

(3) Place the half-opened flower buds of the Daisy or Dandelion in a wide-necked bottle. Cork tightly and leave for twenty-four hours ; again test for CO_2 .

(4) By using expanding buds or developing bulbs, the same results will be obtained.

(5) Apply the same test to roots, to prove that roots respire.

(6) Repeat procedure for Experiment (1), but instead of closing the bottle with a cork, arrange on a retort stand ;

fit up with a rubber stopper and a bent glass tube. Arrange the apparatus so that the tube will be placed in a beaker of mercury. Before dipping the tip of the tube in mercury, slightly warm the bottle with the hands. After setting the tube in the mercury, allow to stand for half an hour, then mark the height at which it stands. Keep the apparatus in a warm room and note the rise of the mercury in the tube. Why?

Transpiration.—(1) Take leaves with long petioles and broad, thin blades, such as the Geranium or Lesser Celandine. Place the cut lower ends of the stalks in red ink; note the coloration of the veins.

(2) Any plant in a pot will serve the purpose of this experiment. Cover over the soil with a sheet of india-rubber to prevent evaporation from the soil. Balance the pot on a pair of scales and observe the loss in weight. Repeat experiment on several days, noting the effect of temperature changes.

(3) Germinate Oats in a flower-pot. When about 2 inches high, place over them a glass jar. Note the drops of water on the tips of the leaves and the moisture condensed on the sides of the glass.

(4) Soak some strips of white blotting-paper in a 5 per cent. solution of cobalt chloride. Dry the strips and note the blue colour. Breathe on dry strips and again note change of colour; test another with a drop of water. The strips provide a delicate test for the detection of water vapour. If a pot plant is available—a Geranium is suitable—attach a strip on either side of a leaf, keeping paper flat by means of glass covers. Transpiration will be shown to be mainly from the underside of the leaf.

(5) A potometer will show the rate of transpiration.

(6) Dip a Laurel leaf in hot water; notice the bubbles which pass off.

Cut a leaf in two and place the cut edge in water. Note the stream of bubbles which pass off.

In dealing with the work of Standard VI, the teacher must have lesson material well prepared in advance, otherwise progress will be slow.

Plant and Flower Study.—A more detailed study of plants can now be made. The common weeds will provide sufficient material for work throughout this term, and for individual observational activity during vacation. Groundsel, Chickweed, Shepherd's Purse, Scarlet Pimpernel, May Weed, Corn Marigold, Creeping Buttercup, Poppy, Thistle, Nettle, Couch Grass and Bracken are familiar weeds, and from these, selections typical of the district should be made. What weeds are, and their place in the plant world, provides an interesting course of study.

Autumn Term

The fruits of the selected weeds studied during the summer should be considered, special attention being paid to the mechanism for dispersal.

Reproduction in the Vegetable Kingdom might be extended: rhizomes, stolons, runners, tubers, tuberous roots, bulbs and corms.

Animal Life.—A more detailed study of the Horse: external features; anatomical structure (see chapter on Animal Life). The value of the Horse to man; well-known breeds seen in the district. Study of the Earthworm by means of a terrarium.

Insect Life.—The life-history of the Wasp. In October or November secure

a Wasps' nest and examine same for construction.

Bird Life.—Simple lessons bearing on the economic importance of bird life to the community, correlating the knowledge gained in the lower part of the school. The necessity for the Wild Bird Protection Act; the effect of fashion on bird life and the reaction which necessarily follows.

Winter—Christmas to March

The weathering of rocks and the formation of soils. Elementary information lessons on the composition of rocks and the agencies which bring about their decomposition.

Plant life as an aid in the decomposition of rocks. (Demonstrate this point by growing seedlings with the roots lying on a slab of marble—roots excrete an acid.) The strength of roots, illustrated by walls built too near trees; the pavement bent and broken by growing roots.

Rain water contains carbon dioxide, and hence assists in the washing out from rocks of calcareous materials. The principle of osmosis dealt with experimentally.

Winter condition of plant and animal life. The identification of common trees revised and lessons given on the great forest lands of the world (correlating Geography).

STANDARD VII

Spring Term

An elementary knowledge of plant anatomy should be acquired during this term. Penknife sections with the aid of a good lens are sufficient, but where a low-powered microscope is

available, the lessons are more effective. For cell formation, a good starting-point is *Spirogyra*, a unicellular plant found floating on the surface of ponds. Divide a stiff leaf, for example Box, Laurel or Fuchsia, as follows:

Boil the entire leaves in caustic potash for about fifteen minutes. Remove a leaf with a pair of forceps and, under cold water, cut off a strip round the margin. With the aid of a needle the leaf can be readily divided into three parts, the upper epidermis, the lower epidermis and the mesophyll. The upper and lower epidermis are each one cell in thickness, and with the aid of a lens the construction can be easily observed. The central portion or mesophyll contains the vascular bundle and is several cells in thickness. This portion can be separated with needles, and the cells isolated. Some will be cylindrical and others of various shapes. The stringy portion or vascular tissue cannot be easily examined, except with a microscope.

The lower epidermis contains the stomata and guard cells through which air passes into the leaves and water passes off. The work in Standard VI will be of value at this stage. The structure of stems, if a microscope is not available, will be partly through penknife sections combined with black-board illustration. It will be necessary for the teacher to explain the positions of the various tissues, such as wood, bast and cambium, e.g. water containing salts in solution is taken up by means of the woody tissue, and food material manufactured in the leaves descends by means of the bast.

The main aim at this stage is to treat in a simple manner the work of the leaves in the formation of carbon

compounds. Take a leaf from a plant growing in a pot; a Geranium, Narcissus or Tulip will serve the purpose. Boil in water for a short time; drain off the water and then cover with methylated spirits. The green colouring matter is removed. Test the leaf for starch with iodine.

Early in the day cover a leaf of the plant with tinfoil, leaving a part exposed in the shape of a letter. Expose the plant to light until the afternoon. Remove the leaf; boil and decolorise; test with iodine; the letter should give the characteristic starch reaction. Even if the leaf is placed in warm water and treated with iodine, on holding the leaf to the light the letter will be plainly seen.

Similar tests can be applied to plants growing outside, e.g. a leaf of a Primrose or Laurel can be covered with cardboard, a letter or word having been previously cut in the card. What happens to the insoluble starch formed in the leaves during sunlight is a further problem for the class to solve.

Early in the term water cultures should be arranged. These will show conclusively that carbon can only be obtained from the air, yet with the normal solution, the plant grows and ultimately produces flowers and fruit. The other nine elements essential for the growth of plants will also be discovered through such experiments.

Root-hairs and their value to the plant; pollination and a very elementary idea of fertilisation can also be dealt with in this class. The development of a pollen grain in a 5 per cent. solution of sugar can be observed with a lens. The main point for the class to realise is that pollination is essential

before ovules become seeds. The agencies effecting pollination will provide useful observational activity. The structure of a grass floret, Oats, Wheat and Barley, compared.

Insect and Pond Life.—A more detailed study can be made of the breathing organs of larvæ and adult Water Beetles by means of an aquarium. Information has been given on these points in the section on Pond Life.

The study of a common fish, e.g. Trout or Roach, can be carried out by means of an aquarium. For the anatomical structure Sprats or Herrings might be used. The covering, respiratory organs, methods of swimming, etc., are points easily within the capacity of scholars of this class.

Autumn

The difference between fruits and seeds; elementary classification of fruits: the achene, follicle, silicle, capsule, pod, schizocarp, succulent fruits such as the pome, drupe and berry; the carbon content of seeds connected up with the work of leaves.

The common Grass of the hedgerow; cultivated Grasses. (A collection of Grasses should be made, mounted on cardboard and named, the mounted specimens being hung in the classroom.)

Leaf-fall.—Correlate transpiration, carbon fixation and the value of root-hairs to show that the process is a natural one. During the summer the leaves have been hard at work manufacturing carbon compounds which are stored in seeds, roots, stems, etc.; the machinery necessarily tends to wear out; colder weather reduces the

number of absorbing organs—the root-hairs—transpiration therefore becomes less ; trees detach leaves by cutting off the supply of food—formation of “ absciss ” layer.

The chlorophyll of the leaves becomes decomposed and passes back into the branches, some of it being stored in the buds. When this movement begins, the leaves begin to lose their greenness and the other pigment becomes prominent, giving the familiar autumnal shades.

Evergreens have leaves capable of withstanding frost. The outer cell walls are thickened, giving the leaves a more or less leathery appearance. With most evergreens the main roots are very deep and the root-hairs are not greatly affected by frost. Transpiration does not, however, proceed at the same rate, yet, as such trees are specially adapted to withstand hard weather, there is no necessity for the removal each year of their leafy coverings.

The Atmosphere.—Revise lower standard lessons on the composition of the atmosphere ; the soil ; plant structure, particularly the formation and position of the root-hairs—osmosis—the work of leaves.

Winter Term

Further study of Grasses collected during autumn and information lessons given on the natural Grass lands of the world.

Man's food supply traced to plant life ; all life depends primarily on the work of leaves. The various ways in which the reserve food material manufactured by plants is stored up—seeds, roots, etc., ultimately becoming food for man or animals. Lowly forms of plant life, such as moulds, studied by the aid of a lens or a microscope—parasites or saprophytes. Bacteria treated in a simple manner.

Animal Life.—The value of animals to man. The influence of man on the lower animals and the methods adopted to fit them for useful service to the community.

Bird Life.—The economic value of birds treated simply and generally.

Throughout the winter term the aim of the teacher should be to bring out, as far as possible, the inter-relationship existing between living things ; to give the scholars a lasting interest in the study of Nature and such an appreciation of the wonders of Nature that the work of the Creator is seen in all things.

SCHEME OF WORK FOR THE COUNTRY SCHOOL

A scheme of work in Nature Study for the small Country School is difficult to frame. The size of such a school may vary from 20 to 100 children, the staff consisting of a Head Teacher and one or more assistants, the Head taking Standards IV to VII. The following scheme may be found useful in a three-teacher school, but should be modified to meet the particular needs of the

district. It is assumed that Gardening will be taught.

INFANTS' DIVISION

In this department there should be no formal Nature lessons. The children should acquire a spontaneous interest in living things, and most of the knowledge should be the outcome of observational activity. A Nature Table is

essential for the display of specimens collected by teacher and scholars. This will be a record of the seasonal changes and will instil a "time order" in the minds of the growing scholars. Flowers should never be left without water, and, when handling flowers, the teacher should do so with great care in order to help the children to realise their delicacy and charm.

