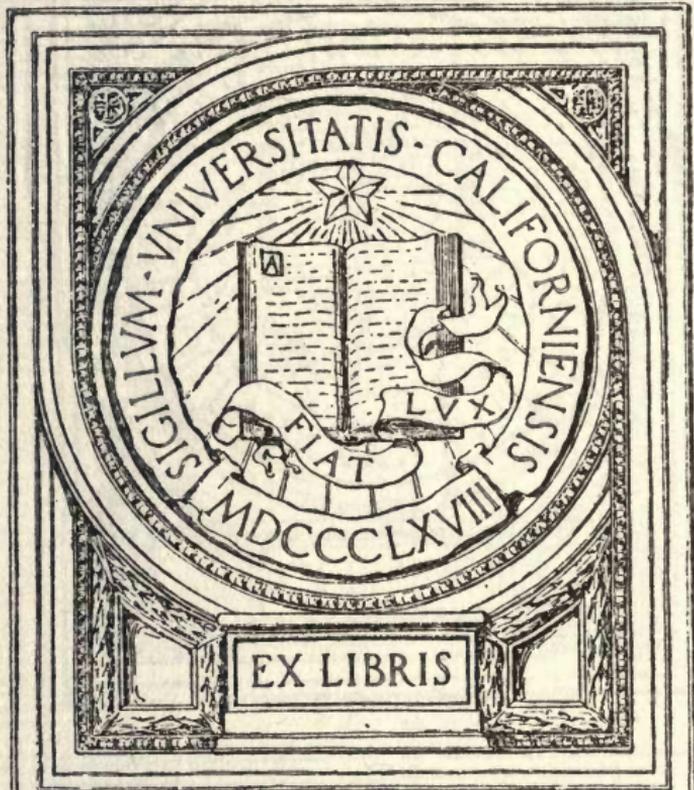
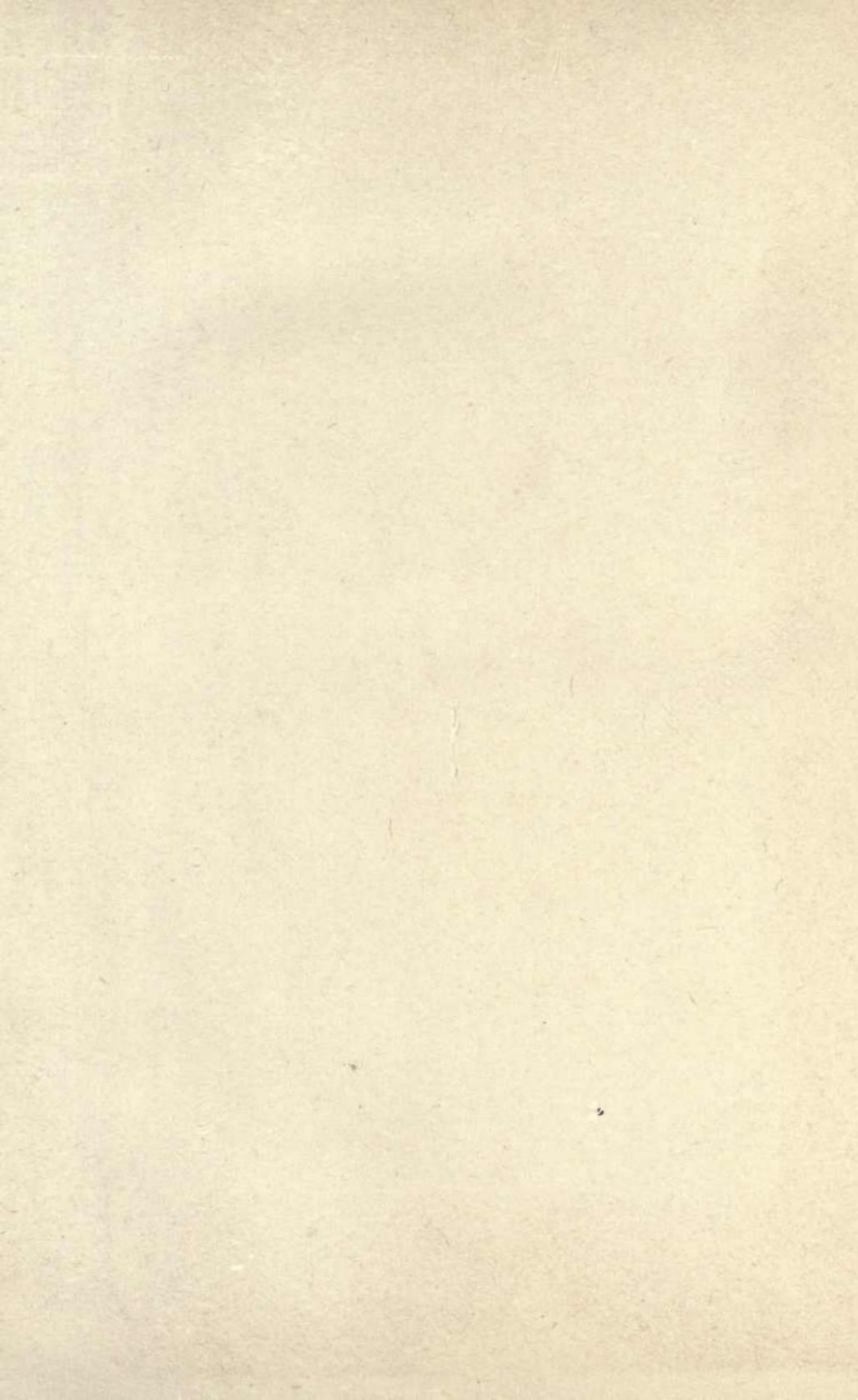


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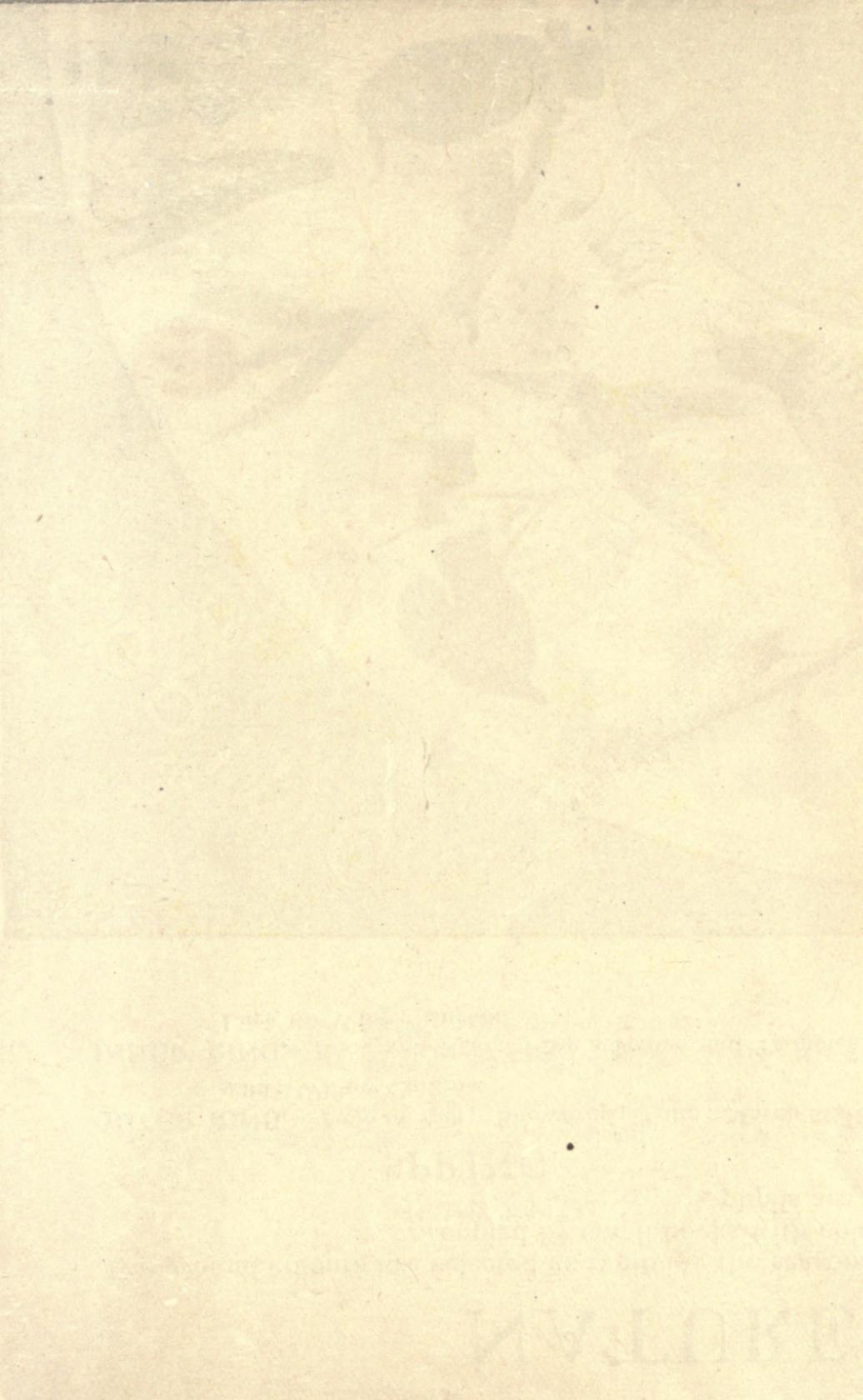


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AIMS AND METHODS
OF
NATURE STUDY



THE AIMS AND METHODS

OF

NATURE STUDY

A GUIDE FOR TEACHERS

BY

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WITH AN INTRODUCTION BY

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OF THE UNIVERSITY OF ABERDEEN

Third Impression



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PREFACE.

THE aim of this book is entirely practical in the sense that the classroom and its needs have been reckoned with throughout. It is a book intended to assist teachers of Nature Study, and sets before them the ideals which the author after a number of years' experience has come to regard as the most worthy. The value of the work is enhanced by the inclusion of an Introduction by Professor J. Arthur Thomson, whose approval of the educational soundness of its aims and methods constitutes an authoritative recommendation of importance, and one which is sincerely appreciated by the author.

Besides setting forth educational ideals the work offers guidance in the planning of courses in keeping with these; by means of fairly numerous and varied illustrations it suggests methods of teaching and generally indicates the best means which in the opinion of the author tend to the attainment and maintenance of efficiency in this subject. In the Courses framed and in the notes given elsewhere, *e.g.* in Chapters XXV., XXVI., and XXVII., the requirements of teachers in training for Rural School work in Scotland have been kept in view. To this extent practical values of Nature Study have been borne in mind.

While the needs of the classroom have been kept in view in the sense that the work suggested is such as can be carried out without disorganisation of the school

routine, the author aims at transferring to the school lesson something of the free spirit of gladness which the child find in Nature out of doors, and that without imperilling discipline. Considerable emphasis is laid upon the development of outdoor work, controlled without being in any degree irksome, and linked to appropriate indoor studies, as the line leading to success.

During past years the author has had numerous opportunities of discussing Nature work with teachers of experience; he desires to acknowledge that in the many classes for teachers he has conducted he has profited much from their practical experience. There are various hints embodied in this work and information supplied by teacher friends which require acknowledgment. In particular thanks are due to Miss Proctor, Gordon Schools, Huntly, for permission to reproduce her Nature Calendar as a frontispiece; to Miss Tennant, of the same institution, for extracts from her pupils' notes of observations; and to Dr. A. W. Gibb, of Aberdeen University, who has written the chapter on "Some Common Rocks." Other acknowledgments are made in the text. Thanks are also due to Mr. William Smith, jun., who has drawn from nature nearly all the zoological figures, and who has copied the frontispiece with taste and skill.

J. R.

UNIVERSITY OF ABERDEEN,
28th March, 1910.

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INTRODUCTION.

BY PROFESSOR J. ARTHUR THOMSON, UNIVERSITY OF
ABERDEEN.

THIS book is intended to help teachers in their Nature-Study courses in school, and I wish to commend it strongly to their consideration since I have seen for many years now the excellent results reached by the author in teaching along the lines here indicated, and since I believe in the educational soundness of the aims and methods which he has ably illustrated in the pages that follow. The conclusions I have come to as the result of many experiments in Nature Study are in close agreement with Dr. Rennie's, so it is at the risk of slightly overlapping his first chapter that I propose to state some of them in this Introduction.

What is Nature Study but the old broad wholesome Natural History—the study of our natural surroundings and what goes on there? It is as high as the heavens and as deep as the sea, but in any particular case it should not be as wide as the world, for, like charity, it begins at home!

Just as there is one big science—the Science of the Order of Nature—so we cannot tie down Nature Study. It is just an inquisitive, appreciative, intelligent outlook on Natural Phenomena; it is learning to interpret natural happenings; it is an application of many sciences with a particular purpose.

Let me give two definitions by two great authorities. "Nature Study is learning those things in Nature that are best worth knowing, to the end of doing those things that make life most worth living" (Hodge). "Nature Study is the culture of the habit of observing and thinking for one's self, and at one's best, without books or helps, in presence of the facts, and in the open air" (Geddes). I should supplement these truths by saying that "*In Nature Study we aim at seeing, understanding, enjoying and practically learning from the natural world round about us.*"

If there be validity in the view of Nature Study briefly suggested above—and expounded in this book—then there are several very important practical corollaries.

(1) For instance, Nature Study should vary in garb according to the locality. Its urban expression is different from its rural expression. Here it should be more physiological and there more biological; here it should have much to do with stones and there with flowers; here it should make much of the migrating birds and there of the shifting clouds. It matters not what the predominant subject-matter is if it be congruent with the locality, if it be not too narrow, and if it be not dwelt on so persistently that the youthful mind becomes bored. All roads lead to Rome, and what we wish to develop is not so much knowledge as a lively interest, a scientific way of looking at things, and some joyful appreciation besides.

(2) Again, Nature Study should vary in expression according to the teacher. Every man should teach his own hobby, and it is better to ride our hobby than wait indefinitely for Pegasus. Enthusiasm is personally infectious. Moreover, although there is truth in the common educational maxim that we should work from the general to the particular, there is reason to believe that most children care more for a turn of the road than for scenery, more about particular flowers than "the plant," more

about the birds the teacher allowed himself to be enthusiastic over than about "the living organism."