In talks about animals and birds, very little detail of structure is necessary. Little ones are most anxious to know "what he looks like" and "what he eats." Greater detail should be left for the upper standards.

Where Rabbits, Chickens, etc., are kept for practical work in the upper department, the little ones should be allowed to handle them occasionally. They seldom forget an animal they have been allowed to hold, and in the presence of "Teacher" much of the inherent "fear" disappears.

Young children are attracted by bright colour, sound, rapid movement, etc., and should be given the opportunity to draw in crayon simple objects, such as large seeds, fruits and flowers, and also to model them.

The "weather lessons" should be arranged to show the children how living things are affected by the sun, wind, rain and frost.

Outdoor lessons should be taken when possible. Interesting work can be carried on in the recognition of trees, flowers, birds, animals, etc. The following will suggest types which can be taken.

Spring and Summer

The re-birth of life; coming of Lambs; Hazel and Willow catkins; opening buds; spring flowers; Frog

spawn; seeds—some to be germinated in the classroom, others outdoors; Chickens, Ducklings, etc.; work of the farmer; pond life—Newts and Sticklebacks in an aquarium; wayside flowers; birds and their nests; Bees and Wasps; Butterflies, Caterpillars; the Hay harvest.

Autumn

The harvesting of crops; gathering of fruits; leaf coloration and fall of the leaf; food-storage organs of plants—very simply treated. Preparation for winter—Cows and Horses kept inside.

Winter

Care of animals by the farmer; feeding of Sheep in the fields. The wild animals and birds characteristic of the area. Resting trees; resting animals—the Dormouse, Hedgehog, Frog and Toad.

Frost and snow; Holly, Ivy, Mistletoe, etc.

MIDDLE DIVISION—STANDARDS II AND III

The scheme suggested here might be considered as a two-year course. Both classes will be taken together for oral work, and although similar topics will be dealt with, no repetition work will be necessary—the first- and second-year course will work quite well alternately.

Spring and Summer

Temperature and weather charts; observations made by the children, recorded by the teacher.

1st Year

Identification of the common trees of the district by means of buds and

bud arrangement on twigs, characteristic bark, etc.

Conditions necessary for germination: (1) air, (2) moisture, (3) warmth. Experiments with dicotyledonous seeds, such as Peas, Beans, Vetches, Turnips, Mustard and Cabbage.

Flowers of the hedgerow—Primrose, Wild Arum, Dog's Mercury, Ground Ivy, Violet, Greater Celandine, White, Yellow and Red Dead-nettle, Garlic, Mustard (Jack-in-the-hedge), etc. Weeds of the corn-fields—Coltsfoot, Thistles, Docks, Ragwort and Groundsel.

Animal Life.—The Cat and the Dog.

Bird Life.—Identification of the common birds of the district, with special reference to those valuable to the farmer—the Plover, Starling, Hedge-sparrow, Owl, Swallow, Swift, Lark, Blackbird and Thrush. Food of the young. Most of this work will be outdoor activity of the scholars. Several lessons should be given, however, to impart information which cannot be readily discovered by young observers; to stimulate interest in bird life and to prevent the robbing of nests for the sake of collecting eggs.

2nd Year

Temperature and weather charts as in first year. Identification of the common plants used to form hedges—the Hawthorn, Elm, Field Maple, Holly and Hazel.

Germination—similar experiments, using monocotyledons—Wheat, Oats, Barley, Rye and Maize.

Flowers and plants—the climbers of the hedgerows, such as the Wild Hop, Black and White Bryonies, Dewberry, Blackberry, Honeysuckle, Convolvulus and Woody Nightshade.

Insect Life.—Wasps and Bees; the Wasps' nest; nest of the Humble-bee; work of Bees.

Pond Life.—Frog spawn developed in classroom; life-history of the Frog as a continuous study throughout the year.

Bird Life.—Birds the farmer does not care for—the Rook, Crow, House-sparrow, Wood-pigeon, Jay, Kestrel, Jackdaw and Bullfinch. Lessons on such birds should help the children to realise that the food eaten by such birds during the winter (ground larvæ, seeds of weeds) and during the nesting season (grubs, larvæ, etc.) well repays the farmer for the small amount of his corn eaten in summer.

Autumn

1st Year

The harvesting and storage of farm crops; fruits of the flowers studied in spring; dispersal of fruit illustrated by the common weeds of the corn-fields. The common poisonous fruits, such as the Bryony, Nightshade, Laburnum, Ivy, Privet, etc. Leaf-fall and autumn tints.

Animal Life.—The care of farm animals—feeding, bedding. Elementary study of the Pig and Sheep. The Stoat and Weasel.

Bird Life.—The domesticated birds, such as the Fowl, Duck, Goose and Turkey.

2nd Year

The harvesting and storage of farm crops. Fruits of the hedgerow plants studied in spring; dispersal of fruits; poisonous berries.

Farm Animals.—The Cow and its value to the farmer; milking time;

butter- and cheese-making treated in a simple manner.

Insect Life.—Caterpillar collecting; subsequent history studied in school.

Wild Animals, such as the Rabbit and Hare; food during autumn; value to man—methods employed for capturing. Rats and Mice—food, habits and hiding-places.

Winter

1st Year

Water, ice and snow. The air. Elementary observations on the effect of burning objects in air; rusting.

Care of animals during winter; the feeding of Sheep in the fields; Cattle and Horses in the sheds and stables. Food used for each type of animal. The feeding of Poultry for market purposes.

Bird Life in Winter—a common resident studied with as much detail as possible.

2nd Year

Elementary lessons on water continued; crystals of snow and ice. Temperature and how to measure same. Artificial freezing—mixture of snow and salt, crystals of alum, saltpetre, copper sulphate (blue stone). Expansion of water on heating and freezing.

Soluble and insoluble substances.

The feeding of animals during winter.

Bird Life in winter. A common resident given particular attention.

STANDARDS IV AND V

Spring and Summer

1st Year

Operations carried out in preparing soil for the reception of seeds; use of

the plough, ridge plough, cultivator, harrow, roller (Cambridge and smooth), drill and turnip drill. Identification of "seeds" such as Wheat, Barley, Oats, Rye, Peas (field), Beans, Vetches, Mangolds, Turnips, Swedes, Carrots, Clover and Mustard.

Insect Life.—Identification of the various ground larvæ, such as the Wireworm, Cockchafer Grub, Caterpillar of the Hart and Dart Moth, Leather-jacket, Centipede and Millipede, the White Cabbage Butterfly and its larvæ, the Ox Warble Fly (maggot develops beneath the hides of cattle), the Turnip Beetle. With the exception of the Ox Warble Fly, the life-histories can be studied in a terrarium.

Grasses should be studied during this and the next term; a named collection should be hung in an easily accessible position on the walls of the classroom. The following forms should be known:

- (1) Hedge Grasses.
- (2) Permanent Pasture Grasses.
- (3) Temporary Pasture Grasses.

Haymaking—conditions for making good stacks—sweating. Visit to a farm to observe sheep shearing.

2nd Year

Weather observations throughout—the thermometer and its uses. Soils and soil formation—composition of soils, sand, clay, humus; soil water, capillarity. Improvement of the soil by deep cultivation. The "Plough," "Lime" and "Iron Pan"—the reason for this formation.

The plant in relation to soil; root and shoot system; kinds of roots; root storage organs; water cultures.

Cultivated Grasses; Spring and

Autumn Wheat ; Barley and Oats ; uses of the cereals.

Common weeds of the fields ; methods used to eradicate same. Bees and their value to man.

Autumn

1st Year

Harvesting of grain crops—threshing, winnowing ; marketing, milling. Fruits—packing and grading for market.

Further Study of Sheep.—Kinds reared for the production of wool. Elementary knowledge of diseases, such as Foot Rot, the Maggot (brought about by the Sheep Maggot Fly, similar to Green and Blue Bottle Flies), the Liver Fluke and Sheep Scab.

Dispersal of fruits, and agencies effecting the spread of weeds.

Practical work on the rearing of Poultry where possible, especially useful for girls ; kinds of Fowl kept for the table, for egg-laying, etc.

2nd Year

The harvesting and stacking of Corn crops ; marketing of fruit and vegetables ; system of grading and packing fruits.

Animal Life.—Cattle—names given to the sexes, e.g. Bull, Cow, Heifer, Steer, Bullock, etc. The value of cattle to the community ; fat and store cattle. Kinds of cattle kept on local farms. Visit to a farm to observe the process of butter-making.

Winter

1st Year

The life-histories of wild animals, such as the Fox, Stoat and Weasel.

Game Birds.—General features and characteristics of the Pheasant and Partridge. The study of Water Fowl where possible—the Coot, Wild Duck, Snipe.

Winter work of the farmer ; care of animals ; treatment of fruit trees (grease banding and lime washing). The school garden during the winter ; reasons for double digging and trenching.

The Wild Rabbit or Hare ; food during the winter ; value to man as food ; methods of securing such animals, e.g. traps, guns and snares, ferreting and shooting.

Elementary lessons on the interaction of country and town.

2nd Year

Manures—farmyard manure—artificial.

Feeding material for stock ; linseed and cotton cake, etc., chaff, Swedes and Mangolds ; special attention to the feeding of cattle.

Wild life of the woods and fields ; the Mole, Hedgehog and Watervole, Squirrel and Dormouse.

Town and country life compared.

STANDARDS VI AND VII

(One-year Course)

Much of the work in this class should be of an individual nature and mainly private study. The leaflets issued in book form by the Ministry of Agriculture and Fisheries provide excellent material for such work, the teacher giving explanatory lessons occasionally. An excellent book under the title

"Rural Science" has recently been published (by McDougall), and this should be found very useful as a guide for individual work.

Spring and Summer

Soil formation and composition; movement of water in soil; water-holding capacity; conditions necessary for germination. The plant in its relationship with the soil. Leaves and their work; formation of starch. Identification of common plant diseases.

(1) Club Root in members of the Cabbage family—Turnip, Cabbage, Kale, etc.

(2) Potato Blight, Scab, Wart Disease.

(3) Blight on Beans.

(4) Rust on Wheat, etc.

Visits to a farm or blacksmith's shop. Farm machines and their work; the drill and self-binder to receive special consideration. The construction of a barometer; its uses, etc.

Autumn

Cereal crops; root crops and tubers; weeds of the farm—rhizomes of Couch Grass, Coltsfoot, Convolvulus (Bind-

weed), Thistles of various kinds, Nettles, etc.

Annual weeds—Poppy, May Weed, etc.

Rotation of crops—reason for rotation. Various systems of rotation explained. Field work—the plough, its parts, etc.

Pruning of fruit trees.

Work in the fields; manuring for special crops; land drainage; reasons for same and methods employed.

Winter

Anatomical structure of the Horse—the hoof to receive special attention. Breeds of Horses used in the neighbourhood.

Cattle.—Dairy and store cattle. Breeds suitable for meat production or dairy work.

Sheep.—Breeds of Sheep; common diseases.

Pigs.—Breeds of Pigs and their management.

Poultry and Poultry Rearing taken from the practical point of view. Incubators and their management; foster-mothers.

Throughout the winter term the work should be as practical as possible.

OUTLINE SCHEME FOR THE SCHOOL GARDENING CLASS

Indoor Work during the Winter

Classification of soils—heavy, medium, light. Practical tests for good and bad soils.

Soil pests; preserving specimens in a solution of formalin.

Composition of soils; how to determine by mechanical analysis.

Soil and subsoil; humus and its properties.

The seed order—plan of cropping. Potato sets.

The effect of lime on clay, demonstrated by experiment.

Simple experiments on clay to show shrinkage; cracking after puddling.

Plant foods in the soil, available and unavailable. Artificial and natural manures. Pot plant tests to demonstrate plant foods. Rotation of crops and reasons for such.

Plant Physiology.—Root pressure; respiration; transpiration; assimilation. Simple experiments to show that each takes place.

Water in soils—capillarity; evaporation. Water-holding capacity of sand, clay and humus compared by simple experiments.

Reproduction of plants—seeds, cuttings, layering, root division, etc.

Pollination, etc.

Enemies and friends of the gardener. Life-history of common pests.

SCHEME OF WORK IN NATURE STUDY FOR THE TOWN OR CITY SCHOOL

The following scheme of work is intended primarily to meet the needs of schools in which experimental work can be carried out in Chemistry, Physics and Electricity. Often such schools neglect the study of Natural History in the upper standards owing to the difficulty in obtaining suitable material, but the study of Natural History can be carried out experimentally even in a school in the heart of a city. Although children of eleven are interested in carrying out simple experiments in Chemistry, Electricity or Physics, they are equally interested in finding out why a seed grows and the conditions necessary for its growth. These points can satisfactorily be discovered by experiment, and as the germination takes some considerable time, such observational work can well be carried out without upsetting the normal Science course.

Further, the food material required by plants can be demonstrated by means of water or sand cultures. By such work a child learns something of the relative position of plant life in the economy of Nature and, in later lessons on the work of leaves, is brought to

realise the value of the Vegetable Kingdom to mankind.

Again, the study of plant life generally can and should receive more attention. Very few towns are without public parks and pleasure grounds, and first-hand knowledge of buds, leaves, the characteristics of one or more common trees and, in most cases, of Water Fowl, can be obtained. Even the rooting system of one or more plants can be successfully dealt with. For example, the Potato will readily develop in flower-pots containing damp sawdust or soil. Carrots and the tap-rooted vegetables can be used for demonstrating the second year's growth of biennials or the production of adventitious roots. Flower and seed production can be followed by means of window boxes, even if annuals only are cultivated.

The study of insect life gives a wide scope for first-hand observational work. In the "New Suggestions" (Board of Education) a description of a very useful type of breeding cage for Butterflies and Moths is given on p. 234, and in a later chapter additional information will be found.

An aquarium gives further scope for the enthusiastic teacher. Even if Goldfish are the only inhabitants, they will provide useful material for detailed observational activity. Frog spawn and various insect larvæ can be obtained by teachers on their week-end excursions. A letter to the head teacher of a country school will be the means of obtaining suitable material if other avenues of supply are not available.

Again, there are many firms in this country which specially cater for the supply of Nature Study specimens to schools. The cost is usually very low, not exceeding £2 per term of 10 weeks, an ample supply of specimens for classes of fifty children being provided. By such a method, children are brought into contact with some of the wonders of plant life, although not with the plants in their natural surroundings.

In any case, the study of Natural History should not be denied to the town child. Obstacles can generally be overcome by the teacher who sets out to bring his scholars into the fullest relationship with the world in which they live.

STANDARD V

1st Term—April to Midsummer

(a) The structure of common flowers, such as the Daffodil, Tulip, Primrose, Wallflower and Marguerite; the position of the ovaries; hypogynous and epigynous flowers compared; penknife sections of ovaries examined and position of seeds noted.

The development of plants grown from seed in flower-pots or window-boxes, carefully noted and recorded—sown in April.

Outdoor or Team Work.—Return of migratory birds, e.g. the Swallow.

Mating-time of Pigeons and Sparrows.

Nests and nesting-places of the bird or birds selected.

(b) Development of Frog or Toad spawn.

(c) The opening buds of twigs in the classroom.

Bud arrangement on common trees of the district.

(d) Lessons on plant structure, e.g. forms of root. Tap root, e.g. Radish and Carrot. Potato tuber.

(e) Elementary chemistry in relation to plant life.

Air—its composition and physical properties; oxygen and carbon dioxide; the respiration of plants.

The Preparation of Oxygen.—Its properties and value to the physician.

The proportion of oxygen in the atmosphere; rusting of iron; very elementary knowledge of oxygen.

The atmosphere from chemical and hygienic point of view.

The Preparation of Hydrogen.—Contrast its properties with that of oxygen; its use as the lightest gas known.

The Preparation of Carbon Dioxide.—Properties; vitiation of the atmosphere; necessity for ventilation.

2nd Term—Midsummer to Christmas

Water—its composition and physical properties.

Elementary lessons on transpiration.

Leaf-fall and Autumn tints.

Fruits and Fruit Dispersal.—Lessons based on the plants grown in window-boxes, flower-pots, etc.

Harvest of crops in the country.

Value of the farmer and gardener to the town dweller.

The Soil.—Lessons correlated with Geography; the formation of the soil; mechanical analysis; water in the soil; movement of water in the soil.

Collection of cocoons—pupæ, etc., for the terrarium.

Properties of Common Substances.—Materials which dissolve in water, such as common salt and sugar; substances which are insoluble, such as sand and chalk; filtration and distillation on a small scale.

Apply information to water in the soil.

Sulphur—its more pronounced properties, insoluble in water, soluble in carbon bisulphide; plastic sulphur, uses of sulphur.

Phosphorus—properties, soluble in carbon bisulphide, insoluble in water; burning phosphorus; manufacture of matches.

Carbon—modifications; charcoal, graphite, diamond; manufacture of wood charcoal on a large scale; manufacture in laboratory; animal charcoal. Wood charcoal used to absorb bad-smelling gases; animal charcoal used to abstract colour in sugar refining. Heat some small pieces of bone in a test-tube and ignite issuing fumes. Manufacture of lead pencils.

3rd Term—Christmas to April

The use of measuring instruments; measurement of the volume of solids by means of a measuring jar; the measurement of the volume of a hollow vessel by means of the burette; how to read the burette.

Measurement of weight—the spring balance simply treated.

Ice—floats on water, measurement of temperature by means of centigrade

and Fahrenheit thermometers; freezing of pipes in winter; temperature of a mixture of ice and water.

The making of a thermometer; its use in determining temperatures; the determination of the melting-point of wax.

Revision of previous work; a second preparation of oxygen is useful.

Plant study—the parts of the seed and seedling; the resisting powers of resting seeds; the visible order of germination. The nature and functions of cotyledons and endosperm; bulbs and their formation—Snowdrop, Daffodil and Onion compared with the corm of the Crocus. (See also Section IV.)

Throughout the year the class should have some definite observational work to perform. Team or group work might include the study of particular trees and birds, records being made by the scholars. From time to time class discussions on the subjects of study should take place. The teacher should use such periods to correct faulty deductions and to suggest lines on which further work might be carried out.

Temperature and weather charts should also be kept throughout the year. Direction of wind, rainfall, barometric pressure and temperature can be graphically recorded, useful deductions being made from time to time.

STANDARD VI

1st Term—April to August

Detailed study of the Potato—external examination; the position of the eyes, the spiral arrangement to be discovered. The eyes might usefully be compared with the buds on twigs, the development of which

can be studied at the same time. This can be followed by experiments to discover the conditions necessary for development; the iodine test for starch should be applied.

(1) Potatoes planted in sawdust and soil (dry and wet medium in each case).

(2) Sets in water only.

(3) Small pieces with and without "eyes."

(4) "Sets" planted outdoors, in 12-inch pots or butter-boxes, using soil.

Germination of "seeds" of Barley, Wheat and Oats indoors and in butter-boxes outside.

Common flowers examined; relative position of the anthers and stigma. Pollination and the agencies which effect same.

Life-history of Bees, as far as possible through observational activity.

The thermometer, construction, both scales. Heat transference, conduction, convection, radiation, expansion, coal fires, gas fires, electric fires, hot-water supply, thermos flask, scale on boiler plates, manufacture of big guns, tyres on wheels, the leaving of spaces between the joints of the rails on railways, expansion bend.

Ventilation, revision lesson on carbon dioxide.

Flames—the bunsen flame, glass bending, the candle flame, incandescent mantles. Simple experiments on friction, the pulley and weights.

Revision of oxygen, reduction of oxides (e.g. red lead) by means of charcoal block and blow-pipe.

Revision of properties of sulphur; mixtures and compounds illustrated by mixture of sulphur and iron filings—how to obtain the iron by means of a magnet and the sulphur by using

carbon bisulphide; heat a mixture of iron filings and sulphur to form a new chemical substance, iron sulphide.

Preparation on a small scale of sulphuretted hydrogen; pass gas through an acidulated solution of lead nitrate and observe reaction; how to test for lead in water: test for sewage in water by Nessler's solution (a solution of mercuric iodide and potassium iodide in excess of potassium hydroxide), hard and soft water.

2nd Term—September to Christmas

Fruits and seeds. Succulent and dry fruits compared. Dispersal of fruits and seeds in as much detail as possible. Composition of seeds; the nature and properties of the food substances found in the cotyledons and endosperm. Wheat and Barley used as a basis.

Soil.—Movement of water in soil by capillarity; types of soil—sandy, clayey, chalky; water-holding properties of types compared.

The study of Caterpillars by means of a terrarium.

Preparation of chlorine; its uses as a sterilising agent for water contaminated with sewage; distillation.

Preparation of hydrogen for study of diffusion.

Mirrors—the 45 Mirror; periscope; eclipses of the moon, lenses, focal length, images, the "magic lantern," cinematograph, candle power.