(3) Again, the Nature Study should vary in expression with the seasons, and since I believe very strongly that the seasonal order of study is the most natural, the most convenient, the most vivid, the most successful order, I am glad that the author has laid particular emphasis on this. There are many obvious advantages in the seasonal order of study, and some which are not so obvious and are probably more important. We may note, for instance, that the seasons have subtle influences on human life, and the natural phenomena of the outer world will be studied with most sympathy and insight at the time of their occurrence.

Dr. Rennie has spoken temperately in regard to the *values* of Nature Study, and perhaps it is well not to say too much about them, leaving the teacher the pleasure of discovering them. The difficulty is that one does not really believe in the values of a particular discipline until one sees them, and yet one cannot teach well what one does not believe in. My conviction is that effective Nature Study is very difficult, but that when it is effective it is very valuable.

In the hands of skilful teachers I have seen Nature Study prove itself of value in school (*a*) in developing sensory acuteness and precision, (*b*) in educating inquisitive interests, and (*c*) in brain-stretching—for there is a fine discipline in its problems if they are honestly tackled. Moreover, it helps us to find Nature "a joy for ever." There is the practical side too, that it is actually useful to understand something of those outer-world activities that are intertwined with our human activities.

Speaking of *values*, however, I confess to the heresy that one of the functions of science in schools is *recreative* in the true sense. Not that one wishes amusement (in the modern vulgar sense at least), nor careless, slipshod

observation, nor making fun of facts! And yet the seriousness may be preposterously overdone with young pupils.

Let me explain. Play is the natural expression of youth, it has a deep biological significance, it is older even than our humanity. Similarly, as Dr. Rennie points out, interest in the world around us is a natural expression of youth. Therefore, just as we must not peer into play *too* much, inspecting and criticising, so we must not codify, rationalise, and examinify Nature Study too much. Grammar badly taught is very bad, but it does not spoil a life, whereas harshly severe Nature Study may dim the eyes for life. Only as we keep it fairly free and flexible will, as Blackmore says, "a thousand winks of childhood widen into one clear dream of age."

Therefore, while we wish to be thorough in parts and most serious at times and clear always, we must keep in mind the risk that scientific study prematurely forced may blast the buds of joyous wonder. It is rather terrible that the lover of flowers should be killed by the botanist, and that he who has "a love exceeding a simple love of things that glide in rushes and rubble of woody wreck" should die that a "Nature-student" may live. I entirely agree, therefore, with what the author says as to *enjoying* Nature. Perhaps the *via media* is most likely to be found if we bear in mind that what we wish is not information but inquisitiveness, not learning-up about things but thinking about things in presence of the things, not to teach scientific principles (an understanding of which comes later, if ever) but to develop the scientific mood which is as natural as breathing.

The author illustrates a third aim of Nature Study besides knowing Nature and enjoying her for ever,—and that is learning lessons that are of practical use. This aim is full of promise, and also full of danger. To learn a little about the weather, about the seasons, about the soil, about

useful and injurious plants and animals, about wholesome and unwholesome habits, about the loves of the plants and animals, about the inter-relations of things in the web of life, about the intertwining of nature activities and human activities—it is all of use; and yet the Nature Study in schools will miss its aim if it becomes too practical, just as it does if it become too emotional or too scientific. For here, as in so many other cases, we come back to the familiar truth that educational aims and method are sound in proportion as they recognise the three sides of our nature—knowing, feeling, and doing : head, heart, and hand.

As to *methods*, the illustration of which occupies so much of Dr. Rennie's book, they may be reduced to three—so easily stated, so difficult to follow.

(1) We must be objective and practical throughout, studying real things, remembering what a wise man once said, "The better half of a liberal education may be obtained without books at all." I hope *this* book will help the teacher to get free from books in Nature Study. They are means, his slaves; he must not be theirs.

(2) We must keep along Socratic or heuristic lines, asking questions, stimulating questions. One good question asked us is of more value than many answers. Nature is a rare Euclid, and the pupil must be encouraged to solve its problems, and he will never do this if he is told too much.

(3) More subtle is the quality of vitality, the dynamic method. Unless the plant be felt as a living creature—growing, feeding, breathing, digesting, moving, feeling, even struggling—the gist of the business has been missed. Of course Nature Study includes much that is not living, but the study of everything—even of the dust—may be vitalised.

Many detailed hints rise in my mind as the results of many mistakes. Big words, be they ever so comforting,

are apt to be a snare, especially if they are abstract ; yet our language must not be babyish. Nothing is common or unclean ; yet stinks are not for school. Correlation with other studies is wholesome, when it is not far-fetched. Finally, so far as we can, we should try to suggest that Nature Study never ends. We must try to leave each study *as something developable*—like a seed in the mind.

NATURE STUDY.

CHAPTER I.

THE IDEALS OF NATURE STUDY.

IN approaching the subject of Nature Study with a view to acting as guides to others in the same field it is desirable that we should at the outset endeavour to arrive at a clear understanding as to what service the study of nature can render as an educational process, what claim nature has upon us in the training of young people towards efficiency in life, and what is the relation between Nature Study and human life in general. In other words, our first question is: What is the place of Nature Study in education, and what is its relation to the larger sphere of human life?

In considering the educational value of any subject, a wide outlook is absolutely essential. In the present instance it must be agreed that to allow children to grow up, we shall not say ignorant of nature in general, but even of those aspects of her which are most familiar, is to deprive them of knowledge not only of a useful kind, but also such as can afford them some of the purest and most elevating pleasures in life.

It must be recognised here that Nature Study stands apart from the formal science courses which already form an important part of the discipline afforded in our school curricula. Nature Study is more than formal science. The latter is rigidly disciplinary, training hand, eye, and intellect, at the same time equipping the mind with knowledge useful in the affairs of life. Of Nature Study, as we seek to teach it, all this can be said, and more.

The discipline is not always so obviously rigid; it is gentler, but none the less real. There can be no doubt as to the training of hand and eye, nor sometimes also of hearing, taste, and smell. And the knowledge gained is always mind-enriching, *i.e.* it constitutes culture, and is not infrequently practical as well. But beyond discipline and beyond the storing of the mind with facts, we aim in our school studies at developing a cultured appreciation of nature, a sympathetic recognition of her aesthetic aspects—that is a love of the open enriched and enlightened by knowledge.

In what particular way, let us ask, is this special value applicable to the child? Why should we seek these things during school age? First of all, it is well to recognise that mankind may be said to possess a functional appreciation of nature.* It is our common experience that nature in most of her moods affects us pleasantly. We feel the exhilaration of the mountain top, the physiological appreciation of the extended view—of the widened horizon; the fascination of the river, endless in its flow; the interest and mystery of the sea. We delight in the glory of the sunset, or of the star-lit sky; in the autumn tints upon the trees, and in the summer flowers; in the grace of movement of the birds and beasts of the field. These are but the powers of life which are born within us.

All these, and such as these, are part of our common experience, and their significance in the present connection is that they are not simply the possession of men and women of matured intellect. Specially cultivated and enriched with knowledge they make of some men artists and of others poets; but undeveloped these powers in varying measure are unmistakably present in the child. We see this functional appreciation in the child's love of pretty things—flowers, leaves, butterflies, birds. When we enquire into it we find that children love nature for the

* Put more generally, we may say that there is in man a functional response to nature. The response is not always pleasurable, though it may be hazarded that with increase of knowledge there is in general increased appreciation of nature's moods and phases.

same fundamental reason as the poet or artist does—they appreciate FORM, COLOUR, and MOVEMENT. Children, for example, gather shells on the sea-shore. They admire them, they speak of lovely shells. So does Tennyson :

“ See what a lovely shell
 Small and pure as a pearl
 Lying close to my foot,
 Frail, but a work divine,
 Made so fairily well
 With delicate spire and whorl,
 How exquisitely minute,
 A miracle of design.