3rd Term—Christmas to April

Magnetism—lodestone, magnetic fields, action of soft-iron ring, permanent magnets, induced magnets, the mariner's compass, the dip needle, the gold-leaf electroscope or pithballs, static electricity, current electricity as produced by a dry battery, its use to

produce a light, an electro magnet made by winding copper wire round a nail and connecting to a dry battery.

The lever used as an introduction to chemical balance; the accuracy of the chemical balance. Use of chemical balance to determine if magnesium gains or loses in weight when heated in a confined space.

Revision of previous work.

The food-storage organs of plants—rhizomes of the Primrose and Solomon's Seal should be examined and the surfaces tested for starch; the development of these rhizomes to be observed in window-boxes.

Cut off the top part of the tap root of the Carrot and Parsnip; plant the lower portion in damp sawdust or place in water and notice the formation of adventitious shoots. Examine the opening buds of one or two trees, noticing the shedding of the bud scales and the unfolding of the young foliage leaves. In March secure a leafy Willow twig or the stem and leaves of a pot plant; with the aid of a potometer revise the work on transpiration.

Throughout the year the study of common animals might be considered as a form of outdoor activity. The Horse, Cow, Sheep and Squirrel are suggested as types. Discussion lessons, collating the group work, should be taken monthly, and information given by the teacher on points of structure, habits and uses, which often cannot be discovered by individual observation in large cities.

STANDARD VII

1st Term—April to Midsummer

Work of leaves—respiration and transpiration revised.

Assimilation of CO_2 . Formation of starch in sunlight by the leaves.

Food required by plants; water cultures (experiments with Wheat and Barley to prove the elements necessary). Formation of root-hairs; value of such to the plant.

Revision of magnetism, static electricity, current electricity, the simple cell, Daniell's cell, bichromate cell; individual work with the bichromate cell, made from small jam jars, carbon rods from used dry batteries and bichromate mixture and zinc rods supplied by the teacher; cells in series and parallel; the electric circle, tapping key, induced currents, electro magnets, electric bells; Rhumkorff's coil and applications; sparking plugs; simple electric motors; an introduction to wireless telegraphy.

Experiments with levers—pump handle, boiler valve, cold water tank lever, crowbar, wheel and axle, very simple calculations.

2nd Term—Midsummer to Christmas

Osmosis and osmotic pressure. Elementary plant anatomy; structure of root-hairs and the connection between osmotic pressure, soil water and root-hairs treated in an elementary manner.

The barometer, pressure of water, water supply; the syphon, pure and impure water; the thermometer, various scales, maximum and minimum thermometers.

Density of solids and liquids treated in a simple manner; use of burette; Hare's apparatus, V-tube, density bottle, a few simple calculations; the peculiar behaviour of water at certain temperatures. The spring balance revised. Centres of gravity; pulleys; the crane.

3rd Term—Christmas to April

The value of plant life to mankind. Leaves considered as factories, stems as the lines of communication and flowers and seeds as the warehouses.

The interaction of insect, bird and animal life in the scheme of Nature.

Mainly revision; lessons based on the cycle pump, thermos flask, hot-water supply; experiments with electric cells, and with common elements—sulphur, phosphorus, carbon; manufacture of soap, acids, oxides; preparation of gases; iodine extraction of starch from Potatoes and Wheat; individual experiments where possible.

Lives of great scientists may be taken.

In industrial areas the Standard VII scheme in science might be modified to meet the particular needs of the district.

For coal-mining areas a course of lessons should be arranged dealing with the formation of coal, general method of mining, safety in the mines, etc.

The following is another scheme suitable for schools in districts where the manufacture of iron and steel is a prominent feature. In the author's previous school, the Syllabus was

carried out with Standard VII boys, the girls taking as an alternative Home Nursing.

It is, of course, necessary that the theoretical work on the iron industry should have a practical bearing, and hence visits to various works are essential. The construction of a Blast Furnace can be explained by means of diagrams, but to see a furnace in operation adds greatly to the value of such lessons. (See Syllabus.)

Metallurgy.—Early history of the iron industry; examination of the chief ores of iron; distribution in the world, with special reference to the ores mined and used in Great Britain.

Local ores; simple chemical composition of ores.

Early method of iron manufacture; gradual development of modern Blast Furnace; modern Blast Furnace work.

- (a) Preparation of local ores.
- (b) Calciners used locally.
- (c) Result of calcination of ores.
- (d) Construction of a Blast Furnace.
- (e) Charging a Blast Furnace.

Fuel—flux and load; action in the furnace, e.g. formation of metallic iron, slag and gas. Tapping of furnaces—pig bed. Moulding and rolling.

SECTION IV

SUGGESTIONS FOR PRACTICAL WORK

THIS section will deal with the practical application of the methods recommended for the conduct of Nature lessons. In several parts reference to "Nature Walks" and "Outdoor Activities" has been made, and here in a brief manner these points will be dealt with.

Nature Walks

The object of all Nature Study is to bring children into an intimate relationship with living things in the world around them. It is, therefore, necessary for children to observe living things—plants and animals—in their natural surroundings. In towns, the public parks should be utilised to the full; in urban and rural areas, very little difficulty arises. Gardens, allotments and fields are usually within easy reach of the school.

Planning a Nature Walk. (Time allowed for the walk, 1½ hours.)—When a walk is to be undertaken, the teacher must have a definite scheme. In spring (February) the study of the general features of one or more common trees might be the object in view. Before leaving the classroom the children should know exactly what they are expected to observe. They should be provided with notebooks and pencils, and can be expected to observe and make notes on the following points:

(1) General character of the branching—open, spreading or close. Position of branches—at right angles to the main stem, drooping or upward tendency. Main branches thick or thin at points where they join the main stem or trunk (cf. Oak, Lombardy Poplar [Fig. 66]).

(2) Bark—colour, scaly, furrowed, smooth or rough.

(3) Buds—colour, arrangement on twigs, number of protecting scales, etc.

(4) Trees or plants growing near to particular trees.

(5) East and west side—presence of an epiphyte on the west.

(6) Characteristics of the younger branches—presence or absence of suckers (adventitious shoots). These develop from the base of the trunk (cf. Lime and Elm).

Nature of soil in the vicinity.

Points 1 and 2 will be sufficient for Standards II and III.

Points 1 to 4 characteristics should be observed by Standards IV and V.

Points 1 to 6 characteristics should be observed by Standards VI and VII.

The names of trees recommended for study within the capacity of the scholars are to be found in the syllabuses.

Although the study of trees is the main purpose of a walk, observations on other points should not be entirely excluded. If the walk is well planned (the teacher having gone over the

ground a day or two before), certain flowers or wayside plants will no doubt be available for study under natural conditions. Attention should be called to the selected plants. Here the teacher must be on guard against unnecessary destruction; observation and examination can be carried out without removing the plants, sketches being made in the Nature Notebooks, of which alternate leaves should be of plain paper.

As there are so many points of interest outside school to attract attention, the teacher must guard against attempting too much. It is better to concentrate on one or two main points than to deal with every feature that attracts the interest of the children. Give the class the opportunity of making notes on any interesting features of the walk which appeal to them, apart from the definite line of study, and in a later composition lesson let the scholars give an account of the walk.

The best method of conducting a Nature Walk with a class of fifty is to arrange the class in teams, each in charge of a leader. When this is done, four types of trees can be studied at the same time, or, when observing one type only, marks can be allocated to the team doing the best work.

At a later date a walk should be arranged over the same ground. The leaves of the trees studied during the earlier walk then form the main topic, and some notice should be taken of the struggle for existence.

For Standards IV to VII long walks might be undertaken early in autumn, immediately after the summer vacation; these should occupy the whole afternoon. Particular attention could be called to Grasses, and this gives

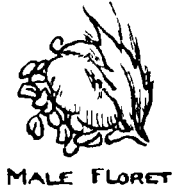
scope for excellent team work, teams concentrating on either Meadow, Hedgerow or cultivated Grasses. Other sections might usefully study climbing plants, such as the Honeysuckle, Convolvulus and the Bryonies; or fruit dispersal, special consideration being given to the poisonous fruits and plants. Previous to walks for Standards VI and VII, a sketch map of the district should be constructed, varying in difficulty with the standard. An ordinary survey map would also be found of value.

Notes on observations should be made by the scholars. Specimens, one of each type, should be brought to school and labelled, a few particulars, relative to the plants, such as habitat and size, being recorded. Later, composition might be written on the subjects studied in their natural surroundings. Class discussions are exceptionally useful; the teacher need not take any definite part, unless incorrect deductions are made. It is, however, advisable to make suggestions for further individual observations, and generally the class will, in their own time, visit the selected spots again.

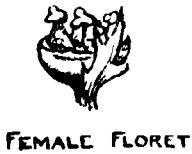
The Nature work carried out in connection with the Boy Scout and Girl Guide Movements is a real help to the town and city teachers. By means of marches and summer camps, the interest of the boys and girls in Nature Study is considerably strengthened. Many teachers show great keenness in the outdoor activities of their scholars. In one of the largest towns of the Black Country it is a familiar sight to see groups of scholars out for a walk with their teachers on Saturday mornings. One head teacher has for many years rented a large

THE LOMBARDY POPLAR

WINTER CONDITION



MALE FLORET



FEMALE FLORET



MALE CATKINS



FIG. 66.

DRAWN FROM NATURE

HR

THE LOMBARDY POPLAR.

This is the most easily recognised of the Poplars grown in this country. Its straight bole and comparatively thin lateral branches are distinctive features. The carpellary and staminate inflorescences are found on separate trees—both take the form of catkins.

orchard three miles from the town. Every Saturday, wet or fine, boys of the upper standards visit the orchard, not to work, but for the study of Nature. Their reward comes in the autumn—the fruit becomes the property of the boys who have shown an interest in some particular aspect of Nature Study.

School camps and other organisations render valuable help to the Nature Study teacher, and, taking all factors into consideration, there should be no difficulty in arranging for first-hand observations to follow up work done through Nature Walks.

Pond Life

A Nature Walk for the purpose of stocking an aquarium and gaining first-hand knowledge of aquatic life should be arranged in June.

Each team should be provided with one or more butterfly nets, each scholar bringing his own collecting vessel—an ordinary two-pound glass jam jar.

On arrival at the selected pond, the plants on the surface should receive consideration (e.g. the Water Crowfoot, Celery-leaved Buttercup, Marsh Marigold, Duckweed). The teacher should demonstrate the use of the net; the best hauls are obtained by sweeping the net under the bank or amongst the water weeds. In this manner, varieties of the Caddis larvæ and the aquatic Beetles will be secured.