 The tiny cell is forlorn,
 Void of the little living will
 That made it stir on the shore.
 Did he stand at the diamond door
 Of his house in a rainbow frill ?
 Did he push when he was uncurled
 A golden foot or a fairy horn
 Through his dim water world ? ”

Now just as there is to be seen here clearly the transition from the functional to the intellectual appreciation of nature's manifestations, so we may note this as an ideal in our nature studies. Nature Study as apart from formal science teaching is distinctively a response to the aesthetic instinct, and as such alone claims important recognition in school work. Apart from the values it undoubtedly has in common with science, properly conducted it will yield a cultured appreciation of nature at large, and will foster the growth of human faculties for which only slight provision has hitherto been made, and which too frequently have been stifled at a period when they are most capable of development. How this may be encouraged as part of the school programme it is the aim of this work to show.

While we thus seek to make clear this important aspect of Nature Study we do not overlook its other values. We seek first to develop interest and delight in nature, but we

know that something else follows. Ruskin has laid it down as "a quite general law" that "in the degree in which you delight in the life of any creature, you can see it, no otherwise." By seeing, in this sense, we know and understand.

The child whose appreciation of natural objects is fostered does not as a rule remain content with unintelligent admiration. Out of a state of pleasant intellectual alertness, which it is possible by suitable methods to induce in the child, the teacher may guide along the paths of deliberate, conscious, directed, observation of nature to profitable intellectual studies. Enquiries arising out of observational studies, whether out of doors or in connection with lessons in school, afford admirable intellectual discipline, giving excellent scope for the exercise of the logical faculty. Nature studies are disciplinary, training the mind to act in a logical manner.

The knowledge acquired by the pupils in the study of nature is of two kinds. Firstly, much of it is of practical value. Whether it be the study of the weather, or of the life histories of insects, or of the functions of plants, the immediate bearing of the facts discovered upon agricultural life in particular is not difficult to see, nor in many cases to apply. And so in other cases.

But well guided nature studies must also yield knowledge which enriches the mind with great ideas. Pupils cannot fail to get glimpses of fundamental principles of nature, *e.g.* the adaptedness of living things to the conditions of their life, or to receive impressions which later in life will enable them to grasp those principles more easily. Something will be gained when the average man or woman realises, for example, an evolutionary development, not of life only, but of the universe. Nature studies will prepare the way. It will always be good if when they look at the rocks they are able to realise that the world is old, or when they see the flowers of the field, they remember a little of what they have learned with regard to the mystery of how they grow.

The nature studies, in dealing with concrete objects, are not only valuable as a relief from those of a literary or

abstract kind, but by being linked to other kinds of school work serve to vitalise these. Our methods of study intimately correlate the nature lesson and the drawing or painting one. Clay and cardboard modelling can also be worked in association with nature studies, with profit on both sides. For example, it will be found on examination of the lessons outlined in this book, that in all studies of particular objects an integral part of the lesson is the drawing of the subject, whether bird, beast, flower, or leaf, and wherever it is possible its representation in colour as well. Something may be done with modelling also.

There can be no doubt as to the value on the artistic side of the child exercising its art upon an object on which it has been or is being guided to exercise its intellect also. On the side of the nature lesson it is a well established principle that for giving precision to observational work pictorial representation or modelling stands in more important relation than handwriting does to literary composition. Also, for exercises in composition or written description, these studies should be utilised; it will be found that they not only add to the pupils' power of expression, but that they distinctly foster precision of language. Further, with the association of the best nature literature it is possible to store the memories of the pupils with sentiment of a lofty and enriching kind.

CHAPTER II.

OUR METHODS IN GENERAL.

√ OUTDOOR AND INDOOR STUDIES.

ALTHOUGH our subject is one for which much is claimed, success in teaching depends upon the methods employed. It is a subject in which it is particularly desirable that general principles be kept well in view by the teacher, and while considerable latitude is possible in the matter of details, it should be the teacher's aim to carry out well balanced courses, which will exercise an all-round influence—aesthetic, disciplinary, informative—cultivating a love of the open, each in degree suitable to the particular school grade under instruction.

It will readily be recognised by the teacher that if our ideals are to be realised, even in measure, a series of lessons taught indoors on definite natural objects is not sufficient. Our aim is

- (1) to cultivate *vital contact* with the outdoor world;
- (2) to exercise the various disciplines which Nature Study is capable of supplying, so as to yield a wide culture, together with an appreciation of human relations—practical and other—to nature.

To effect these, some organisation for the carrying on of outdoor work is required, and here certain practical questions arise. Even in schools most favourably

circumstanced for the teaching of Nature Study, problems of organisation and discipline will to some extent restrict or modify the development of the outdoor studies. The following suggestions are framed with these difficulties in view.

ORGANISATION OF OUTDOOR WORK.

In the first place a great deal can and ought to be done in the way of encouraging the pupils to observe and report outdoor occurrences. In the school situated in the country such work is particularly easy and proves of very great interest and value. In town, on the other hand, this part of the work is bound to be restricted in its scope. At the same time many of the things suggested which seem to be suited only for the country school can be observed in the public parks of our cities. The children should be encouraged to go to these parks, to use their eyes when there, and to take walks into the country. And, after all, it is not making a great demand upon the teacher to expect him or her to have something of personal observation to report to the scholars week by week of the happenings in the world of nature, which will act as a stimulus to the pupils to do likewise.

Calendars of outdoor observations.

(a) *Pictorial Calendars*.—Calendars for recording the observations out of doors should be kept. The number and type of these will depend upon the age, capacity, and opportunities of the scholars. For the youngest scholars the calendar should appeal largely to the eye and should therefore be framed upon pictorial lines. An example of this type of calendar is given in the frontispiece. The illustrations for such a calendar should be decided upon by the teacher and scholars jointly and the aim should be to have in it, when complete, a kind of conspectus of the succession of appearances and events typical of the various seasons of the year which have come under the notice of the pupils.

It should be clearly understood that this is really a calendar which is to be filled in month by month, and is not a scheme to be drawn up a year beforehand. Much profitable discussion may be got with the pupils over the questions of appropriate illustrations for each period of the year.

This calendar should be drawn up upon a large sheet of cardboard to hang in the schoolroom; the making of the illustrations will in most instances fall to the teacher, but in the central space small books should be attached in which are written down the observations of the pupils on their way to and from school or at other times. It is quite likely that this portion of the calendar will require some editing on the part of the teacher, if for no other reason than that of training the pupils to distinguish between the trivial and the significant. The following are extracts taken from the observations of pupils in the north of Scotland and recorded in a calendar such as is here described:—

1909.

March 1-20.—Heavy snowstorm. Birds coming to school door to be fed. Fieldfares, Thrushes, Blackbirds, Robins, Sparrows, Starlings noted.

21.—Heard Larks singing.

22.—Worms coming to surface of ground.

April 1.—Lilac leaf-buds bursting. Snow on "Tap o' Noth."

5.—Primroses in flower.

6.—House-fly and hive-bee seen.