Then let the team leaders commence operations; it will be found that all scholars are good pond hunters and keen observers of the specimens secured. Some of the scholars will be interested in the aquatic plants, others in the

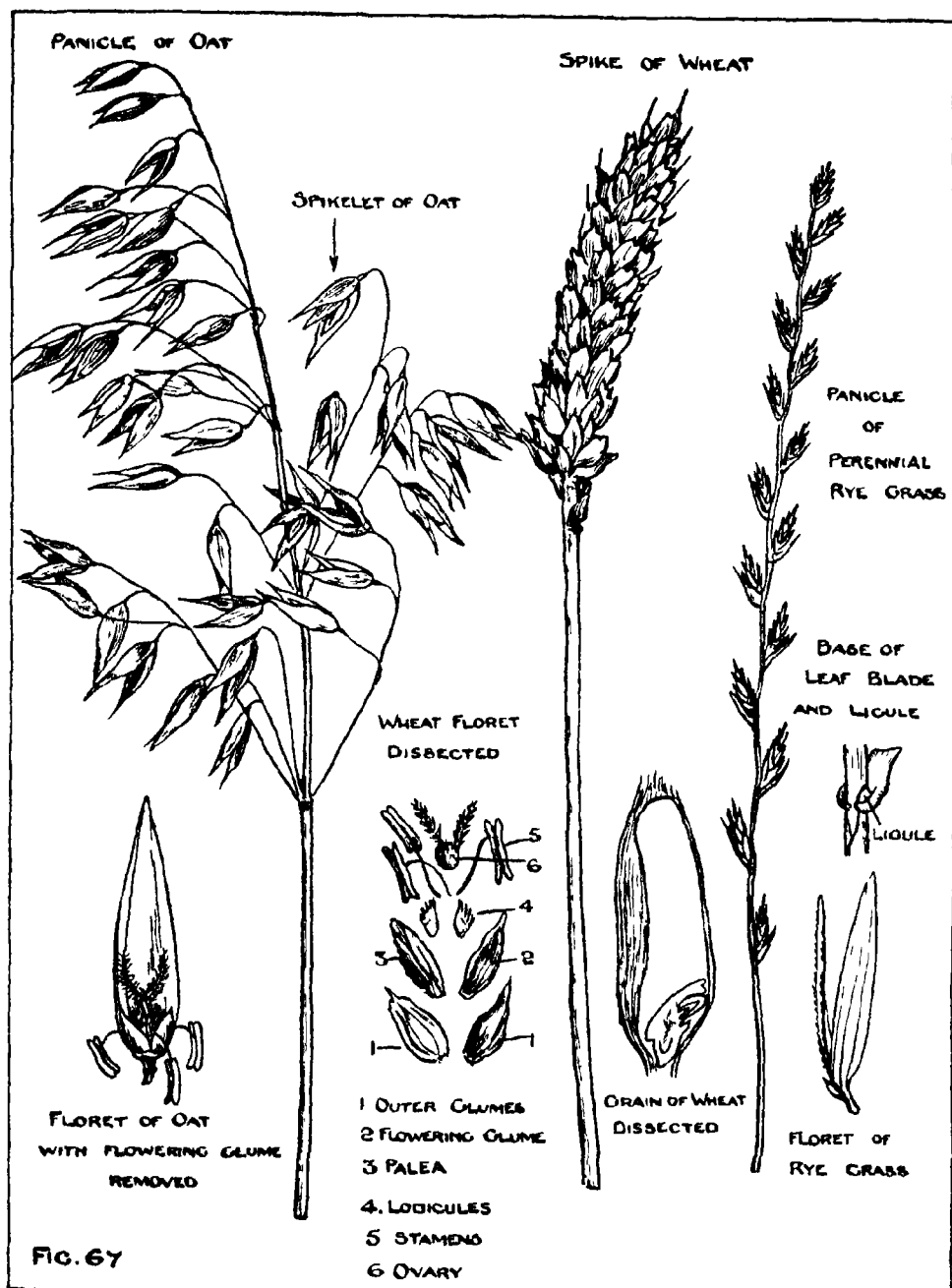
larvæ, many in the adult stages. After each pupil has received a specimen, fishing operations should cease. The next half-hour should be given up to individual observational work. Each scholar should make drawings of the object in his particular jar and record special points of interest observed.

Specimens not required for the aquarium should be returned to the pond.

The Aquarium

Of all forms of observational activity undertaken in the classroom, the keeping of an aquarium is perhaps the most interesting from the child's point of view. It supplies a never-ending fascination and provides a source of pleasure and interest. If well managed, the class aquarium requires the minimum of attention and is a beautiful adjunct to the room.

A Permanent Aquarium.—In towns an old glass accumulator provides an excellent form. The illustration given (Fig. 68) is that of one in use at the present time containing Goldfish, Water Snails and a Mayfly larva, the latter being an especial favourite with the children—Canadian Pond Weed, Bladderwort and Duckweed. The type mentioned is 20 inches long, 18 inches wide and 13 inches deep, originally purchased for 3s. 6d. The second illustration is of a type not generally used. This was purchased from a jam factory for 2s. 6d., and takes the form of a "carboy" (large vessels used by firms supplying laboratory reagents), the top of which has been broken off. Such vessels are often damaged in this way and are sold as "scrap" (Fig. 69).



THE OAT, WHEAT AND PERENNIAL RYE GRASS.

The illustration gives the clue to the technical terms applied to the various parts. Note that in the Oat and Wheat three stamens are present—this is a characteristic feature of the Natural Order. The "ligule" is another important feature.

For schools having classes in woodwork and metalwork, the construction of a suitable aquarium should form part of the scheme.

When adult Beetles and Water Boatmen are the objects of study, the aquarium should be covered over with perforated zinc.

In many cases a permanent aquarium cannot be installed, but even in these unfortunate schools the study of aquatic life can temporarily be carried on. Much good work is accomplished with ordinary jam jars or Goldfish globes, as supplied by the world-renowned "Sixpenny" Store.

Whichever form the aquarium takes, it is essential to bear in mind that plants and aquatic animals require oxygen. Although water plants absorb CO_2 in daylight, it is advisable to change the water occasionally; more often when small vessels are being

used. Teachers often fail in their attempts to show the development of Frog spawn in glass jars for two reasons. In the first place, too much spawn is placed in the jars (half a dozen eggs being sufficient), and in the second they do not realise that the developing spawn requires a supply of oxygen (fresh water is necessary every other day).

The Terrarium

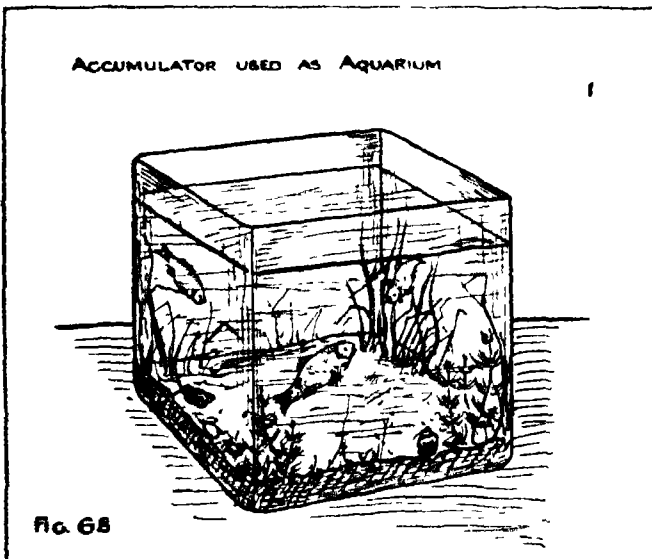
For studying the life-histories of Moths, Butterflies and ground larvæ, a very simple terrarium can be constructed out of a sugar or other box. Part of the sides should be removed and replaced by glass, a piece of perforated zinc being substituted for the lid. When possible the bottom of the cage should be covered with a layer of turf or soil, food suitable to the objects of study being supplied. Such

an apparatus can be modified to meet the needs of Frogs, Toads, Earthworms, Ants or Spiders.

In the "Suggestions" a very simple form of breeding cage is described. The above box terrarium will be found suitable for general observational work; several, of course, may be used at the same time.

Bird Tables

The simplest form of Bird Table consists of a flat board $2\frac{1}{2}$ feet square, nailed to a



ACCUMULATOR USED AS AQUARIUM

ACCUMULATOR USED AS AQUARIUM.

Glass vessels suitable for use in schools can usually be obtained at a reasonable price from firms who make submarine accumulators.

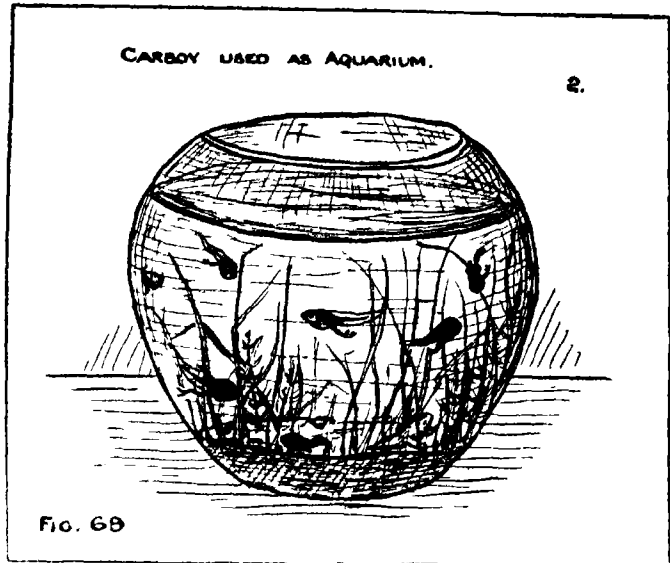
pole about 4 feet high, erected in the corner of the playground. Throughout the year, food of various kinds—breadcrumbs, small seeds, scraps of meat, etc.—should be supplied, together with a small vessel of water. If this is done, the birds get accustomed to the table and become so tame that, even with the scholars in close proximity, they will feed quite readily, giving ample scope for observational work. To obtain the best results it is advisable to supply the food at definite times

each day; the birds will become accustomed to the "feeding" time, and in winter will be at the table before time.

Another form of table consists of a single board, with a quarter of an inch edge all round to prevent food rolling off, erected outside the classroom window in such a position that it can be readily seen inside the room and food can be easily placed on the structure. When first erected a good supply should be provided before the dinner recess and on a Friday afternoon. Gradually the birds discover the feeding-place, and eventually become so accustomed to the position that during lesson periods they are frequent visitors. In winter especially, after school opens each morning, much useful work can be accomplished.

The Keeping of Pets

Whenever possible the keeping of



CARBOY USED AS AQUARIUM.

Although quite suitable, the carboy does not meet the purpose so well as an old accumulator. The surface of water exposed to the air is much more restricted.

pets is advisable, although it involves a certain amount of work during week-ends and holidays for someone. In country areas the keeping of Rabbits and Fowls provides excellent and useful activity for the older scholars, but for town and city schools Mice and White Rats are perhaps more suitable. Generally speaking, town schools are somewhat handicapped in this direction, but if Mice or Rats are kept, they not only provide useful observational work, but an idea of the care necessary for the welfare of such animals is instilled into the minds of the scholars. The best course to adopt seems to be to allow a senior boy or girl to take the pets home for the week-end. This plan works admirably, and incidentally brings the home into intimate relationship with the activity of the school.

Absolute cleanliness is essential where pets are kept. The Common Tortoise

makes an excellent pet for the town school. A large terrarium is essential for sleeping quarters. Its food consists of vegetable material, and in summer Lettuce may be regarded as the chief diet.

Sketching and Note-taking

Whenever seeds, plants, insects or trees are being examined, scholars should not only make notes of their own personal observations, but should make sketches illustrating the points noted. In the lower classes, such sketches will be crude when considered from the artist's point of view, but so long as they are a clear indication of the child's developing observational powers, they should satisfy the teacher. With the middle

classes an advance from the artistic viewpoint can be expected, and the Senior Department should be able to illustrate artistically and correctly the various aspects and points noticed during their studies.

Notebooks having interleaved drawing-paper should be used from Standard IV upwards. Sketches must be made during the Nature lesson and not reserved only for the Drawing Class.

In the Infants' Department, and up to Standard II, models in clay or plasticine of large seeds, fruits and simple flowers might usefully be made. This helps considerably the work of the upper classes and provides keen observational work for the children.

In sketching and note-taking, let this be the children's own work, and not reproductions from the blackboard.

SECTION V

NOTES ON LESSONS

1st Lesson

Structure of a Grass Plant

EXAMPLES of any kind of Grass will serve for this lesson.

Rooting System.—Reference should be made to the rooting system observed during experiments in germination. Compare a well-developed plant and notice the large number of adventitious roots which arise from all the underground nodes of the stem.

Stem.—The stems, which are termed *culms*, are cylindrical and hollow; the nodes, however, are solid. (The Maize is an exception to the rule, being solid throughout.) Generally the buds break through the base of the enclosing leaf sheath and for a short time the branches grow more or less horizontally, sometimes underground, forming rhizomes, from which leaves and flowering stems are sent up. Couch Grass and Smooth-stalked Meadow Grass are good examples.

Sometimes branches emerge at the point where the leaf sheath joins the stem, ultimately tearing the subtending leaf. This is well illustrated in Wheat, Barley, Oats, Cocksfoot and Rye Grasses.

Leaf.—The leaf of a grass consists of two parts, the blade and the sheath. The latter surrounds the stem like a tube split down one side, its free edges overlapping for some distance. In the

Cocksfoot and many Meadow Grasses the leaf sheath is not split, but forms an encircling tube.

The leaf blade is generally long, narrow and flat, but in grasses growing in dry places is often folded and appears cylindrical. At the point where the blade joins the sheath, the inside of the latter often protrudes as a tongue-like structure termed the *ligule* (Fig. 67). This forms a distinguishing feature in Grasses, and is one of the means by which various species are identified. In some Grasses the sides of the leaf near the ligule terminate in claw-like projections which partially or entirely encircle the stem. Excellent examples of this arrangement are to be found in the Couch Grass and Barley.

2nd Lesson

Grasses

Brief Notes on Lesson.—Ears of some large-flowered Grass required. The Oat is the most suitable for a first lesson. The nodding structures at the end of delicate stems are called *spikelets*.

A lesson on the general structure of a spikelet of the Oat should be given early in July. A spikelet consists of several parts, to which special names are applied—Outer Glume, Flowering Glume, Palea, Lodicules (representing the perianth of ordinary flower)—three stamens and an ovary surmounted by

the divided, feathery stigma. Let the scholars dissect a spikelet and draw the various parts in their notebooks; a lens for each scholar is essential. Blackboard illustrations should be used for naming the various parts (Fig. 67).

Call attention to the position of the lodicules and elicit, if possible, their special function; open out the flowering glumes and note the position of the anthers, the number, etc. Let the class suggest the method of pollination; special adaptations to ensure cross-pollination by the wind. The following are points to note:

- (1) The feathery stigma.
- (2) Position of anthers, which hang out of the glumes below the stigma.

The following is a summary of the work:

- (1) At the base of the spikelet are two boat-shaped leaves called outer glumes, not quite opposite each other, on a stalk or axis.

- (2) Inside the outer glumes are two or more structures called florets (or little flowers).

- (3) Each floret is situated on a short stalk and has at the base two chaffy leaves; the larger and lower one is called the flowering glume; the smaller upper one is the palea, or pale.

- (4) The flowering glume, at its edge, embraces the pale. From the middle of the back of the lowest flowering glume an awn, or bristle, is seen to arise.

- (5) Between the flowering glume and the pale are contained the three stamens (anther lobes containing pollen).

- (6) Above the insertion of the stamens, the ovary with its divided feathery stigma is seen; this eventually forms the grain.

- (7) At the base of the ovary on the

side opposite to the pale, that is, on the side next to the flowering glume, there are two transparent scales—the lodicules—which are often considered as the perianth of the floret.

- (8) Additional information by the teacher. When the spikelets are upon long stalks the inflorescence is called an ear or panicle.

- (9) A panicle consists of a number of spikelets, each containing two or more florets.

3rd Lesson

Inflorescence of Grasses

Specimens of the Oat, Wheat, Cocksfoot, Couch Grass, Perennial Rye Grass, Dogstail and Yorkshire Fog.

Revise lesson on the spikelet of Oat.

Points to observe:

In most Grasses the spikelets and florets are much smaller than they are in the Oat plant, and various modifications are found. In the Wheat inflorescence the florets are large, but the spikelets which contain them have no stalks. Where the spikelets are not supported by stalks, as in the Couch Grass, Perennial Rye Grass and Barley, the close, narrow ear, as seen in the Wheat, is the result. When the spikelets are upon long stalks, such panicles as those of the Oat, Cocksfoot, Yorkshire Fog, Meadow Grasses and Quaking Grasses result. In the Dogstail and Timothy the stalks of the spikelets are very short and lie so closely against the stem that the panicle looks as if it were without stalks. It should be noted that just as the ear or panicle of a grass or cereal is made up of spikelets, so is each spikelet made up of one or more florets.

From the illustration of the Oat and

Rye Grass, it can be plainly seen what is meant by a panicle and a spikelet. To the "ear" or "panicle" of Wheat the term "spike" is often applied; the ear is in reality a spike of spikelets.

Fruits and Seeds.—The fruit of Grasses is in most cases a one-seeded form of nut, the seed of which has grown completely into union with the surrounding thin pericarp, or carpel walls of the ovary. This formation is usually termed a "*caryopsis*." Hence the so-called "seeds" of Wheat, Barley, and other Grasses are really fruits, and the true seed contains a large proportion of starchy endosperm at the side of which the embryo is placed (cf. Fig. 67).

NOTES FOR LESSONS ON GERMINATION

STANDARD II

First Lesson on Germination

Aim

To find an answer to the question, Why do seeds grow?

Apparatus

A few pods of Peas and Beans (kept from the previous year), sufficient dry Peas or Beans for each child to have a specimen, a flower-pot containing ordinary moist soil and one containing dry soil.

Preparation

Even at this early stage the children will know in a simple manner the cycle of life—birth, youth, flowering and fruiting stages. A simple introductory talk will lead up to the point that seeds are obtained from fruits; do not try to find out technical details—cf. pips

of the Apple, Peas and Beans. Lead on to the parts which are used for food. The Peas and Beans are taken from their shells and cooked, etc.

Presentation

Call attention to the dry and shrivelled appearance of the Pea or Bean pods. Open one or more before the class and let scholars observe the dry condition of the seeds; then let the class find out all they can about the specimens they have; with the Broad Bean, general size and shape should receive attention. The black scar or hilum will give scope for keen work. The seed is attached to the pod by a short stalk (sometimes this point is difficult to show to the class owing to the shrivelled appearance of the funicle). For the benefit of those teachers who have not dealt with Nature Study on the lines suggested, and have had little experience in preparing material, a good plan is to keep one or two specimens of pods in a weak solution of formalin; no difficulty then arises in showing the use of the hilum.

Conclusions

The Bean. The following points will be observed:

1. The skin is tough, yellow (or green) in colour.
2. Two lumps appear near the scar.
3. One end is thicker than the other.
4. A light-coloured line can be seen in the scar.

With the Pea:

1. The seed is round and wrinkled.
2. A light-coloured scar is seen.
3. The skin is tough and hard.

Lead to the questions, What does the gardener do with the seeds? When put in the soil, what is likely to happen to them? How can we find out what happens?

Let the scholars suggest sowing the seed in soil and allow them to carry this out, placing some in each pot (no reference being made to the fact that the soil in one pot is dry).

Second Lesson on Germination

Aim

As in Lesson 1.

Apparatus

Have a sufficient number of soaked Beans (or Peas) in readiness, the two flower-pots used in the previous lesson, one or two dry seeds, a germinator—either a glass jam jar lined with blotting-paper, thus being kept in position by filling the jar with sawdust, or a special apparatus for the purpose (the illustration (Fig. 71) was constructed from a sweet-box, the two sides being replaced by glass)—and two glass jars which can be tightly corked.

Preparation

Revise the subject-matter of Lesson 1, the general appearance of the seeds dealt with, etc. Let the scholars who planted the seeds in the flower-pots remove same. What has taken place?

Presentation

The seeds in one pot have swollen, the others are the same as they were. Why? (After examination, the seeds should be replaced.)

Now hand out the soaked seeds with instructions not to touch. Explain to

the class that the seeds have been soaked in water. Using a dry Bean, demonstrate to the class how to hold a seed between the thumb and first finger—the scar towards the observer. Let each child take up a specimen. Now instruct scholars to squeeze the seed lightly and notice what happens. Two points should be noticed: (1) Water oozes out of a small hole just below the scar; (2) the skin is soft.

Allow the class to work in groups of four; one of each group should now carefully remove the skin. The internal structure can then be simply treated. Generally the scholars will note the young plant lying between two thick parts. At this stage it is sufficient for the scholars to know that inside the seed coat is a tiny plant having two large leaves.