7.—Insects becoming common.

15.—"Pee-wits" nest, 3 eggs, found by J. McK.

19.—Swallows seen.

27.—Worms numerous after rain, 216 counted by M. G. on school path. Plane tree and lilac buds unfolded.

May 9.—Cuckoo heard in woods (A. L.).

10.—Oats sprouted in field near school. Butterflies seen.

15.—Snow!

18.—Robin's nest in hedge, 6 young birds (A. L.).

20.—Lime trees in leaf.

24.—Elm fruit falling thickly.

- Sept. 15.—Worms seen pulling decayed leaves into ground.
 Corn in fields turning yellow.
- Oct. 26.—Snow fell.
 27.—Hail showers.
-

- Oct. 18.—Squirrels seen in wood. A store of beech-nuts found
 at the foot of an oak tree.
- 21.—Beech twig with new buds opened (autumn shoots).
 22.—Leaves being pulled underground by worms.
 28.—Potato-lifting begun.
 29.—Ploughing commenced. Ground hard with frost.

The opportunity should of course be taken by the teacher to comment suitably upon all occurrences reported which have particular seasonal or other significance.

Calendars of this type for the youngest pupils might well be confined to illustrations of the animal and plant life characteristic of the seasons. For older pupils, according to their capacity to appreciate, the following might also find a place:—

(1) A ground colour for each season to be painted in each quadrant. The colour to be decided on by the class in consultation with the teacher (see lesson on Colour, p. 56).

(2) The kind of cloud most in evidence each month.

(3) The zodiacal signs month by month.

(4) Seasonal occupations of the country or of the district. These need not all be included in any one year; indeed to maintain interest changes in successive years are desirable.

Whilst the pictorial or artistic calendar is the place in which to record the general outdoor observations of the pupils, other calendars or records of outdoor occurrences which cannot be conveniently incorporated with it ought to form part of the school work.

(b) *Weather Records*.—The usual observations should be recorded daily, especially by the senior pupils, *e.g.* barometric pressure, temperature, rainfall, wind, etc. Weekly averages should be charted in graphic form. Besides these the following important weather indicators should receive prominence. In schools situated in rural districts there should be recorded the dates of commencement of the more important agricultural operations, together with the name of the farm on which the operations take place. In order that such a record may have some permanent local value, it should apply to the same farm each year, and such farm should be selected for its average situation as regards exposure, etc. Dates of the commencement of the following operations in each year, or of the more important of them might suitably be included in this list:—

CALENDAR OF AGRICULTURAL OPERATIONS.

Winter—

Ploughing Stubble and Lea.
Ploughing clean land (after Turnips).

Spring—

Sowing of Oats, Wheat, and Barley.
“Brairding” (Sprouting of Cereal Crops).

Summer—

“Shooting” of Grain (extrusion of ears from leaf sheath).
Sowing Turnip Seed.
Planting Potatoes.
Turnip Hoeing.
Mowing Hay.
Stacking Hay.

Autumn—

Lifting Potatoes.

Sowing Wheat.

Reaping { of Barley.
of Oats.
of Wheat.

Finished Reaping.

Finished Harvesting.

There should also be included amongst the weather observations the date of leafing of particular trees of several species in the neighbourhood. Records of this kind are of particular value for comparing the weather in successive years and appeal to the child mind in an effective way. The following observations also, which are suggested by the Meteorological Office Authorities as of particular value, might be in part at least aimed at in suitable localities with the help of scholars:—

- | | |
|--|-----------------|
| 1. Hazel (<i>Corylus avellana</i>) | } Flowering of. |
| 2. Coltsfoot (<i>Tussilago farfara</i>) | |
| 3. Wood Anemone (<i>Anemone nemorosa</i>) | |
| 4. Blackthorn or Sloe (<i>Prunus spinosa</i>) | |
| 5. Garlic Hedge Mustard (<i>Sisymbrium alliaria</i>) | |
| 6. Song thrush (<i>Turdus musicus</i>), first heard. | |
| 7. Cuckoo (<i>Cuculus canorus</i>), first heard. | |
| 8. Honey bee (<i>Apis mellifica</i>), first seen. | |
| 9. Wasp (<i>Vespa vulgaris</i>), first seen. | |
| 10. Small white butterfly (<i>Pieris rapae</i>), first seen. | |

Other suggested observations are given at p. 41.

(c) *Local list of Fauna and Flora.*—Even in districts where such lists have long since been made and printed the scholars should note the wild flowers as they appear, recording dates. In this way, making a record from the specimens found by themselves, they will gradually learn the names of the flowers and trees. Such lists can be extended in successive years by records of such points as: *length of time* particular species of plants are found in flower, *census of colours* of flowers in the different seasons, *time of first appearance of various wild fruits*, *order of leafing of the trees*, and so on as the circumstances suggest.

On the animal side such points as the following might find a place in this calendar. The first appearance of the spawn of frog or toad, the nesting of rooks or other birds, the arrival of migrants, *e.g.* swifts, swallows, cuckoo, the appearance of particular caterpillars, or of humble bees, the first butterfly, all wild animals observed out of doors not previously recorded in the school faunal list, etc.

Since much of the information which can be gathered in this way has a permanent value for the district, the teacher should take some pains to see that the facts submitted are in the main correct and also that they are recorded in some permanent document such as a School Nature Diary or in the Transactions of a local society.

(d) *School Excursions.*—Whilst a very great deal can be done by means of such lists as have been suggested to quicken and maintain the observational powers and interest of the pupils and to develop an intelligent love of nature, this can be further aided by class excursions. These may consist of rambles into the country, to wood, or moor, or pond, when in particular the relation of animal and plant to environment may be studied, or a general acquaintance with nature cultivated. Or short excursions may be made to particular spots at which definite lessons can be taught or illustrated.

It is well in such cases to keep the significance of the visit clearly before the pupils and to require from them an account of the excursion as a subsequent exercise. Further, the opportunity should be taken of giving lessons

indoors of a detailed character upon material collected or observed at the excursions. Some judgment will be required on the part of the teacher so that he or she may on the one hand encourage a free delight in nature and at the same time exercise a controlling influence, guiding thought and action so that the work may be really educative.

THE WORK WITHIN THE SCHOOL.

The work within the school is designed primarily to heighten the interest and cultivate the understanding of the pupils with reference to the world of nature outside. It is calculated to store the mind with knowledge, and to afford mental discipline, cultivating the art of clear thinking and giving power to interpret nature's problems.

The Courses here outlined and the lessons worked out in detail are put forward as practical illustrations of indoor studies which ought in large measure to fit in harmoniously with outdoor work. In the case of the lessons, the main idea has been to convey the subject-matter in a form such as the teacher might adopt with a class, and different grades of class have been kept in view.

It will of course be understood that the information worked out in some of the lessons may prove beyond the capacity of even the senior pupils. None of it should be beyond the teacher, and while the general methods of teaching adopted are suggested as suitable for school work, the teacher must decide ultimately exactly what facts are to be taught to a particular class. But our aim as a rule has been to enlarge the horizon of the teacher, so that he or she may be in possession of more facts than are suitable for the child. Only when so equipped can the teacher be effective in the best degree.

It will be understood that whilst a considerable number of subjects is dealt with in the lessons, no attempt has been made to cover all the subjects which are suggested in the Courses outlined

No pretence at uniformity of method in the ordinary sense is put forward in the attempt here made to realise our aims. Such we hold is unsound in principle with reference to nature study whose ideals are complex. It is true great stress will be found to be laid upon observational work as a basis for subsequent reasoning, and in general the scientific method is utilised. But we have tried also, in spirit at all events, to capture the imagination, to appeal to wonder, to acknowledge mystery. For these studies—according to our view—in seeking to develop interest in nature are seeking to add to the joys of life. Consequently—no sarcasm is intended—we hope our methods have but little flavour of the scholastic. We would sum up thus: Awaken interest; having secured it, keep it as long as you can. Never destroy interest (which is but quickened intellect) for the sake of adherence to a scholastic method—heuristic or otherwise.

CHAPTER III.

SCHOOL COURSES.

The Framing of Courses.

The following courses are framed as a continuous series to extend over five years of elementary school life. Teachers will probably not be able to adhere rigidly to the details submitted, since there is no doubt that local circumstances ought in the main to determine these. While this is so it will be found in most cases that much material of a kind common to all localities is included. The general principles applied in the drawing up of the courses should, however, not be lost sight of.

Seasonal Studies.

The work of the courses should be carried through with some recognition of the seasons. In a sense such advice is scarcely necessary, for practical teachers are compelled from force of circumstances to utilise almost exclusively just the materials which the seasons bring, and as a matter of fact studies out of season are comparatively rare. But the opportunity should not be lost of tracing the relation between the seasonal cycle of the earth and the life upon it. This may be done in the lower classes simply by teaching lessons at the appropriate time, in the higher by showing the dependence of all life upon the heat of the sun, and by tracing a correspondence between the cycle of increasing and declining heat and the flow and ebb of life upon the earth.

In illustration, let us trace through the spring this seasonal influence. In the plant world, on the arrival of spring there becomes evident a stirring of dormant life. Seeds, scattered in the autumn, which have lain dead-like in or on the ground throughout the winter, germinate. The minute roots emerge and penetrate the ground, whilst upward into the air there push the embryo stems (plumules) bearing their seed leaves, and growth goes on apace. In underground stems there is a movement of sap, buds below and above ground swell out and unfold. The chemistry of these things is invisible; its results are visible and impressive. Trees which through the winter have stood bare and dead-like are already in that transition stage 'twixt bud and leaf so pleasant to look on.

“Such a time as goes before the leaf,
When all the wood stands in a mist of green,
And nothing perfect.”

But perfection is delayed only for a time, and we welcome each returning year the fresh tender leaf of springtime upon the trees, the flowers of the shady woodlands and of the fields. With the early sunny days there comes the awakening of the winter sleepers—flies, bees, squirrels, hedgehogs; the hatching out of winter eggs and pupae; the singing of the birds, mating and nest-building; the re-peopling of the fresh waters; over all the land a wealth of awakening life, convincing evidences to us, even when we ourselves are scarcely conscious of increased warmth, that the physical changes are acting upon life.

In our school courses such relations as these ought to be realised, in the mind of the teacher, at all events. In this connection it may be pointed out here that it is not desirable in Nature Study to have a time table allotting an equal amount of time for each week throughout the year. In spring and summer considerably more time should be given than in autumn or winter, and it will be found that the materials prescribed in the courses are distributed in keeping with this view.

General Principles to be Taught.

If the advocates for Nature Study are to save the subject from reproach they must, whilst utilising materials varied in character, aim at teaching with definite continuity of principle; the material should be illustrative of such. That is to say, a year's course of lessons unconnected by any set of generalisations, or which is not capable of being summarised under a set of principles, cannot be regarded as satisfactorily planned.

Not only single courses, but the whole series of courses within a school, should be framed in logical continuity, so that by the time a pupil has passed through the school he has been put in possession, not simply of a large number of facts regarding nature, but has obtained a grasp of fundamental facts, which give him some power in interpreting nature's problems.

Such an aim has been kept in view in the following courses. Fundamental principles are made clear by simple experiment and otherwise to the pupils at the earliest stages. In the later stages, as the pupils come into touch with more detail, complexities and amplifications of principle are in measure introduced.

Much energy may be dissipated for lack of summarising or of focussing the results of a series of lessons. It does not follow, of course, that the principle under which the facts dealt with are grouped need be always enunciated to the pupils. But undoubtedly the facts will gain in presentation if they are always so grouped first of all in the mind of the teacher. And conversely, if they are not so grouped, will their presentation tend to be ineffective and lacking in interest.

The teacher who adheres to this rule in the planning of his Nature Study lessons will not find it difficult to build up well connected courses likely both to develop the interest of the pupils and to provide them with a unified scheme of nature knowledge.

COURSE I.—*For pupils of ages seven to eight.*

I. PLANT STUDIES :

Make the children familiar with from fifteen to twenty Flowers which grow wild in their neighbourhood. At each lesson on the flower, the children to learn its name, to write its name out, to decide its colour, if scented to note this, to remark on its shape, and to say if they have ever seen bees, flies, or other insects visit it. The teacher to draw and colour the flower. The teacher must exercise judgment in the selection of flowers for these lessons, and in particular plants of the order *Compositae* should be avoided at this stage, as also any showing peculiarities of structure. Some examples may be given:—

Snowdrop, Wood Anemone, Periwinkle, Marsh Marigold, Primrose, Sweet Violet, Hawthorn, Germander Speedwell, Dog Rose, Harebell, Ragged Robin, Forget-me-not, Buttercup, Wild Hyacinth, Queen of the Meadow, Wood Sorrel, Silverweed, Apple Blossom, Poppy, Meadow Crane's Bill.

In the course of the year the children to become familiar with the fact that, besides Flowers, plants have Seeds, Leaves, Stems, Roots. The teacher must in these lessons educe by showing relations that

(a) The flower yields the seed and fades away.

(b) The leaves are flattened parts spread out to the light; they make food for the plant, getting it in the air when the light is shining on them.

(c) The stem is a part to hold up the leaves to the sunlight and also to support the flowers.

(d) The root takes food from the earth; water is necessary for this.

Simple experiments might be devised to show that light and moisture are necessary for plant life. For pupils at this stage these must be of the simplest possible nature.

Experiment.—Take two plants in pots, place alongside, cover one so as to exclude the light from the plant. Otherwise treat both similarly as regards watering and heat. Leave for a few days and then compare.

Experiment.—Perform a similar experiment, this time depriving one of the plants of water. Continue the experiment as long as necessary.

Experiment.—Perform a similar experiment, this time place one in the most favourable place as regards natural heat, and the other in a cold place. Otherwise treat similarly, and compare after a time as regards growth. Seedlings may suitably be used for these experiments.

The scholars may thus be led to realise the elementary needs of the plant. The teacher should make the scholars write out, and also show by a simple blackboard drawing, what these needs are.