Sum up the information gained, using the seeds placed in the moist and dry soils to illustrate the points.

1. Seeds swell when soaked in water or placed in moist soil; the skin becomes soft.

2. Each seed of the Bean or Pea consists of a seed coat, a tiny plant and two large leaves.

Let the class draw or model the internal arrangement of a seed or write a few sentences on the observations made.

Before the lesson closes, call attention to the fact that the seed only swells in water or in the moist soil. What is necessary to make the tiny plant grow bigger?

Explain to the class the structure of the germinator (do not, of course, use this term). Let the scholars see that the jar is filled with sawdust. Allow one or two scholars to place the soaked seeds in between the blotting-paper

and glass. Knowing that the soil is damp, let one scholar carefully moisten the sawdust.

Leave the glass jam jar or germinator in such a position that observation may easily be made by the class.

By means of suitable questions, call attention to the fact that when the seeds are put in the ground, they are in the dark. Will the seeds in the jar grow in the light?

In succeeding lessons the class should discover that seeds will grow (germinate) if they are kept moist. Ultimately they should be able to say that a seed of the Pea or Bean is a tiny plant with two leaves containing food packed inside a strong coat.

An interesting experiment can be carried out as follows:

The unused soaked seeds should be placed in one bottle, completely filling it. The cork should be fastened down securely. Fill a similar bottle with dry seeds and again cork tightly. Let the class observe results.

BRIEF NOTES FOR LESSON ON CATKINS

Catkins

SUITABLE FOR STANDARD III

Aim

To give children a simple idea of tree flowers.

Apparatus

Catkins of Hazel, and a few twigs of other trees.

Preparation

A simple talk about trees, leading up to the consideration of catkins.

Procedure

If convenient, a visit to the trees mentioned would be an advantage and stimulate a greater interest. Failing that, twigs of the trees should be given to groups of children.

The Long Hazel Catkin or the Male Catkin.—What do you notice about the long, drooping parts of the hazel? When you shake them, what do you see falling? A yellow powder. What is the powder? It is the pollen just as you find it in the Celandine and Primrose.

The Female Catkin.—Call particular attention to the twig. What is strange about the buds? Some of them have little bright-red hairs coming out of them. Tell the class that certain buds contain flowers, too, and illustrate the formation on the blackboard. These are the female catkins, from which the nuts are formed.

Now examine the Willow catkins. It will be noticed that there is not a great difference between the two kinds of catkins. Look at them and point out the difference. One shows pollen dust; the other contains little bottle-shaped pieces. Call attention to the fact that the pollen is not covered up or protected by petals, but can easily be blown away by the wind. Show, by simple diagrams, the arrangement of the staminate and carpellary florets. Point out the nectary at the base of the Willow florets and ascertain what this might attract. By careful treatment, lead the class to see that the pollen from the Hazel is blown about by the wind before the leaves appear, hence this can easily fall on to the red hair-like stigmas.

With the Willow, the male and female are on different trees. Insects search for the nectar and carry the pollen

from one tree to the other. Some of the pollen is blown about by the wind, and may reach the female florets. Call attention to this wonderful arrangement of Nature.

Let each child use a lens for the examination of the catkins and make drawings of the structures noted.

Summary

1. Catkins are the flowers of trees, e.g. Hazel.
2. There are two kinds, the male and female.
3. The male is much prettier than the female catkin. It holds the pollen, which is carried away by insects and the wind.
4. They appear a long time before the leaves, except in the case of the Birch.

For blackboard sketches, see Fig. 38.

BRIEF NOTES FOR LESSONS ON MEMBERS OF THE BUTTERCUP FAMILY

SUITABLE FOR STANDARD IV

First Lesson—The Lesser Celandine (Fig. 70)

The Lesser Celandine (*Ranunculus ficaria*), often called the Smaller Celandine, incorrectly called a Buttercup.

Apparatus Required

Several complete plants; flowers sufficient for each scholar to have a specimen; specimen growing in a flower-pot, planted the day before lesson; botanical lenses (one between two scholars).

Observational Features

Call attention to plant in pot. Place specimen in the dark—a cupboard will serve the purpose; remove after about twenty minutes; note appearance of flowers. Are they sensitive to light? Outdoor observation of plants under natural conditions to test sensitiveness. Early Spring flowers, March and April, found in hedgerows and damp, shady places.

Rooting System.—No definite tap root. Tuberous roots; examine tubers to ascertain if they possess buds or are formed by the swelling of roots, which do not arise in any particular order (adventitious roots form tubers and act as food reserves).

Leaves.—Heart-shaped or cordate, on long stalks (petioles); dark green and shiny.

Flowers.—Yellow, single flower on a stalk; three sepals, eight petals, numerous anthers and ovaries (carpels). Note how the anthers cover the ovaries. Why?

Drawings to be made of leaves, dissected flower and rooting system. Test tubers for starch.

Other Lessons

Lessons taken when flowers of the various species appear, e.g. Creeping Crowfoot or Sitfast (*Ranunculus repens*) June to August; the Buttercup (*Ranunculus bulbosus*) June to September; Celery Leaved Buttercup (*Ranunculus celeratus*) June to September; Water Crowfoot (*Ranunculus aquatilis*) June to August.

Apparatus Required

Same as for the Celandine.

THE LESSER CELANDINE



FIG. 70

DRAWN FROM NATURE.

THE LESSER CELANDINE.

This drawing is intended to show how the observational work on the Celandine should be illustrated in the scholars' notebooks—the complete plant, then a section of a flower. Such work is best done as part of the Nature Study lesson and not as a separate "Art" lesson.

Creeping Crowfoot

Long, strong, straight white roots, difficult to remove from gardens and fields.

Creeping Stems or Runners, hence colony of this weed quickly formed; other plants choked.

Leaves.—Large, deeply indented, lie close to the ground.

Flowers.—Single on stems; five sepals, five petals, a large number of anthers and carpels.

Notice nectary at the base of each petal; insect pollination, cross pollination. Outer anthers shed pollen before carpels are ripe; inner ones can pollinate carpels if cross pollination has not been effected.

The Buttercup

Bulbous root; tall flower stalks. Two kinds of leaves; one from the ground, other from flower stalk; deeply indented.

Familiar flower of meadows. Flowers single on stem—cymose. The sepals in the flower are bent back against the stem—a distinguishing feature—otherwise floral details are the same as *Ranunculus repens*.

Water Buttercup or Crowfoot (Ranunculus aquatilis)

Found growing in ponds and marshy places. Two kinds of leaves—finely divided, submerged and aerial.

Celery Leaved Buttercup

Found growing in ditches and at the sides of ponds. Flowers similar to other types, but smaller petals. The leaves are deeply indented.

Information necessary for the Teacher to supply

The members of the Buttercup family are all poisonous. Notice that a cattle-grazed field is often quite yellow with untouched Buttercups. This is due to the bitter juices present in the leaves and stems; test this by chewing a leaf for a few moments.

Goats will occasionally eat Buttercups, but Horses, Cows and Sheep avoid them (the possession of bitter juices is the most common protection of soft herbaceous plants against the attacks of grazing animals).

The leaves of the Celery Leaved Buttercup possess acrid qualities. In pre-war days, tramps who wished to secure compassionate treatment in work-houses rubbed their hands with the leaves, the juice of which sets up an irritation and produces blisters.

Often when hungry animals are turned out into a field containing Buttercups, they will consume many in their eagerness to obtain food, and on the following day their mouths and tongues are sore and blistered.

Many Buttercups in the dry state must enter largely into the composition of hay. Their acrimony is lost, however, in drying, and hence they become harmless and probably nutritious.

The Monkshood (*Aconitum*) is a member of the same natural order. The juices obtained from the leaves, stems and roots are used for medicinal purposes at the present time. The flowers of the Monkshood are generally blue in colour and different in general appearance from the Buttercup; the arrangement of the essential organs, however, is identical. The root is thick and tuberous, and is sometimes

mistaken for that of the Horse-radish with fatal results. When lessons on the Buttercup family are being given, it would be well to point out the characteristics of each root, e.g. the root of the Monkshood has a tapering form, similar to the wild Carrot; its taste is bitter, causing the lips and tongue to become numbed and tingling; it has no particular smell. The root of the Horse-radish does not taper; it is practically the same size throughout and ends quite abruptly. When fully developed, the Horse-radish is a dirty yellow, the Monkshood being dark brown. In the early stage the root of the Monkshood is white, that of the Horse-radish being yellow. It is pungent but not bitter to the taste.

A Later Lesson

Fruits—taken during Autumn.

Observe the collection of small bodies. Are they seeds or fruits? (Compare a fruit with a nut.) The outside is tough and leathery and does not burst open to release the seed. "Achene" is a special name given to this type of fruit.

The Monkshood shows a slight variation in its fruits. These are long and many seeded. The outer covering is tough and leathery, but each fruit splits along one side to release the seeds; the name "follicle" is applied; the nut and achene are known as dry indehiscent fruits; the follicle is a dry, dehiscent fruit. Other typical examples of the natural order are found in the Wood Anemone and Anemone Japonica (achenes); Marsh Marigold, Columbine, Larkspur, Winter Aconite and Hellebore (follicles). When follicles are being examined, it is easy to

call attention to the likeness of such structures to a leaf folded over—technically the carpel forming the follicle is a leaf united along the edge of the lamina; the edges of the leaf form the point of attachment for the seeds. The pods of the Pea and Bean are other good examples of this modification.

NOTES FOR LESSON ON SNAILS

SUITABLE FOR STANDARD V

Aim

To give the class an elementary knowledge of the life-history of the Snail.

Apparatus

A terrarium containing Garden Snails and Slugs, Water Snails in an aquarium. Several Snails, sufficient for group work, an old photograph plate which has been cleaned or a piece of glass for each group to use. A Snail on the glass in front of each group.

Preparation

A few questions might be asked to find out what previous observations the scholars have made. Many points will, no doubt, be given—the destructive nature, tracks left by Snails, etc.

Presentation

The shell will be the first part for observational work; its shape, size, etc. Let the scholars turn the glass over, holding it above the desk. Note that the Snail is attached to the glass by means of a muscular foot, which extends along the entire length of the animal. It is by means of this

organ that all Snails (and Slugs) creep along. The Snail will, no doubt, move ; notice how the movement takes place—expansion and contraction of the muscular foot, aided by the ejection of slime or mucus. This is given off from the whole surface of the body. Reverse the glass and lay on the desk. Observe the position of the two pairs of "horns." The more posterior "horns" or tentacles bear at the tips a black spot, the eyes. Carefully touch one and it should be observed that the tip sinks first. The other pair of tentacles act as feelers, and these also can be withdrawn.