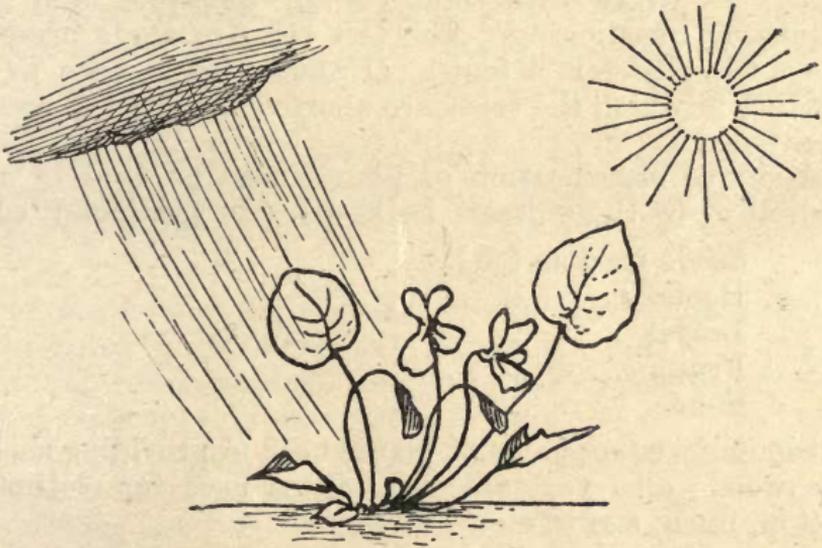


Fig. 1.—Diagram to illustrate the needs of a plant.

Plants require

Sunlight (heat and light).

Air.

Water.

Soil.

Supplied with these they grow.

Fact grasped by the child: A plant is a living thing.

About six of the commonest trees in the district to be recognised by their leaves. Scholars will be supplied with leaves, the teacher will draw and colour and scholars will recognise by comparison. Scholars will write out the names. A fact which may be educed here observationally is the difference between trees not evergreen (shedding all their leaves each year) and those evergreen (shedding some only each year).

Fruits.—Attractive—In what way? By colour, smell, taste, shape. Wild fruits not specially attractive to be left out of account at this stage.

Distinguish amongst common edible fruits two kinds—dry and juicy. Show that *seeds* are an essential part of a fruit. Contrast with some edible vegetables, and drill pupils by questioning. The test is: Are seeds present? If so, the object is a fruit. (Unusual fruits, such as the banana, in which the seeds are aborted will for the present be avoided.)

A simple classification of plants used as food by man himself or by the animals he keeps. In particular, educe

Seeds used as food.

Roots „ „

Leaves „ „

Fruits „ „

Stems „ „

Similarly educe parts of plants used in providing shelter, e.g. wood; also vegetable substances used for clothing—cotton, linen, straw, etc.

Fact grasped by the child: **Animal life is dependent upon plant life.**

Appropriate poetry to be learned or quoted at the time of study of particular trees or flowers. For suitable poetry see *The Greenwood Tree* (Arnold).

Also for many short quotations, some of which pupils might write out or learn, see *Nature Knowledge in Modern Poetry*, by Mackie (Longmans, Green & Co.). Teachers will find these works generally useful.

II. ANIMAL STUDIES:

The school should be supplied with a fresh water aquarium containing the commoner animals of the pools. The children are to be made familiar with these so as to know by name tadpoles, newts, gnats, water boatmen, water beetles, pond skaters, etc.; also they should have a general knowledge, acquired by observation, of their feeding and breathing habits, and of the more obvious changes which some of them undergo. Drawings are to be made by the teacher at the lesson time, scholars are to identify and to write out sentences descriptive of the facts learned.

The rearing of insects should form a definite work of this class. The scholars will bring food when required, they will assist with the cleaning out of the cages. As a definite exercise, some time should be spent regularly watching the feeding of the caterpillars, and noting generally their behaviour.

The teacher will draw from time to time the outline of a caterpillar, and on each occasion draw attention to the more important structural points which they can easily verify.

Definite lessons on a series of familiar animals should be included in this course. Circumstances will largely determine what examples are to be taken, but the lessons should be taught on observational lines.

As examples may be suggested the commoner domesticated animals—sheep, ox, pig, horse, dog, cat, rabbit, etc. In revision lessons, comparisons should be made on such points as food and mode of feeding; distinctive peculiarities in locomotion; types of limb, with number of toes; characters of coat, etc. Drawings should be made on the blackboard.

As opportunities arise simple lessons may be given on the commoner wild animals of the country, *e.g.* weasels and stoats are to be got without much difficulty from gamekeepers. Such animals as these may be stuffed, without being set up, at a trifling cost. Hedgehogs, moles, and bats are other types not at all difficult to procure. All distinctive habits of such animals should be noted, and

generally with this class some attention should be given to the play of animals.

Similar lessons should be given on common birds; outdoor observations on the lines of recognition by plumage, flight, song should be encouraged. The birds should be fed in winter, when excellent opportunities for general observation work are afforded. General appreciation of prominent functions of the birds—parental care, nest building, power of flight and general gracefulness of movement, etc., should be encouraged.

Collections of objects of natural beauty, such as shells, butterflies, feathers, should be available; if not the teacher might by degrees with the help of the scholars build up such a collection. The objects will be available for simple lessons designed to develop the artistic sense-appreciations of form and colour. The simpler objects can be drawn and coloured, the more difficult, such as butterflies, can be used for purposes of verbal colour description and for lessons in recognition particularly of the commoner examples.

III. OBSERVATIONAL WEATHER STUDIES:

For this grade these will be of a fairly simple character. A daily opinion of the kind of weather should be got, say, in the afternoon and a simple record kept by the teacher:

Spring: Number of good days (fine, dry, warm),

„ „ bad days (cold, wet),

and so on for each season. Notwithstanding the fact that a complete record for the year is not likely to be obtained (owing to holidays, etc.), the teacher will not have much difficulty in comparing seasons as to amount of heat in each, and in associating the season of greatest heat with greatest abundance of life.

Pupils at this stage should be taught to recognise generally the direction of the wind, and to name the simpler cloud forms.

Fact grasped by the child: Dependence of plant life upon the Sun.

IV. CALENDARS :

A pictorial calendar typifying month by month the outstanding natural occurrences which are familiar to the children, and suggested by themselves, and including in writing also their outdoor observations, should be kept in connection with this class. Particulars as to the keeping of such a calendar are given at page 8. It is understood that the work is to be distributed over the year on a seasonal basis.

GENERALISATIONS :

The teacher will find that to secure good results a fair amount of revision is necessary. Pains must be taken to maintain interest at such a time. The form of the lesson should be varied, and even new examples taken. This can readily be done when it is borne in mind that in the main we are seeking to develop an appreciative spirit and to impart to the child mind a grasp of fundamental principles. The work can be well done only if the teacher clearly keeps these principles in view. The aims of the present course may here be summarised :

(a) To develop an appreciation of nature on the aesthetic side. This is the chief aim at this stage.

(b) To make clear to the youngest children the following great facts :

- I. Plants are living things ;
- II. Plants, in order to live, require sunshine (light and heat), air, soil, moisture ;
- III. Animals are dependent upon plants ;
- IV. Animals are active *feeding, breathing* (it is noted in connection with the aquarium studies that some animals have to seek air as they seek food), *playing* (in youth). In other words, Animals in order to live require *Food, Air, Exercise.*

COURSE II.—*For pupils of ages eight to nine.*

I. PLANT STUDIES:

Plant recognition.—It will be found that the work of the previous year will be again undertaken with zest, and pupils will be found eager to renew their acquaintance with the flowers identified then and to add to their number. In the course of the spring and summer other twenty flowering plants may without difficulty be recognised, and some distinguishing character noted for each. This character should be illustrated by means of a blackboard drawing. Other points as noted for the previous course should be continued. Suitable examples are:—

Chickweed, Gorse, Dog Violet, Golden Saxifrage, another Buttercup, Shepherd's Purse, Lady's Mantle, Sweet Briar, Red and White Deadnettle, Vetch, Sweet Pea, Lady's Fingers, Birdsfoot Trefoil, Lesser Stitchwort, White and Red Campion, etc.