It may be necessary to give information on one or two points, e.g. the shell is made of lime obtained from the plants consumed. When damaged, the Snail is able to repair or patch up the hole in a short time. The mouth, at the anterior end, consists of a hard and horny upper jaw bounded by soft lateral lips and by a short horizontal lower lip. As the Snail moves, a cream-coloured collar is noted between the edges of the shell and the body. On one side of the collar is a large hole which alternately closes and opens ; through this opening the animal breathes, air being taken through the opening to the part of the body which acts as a lung (between the mantle fold and the dorsal surface of the body ; in this chamber are a large number of blood vessels, which receive fresh supplies of oxygen before entering the heart).

The foot is covered with a large number of tiny hairs or cilia, and by these and the muscular expansion and contraction the body is moved along in the canal of excreted slime.

The terrarium will, no doubt, con-

tain eggs of the Snail. These are generally round, white and shiny bodies found in batches of sixty to seventy. It is interesting to discover the time taken for the eggs to hatch out. This point may be given as observational work after the lesson. The young Snails have thin, transparent shells, which increase in size and change colour rapidly.

Natural enemies of the Snail might be discussed. Most children know how the Thrush breaks the shell of the Snail. Fowl are also particularly fond of Snails, and when in the young stage they form the chief food of Toads and Frogs.

Compare Slugs and Snails with the Water Snails in the aquarium ; general structure is much the same with the exception of the shell.

Conclusions

Snails and Slugs belong to a family of animals called Mollusca ; most shell fish belong to the same family. They feed chiefly at night by drawing the food between the rasp-like lower jaw and the horny upper one. During the day they hide in a cool spot, hidden as a rule by decayed foliage or any litter left about.

Often Slugs bury themselves in the ground, coming out after rain.

During the winter, Snails hibernate. Clusters of shells are often found in rubbish heaps, in the trunks of rotting trees and under decayed vegetation in a sheltered and dry hedgerow. The shell is partially closed by a horny secretion at this stage.

Slugs bury themselves in the soil during cold weather, but they continue to feed throughout the year when temperature conditions are favourable.

NOTES FOR LESSONS ON SURFACE TENSION

SUITABLE FOR STANDARDS VI
AND VII*First Lesson**Aim*

To enable the scholars to understand why the bodies of aquatic, air-breathing larvæ do not come above the surface of the water.

Apparatus

Sewing and knitting needles, a large bowl or vat, a glass tumbler and a supply of water.

Preparation

The class, before the lesson, should have been instructed to observe the Black or Brown Beetle larvæ and the Water Beetles or Boatmen in the aquarium. Questions might be asked dealing with the observations. It should be noted that the insects or larvæ remain still and rise to the surface of the water. Why?

Presentation

Experiment 1.—Call a scholar to the front of the class and instruct him to dip his finger in water and lift it out again. Let the class make observations. The water does not run off, but forms a big drop at the tip of the finger. Note the rapidity with which the drop comes to rest.

Experiment 2.—Take a sewing needle and poise over the water by means of the prongs of a fork. Lower both to the surface of the water in a tumbler; gently lower the fork below the surface;

the needle will be left floating. Touch one end of the needle; it immediately sinks to the bottom. Let a scholar repeat the experiment.

Experiment 3.—Carry out similar experiments, using a large vessel of water and a knitting needle.

Experiment 4.—Fill a tumbler with water until the water level is as high as the edge of the glass. By means of a pipette, add more water. The class will observe that the level of the water rises above the edge of the glass, and if care is taken a considerable quantity can be added before water is spilt.

Experiment 5.—Let a scholar dip a paint brush in water, and ask for observations after it is taken out. It appears as if there is a coating of some kind keeping the hairs together. Another scholar should make observations on the hairs of the brush when in water.

Experiment 6.—Take the leaf of any plant having a long petiole—Geranium, Nasturtium or Primrose. Blow down same and note the bubble of water appearing on the under side of the leaf.

Conclusion

Let the scholars working in groups try one or more of the experiments and make notes on their observations.

1. A needle made of steel will float on water.

2. Water forms a film round the hairs of a brush.

3. A tumbler full of water can be made over-full. Water seems to possess a "skin." The cohesion between the particles (molecules) at the surface appears to be greater than that between the molecules in the body of the liquid.

*Second Lesson**Apparatus*

A strong soap solution, a clay pipe, two thin strips of wood (ordinary matches with the heads cut off will serve the purpose), a small amount of thread.

Preparation

Revise previous lesson. The name surface film should now be applied to the "skin" of water, and as the film exerts a certain "pull," the term tension might be given (reference might be made to an elastic band or the string of a violin).

Presentation

Surface tension can be shown in other ways. Let a scholar blow bubbles with the pipe. What is each bubble?—an exceedingly thin film of soap and water inflated with air. It should be observed that the bubbles easily float about, get smaller and soon burst. The brilliant colours may call for explanation—these are produced by the action of light falling on the film.

With the two thin strips of wood and thread, form a square. Into the centre of one strip run the point of a darning needle. Dip the framework into the soap solution. On lifting out, a film of soapy water is formed in the square. It will be observed that the threads will curve inwards by the tension of the film. (In reality this is a double film.)

Try similar experiments with a thin ring of metal or a thin strip of wood bent in the form of a circle, dipped in the solution by means of a thread.

It will be known that objects lighter than water bulk for bulk float on water. The larva of the beetle is lighter than water, and hence, when movement ceases, it rises to the surface, the heavier part of its body downward. Which organs break the surface film? In this position it can remain suspended, taking in air through the spiracles. A certain effort is necessary to get the spiracles under water again.

What would happen if an aquatic larva came above the surface film? Great difficulty would be experienced in re-entering the water. Why?

NOTES FOR LESSON ON THE WINTER MOTH—SPECIALLY WRITTEN FOR TEACHERS OF GARDENING

The attacks of the caterpillars of this particular Moth are not confined to fruit trees. All trees, with the exception of the Pine, are attacked, and hence there is great difficulty in controlling the pest.

The gardener or fruit grower must take precautions if he wishes to keep his trees intact, and even in school gardens preventive measures should be taken.

Life-history

Early in October and onwards to December, small Moths may be seen in the evening flitting about near fruit trees and hedgerows and often near artificial lights. These are the males, and they are greyish brown in colour with dark, wavy lines on the forewings, but with hindwings of grey without any

markings. When fully grown the wing expanse is 1 to 1½ inches.

The female Moths are quite different; they are practically wingless, since their tiny, shrivelled-up wings are too small for support in flight. In general appearance they resemble Spiders, having long legs and comparatively large bodies. Early in October the female Winter Moths emerge from chrysalides buried in the ground at the foot of the tree, and crawl up the trunk. During their journey to the terminal points, the male Moths pair with them and, unless prevented, the females deposit eggs on the terminal shoots at the base of resting buds. These eggs may be laid singly or in groups, and it has been calculated that each female may lay 150 eggs or more. The eggs can be seen with the aid of a good lens. They are, at first, small, cylindrical and green, but later on assume a reddish colour. In early spring the eggs hatch out into tiny caterpillars, which consume buds, blossoms and young fruit. They have greenish skins with white stripes, six true legs and two pairs of claspers behind, and move by "looping."

Towards the end of May, when fully fed, they let themselves down to the ground by means of silken threads, and form chrysalides in the soil. Moths develop from these between October and December and carry on the cycle of life.

Protective Measures

If the study of bird life has been

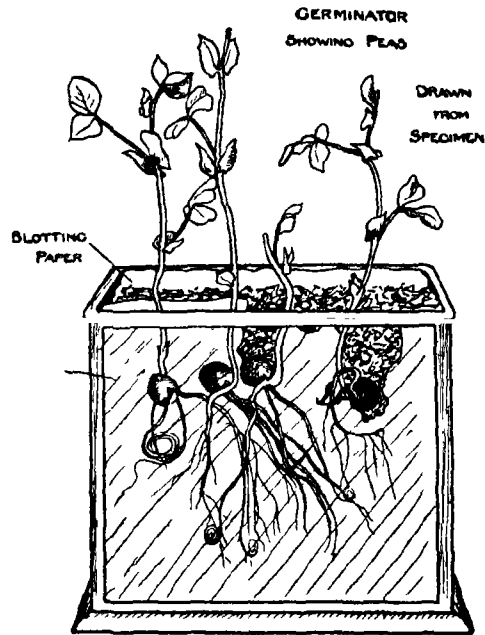


FIG. 71.

A USEFUL TYPE OF GERMINATOR.

The class can readily observe the development of seeds. The sides are made of glass held in position by metal-work.

closely followed, the class should recognise that many thousands of the caterpillars are consumed as soon as they hatch out; in fact, many of the eggs are destroyed by Finches during the winter months. However, the birds do not keep the pest in check, and other methods of control have to be adopted.

Generally standard fruit trees are grease-banded; this prevents the wingless females from ascending to the terminal buds.

Great care is necessary in banding. A good quality grease-proof paper, 9 inches wide, should be fastened securely round the trunk of the tree 4 to 5 feet from the base. It is advisable to fasten the paper in two places—one piece of string an inch from the

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top of the band and another an inch or more from the bottom. There are many adhesive compounds on the market useful for grease-banding. Tanglefoot is very effective and retains its stickiness for some considerable time. When the paper has been placed in position, this should be applied to a width of about 6 inches by hand. A smooth surface is not necessary; it is preferable to arrange the material in horizontal ridges. Occasionally the material should be examined to see if the "tacky" surface is still retained; a light scraping occasionally will also assist in keeping the band in a good condition.

Bush and half-standard trees cannot be "banded," and hence it is necessary to spray these at the time the eggs hatch out—as soon as the leaves appear. The most effective material

for this purpose is lead arsenate. As this substance is poisonous to man, the greatest possible care is essential; in fact, it should only be used by teachers who thoroughly understand its nature. Half a pound of lead arsenate paste is sufficient to make 10 gallons of spray fluid. This must never be used when the trees are in bloom, otherwise all bees visiting the tree will be destroyed.

Another spray which can be used is Burgundy Mixture, made up as follows:

Copper sulphate . . .	$\frac{1}{2}$ lb.
Sodium carbonate . . .	$\frac{1}{2}$ lb.
Water	3 gallons.

The salts should be dissolved in water separately and then slowly mixed. When this solution is used, spraying should take place before the buds open, that is towards the middle of February.

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