A beginning might be made in noting distinctive situations for particular plants, *e.g.* Lesser Celandine, Golden Saxifrage, Wood Sorrel. But clear cases only should be taken. In a few instances lessons of a more extended nature, including some reference to the history of plant names or plant legend, should be given.

Plant functions.—A restatement to be got from the scholars of the prime functions of the parts—root, stem, leaf, and flower. The experiments may be repeated, if necessary. Not much advance in the way of detailed explanation of these functions should be attempted, either experimentally or orally. As a guide, however, to the understanding of the relation of the plant to moisture and to the soil, the following experiments will not be found too difficult.

Experiment.—Procure four tumblers of large size. Cut two pieces of cardboard a size suitable to cover the mouths of two of the tumblers. Bore a hole in one of the pieces of cardboard and insert

a small portion of the stem of garden cress with a few leaves upon it. Thoroughly dry one of the tumblers and fill up another with water. The sprig with the cardboard is to be placed in the water and the dry tumbler inverted over it. A similar arrangement is to be made with the two remaining tumblers, but in this case no plant is introduced. The whole to be placed in a good light and moderately warm place. Compare results after a time. The scholars will draw the apparatus and write out :

Water passes through the plant from below upwards, coming out again at the leaves.

Experiment.—Repeat the above experiment on another occasion with a pot plant. Water the soil carefully. Slit the cardboard and pass it round the stem, afterwards gumming the slit, and closing the opening around the stem with vaseline. Invert a dry tumbler and await results. As in the foregoing experiment set up a control pot in which there is no plant. Scholars will again draw the apparatus, and after satisfactory verification will write out :

Water, from the soil, passes through the plant, coming out again at the leaves.

Fact grasped by the child: The transpiration of plants.

A further step may now be taken by an appeal to the child's knowledge of the fact that water dissolves many substances, *e.g.* sugar or salt, and a demonstration may be given to show that it dissolves various mineral salts found in the soil. The inference may therefore be suggested that some substances are carried up from the soil in the water passing through the plant. The proof that these substances do not pass through with the water must be left to a later period.

Examine some early plants such as Snowdrop, Daffodil, Hyacinth, as illustrations of an easily observed modification of a part; in this case, the leaves forming the bulb. Cut up an onion so as to demonstrate the parts, in particular the thickened, colourless, fleshy, food-containing leaves. A comparison may be made with an ordinary leaf bud. Suggest the value of storing food for future use. Note in particular early flowering plants which store:—Early Purple Orchis, Lesser Celandine, Crocus, and the others named above, with a demonstration in each case of

the storage organ. Recall other storage organs the scholars are already familiar with, *e.g.* carrot, potato, turnip.

Pupils in this grade might undertake the rearing of a plant from seed. This might be done out of doors in a school garden, if circumstances admit of it, or indoors in pots. The supervision of the teacher will be required in the matter of planting, watering, and general tending of these plants, but such an exercise will afford many opportunities for developing interest on the part of the pupils.

Trees.—The list of trees to be recognised by foliage should be extended. The leaf should be drawn by the teacher, and in each instance all characteristic features distinguishing each type, such as nature of surface, colour, general arrangement of veins, exact shape, etc., should be got from pupils. The following will afford good examples for discrimination:—Beech, Elm, Lime, Willow, Hawthorn, Oak, Rowan, Horse-chestnut, Ash, Larch, Scots Pine.

Flowers of common trees should be included in the list of flowers for recognition, and these may be grouped as noticeable, *e.g.* Horse-chestnut, Hawthorn, Cherry, Lilac, and not readily noticed, *e.g.* Elm, Sycamore, Ash. Note the meaning of this, and also of their odour in relation to insect visits.

Fruits of Trees.—A commencement has been made with these in the previous course, in which fruits edible by man have been looked at. The scholars should now recognise as fruits the following:—“Hips” and “Haws,” Acorns, Beech-nuts (complete fruit), Horse-chestnut (complete fruit), Lime-fruit, Rowans, Elm, Ash, and Sycamore fruits.

A set of drawings of these fruits should be made.

Exhibit seeds and seedlings of familiar trees.

In cases where trees can be conveniently watched the development of the flowers and fruit may be followed.

Fact to be grasped: From a seed may grow a tree.

Collections of autumn leaves should be made by this class and some work done in drawing and colouring.

II. ANIMAL STUDIES :

The work detailed under this heading in the previous course (Section II.) ought to be repeated this year with such amplification or change as the circumstances call for.

III. WEATHER STUDIES :

A continuation of the work of the previous course, with the addition of a simple chart to illustrate the rise and fall of the thermometer as observed daily. The scholars should be taught to take the reading. The teacher will keep the chart, which should be drawn upon a large scale, and show the relation between its rises and falls and corresponding fluctuations of temperature.

IV. CALENDARS :

Similar work as for previous course, with a change of illustrations.

SUMMARY OF AIMS :

These are as for the previous course, with the addition of some details as to Nature's methods in Plant and Animal Nutrition, general functioning, and Adaptation to Environment. It need scarcely be pointed out that GREAT FACTS can be learned by very young children although their ears are not fit to hear the high-sounding terminology we find necessary for ourselves. But here also our chief aim is, through knowledge, to foster a love of NATURE.

COURSE III.—*For pupils of ages nine to twelve.*
(A Two Years' Course.)

I. PLANT LIFE:

Continuation of Plant identification studies—from 30 to 50 new plants; talk about simple recognition marks; more particular notice of colour, odour, shape, and size of flower.

Census of colours of flowers within the different seasons. Some notice of conspicuous and inconspicuous flowers. Conspicuousness of inflorescences of some small flowers, *e.g.* Queen of the Meadow or Clover. Recall the function of flowers (to produce seed), and revise the importance to the flowers of colour, scent, size, etc.

Recognition of two noticeable types of flower-form—avoid Actinomorphic and Zygomorphic as terms and speak rather of Symmetry of two kinds, radial and bilateral, taking numerous illustrations. A talk here about symmetry of living things in general is appropriate, contrasting the symmetry of the inorganic (*e.g.* Crystals). A general appreciation of form and colour, associated with drawing and painting.

Parts of the flower.—This should be touched on, simply as far as is required to make the functions of the flower quite clear. The names of the parts may be taught informally as they are required with simple explanations of their use, *e.g.*—

Sepals	. .	Protecting.
Petals	. .	Attracting.
Stamens	. .	Fertilising (pollen-producing).
Carpels	. .	Ovule-producing.

Some comparative work on the number of parts in different flowers, but no suggestion of floral formulæ to be made. Some talk on nectaries, with study of special illustrations, *e.g.* Buttercup, Violet, Pea, Clover. Recognition here of

different types of insects found visiting flowers, *e.g.* flies, beetles, wasps, bees, butterflies, moths.

A beginning should be made with floral lists, such as

- Wayside plants ;
- Plants of shady, damp regions (by shaded streams, ditches, woods, etc.) ;
- Seashore plants ;
- Moor plants ;
- Plants of fields ;
- Marsh plants ;
- Aquatic plants ;

and some time should be devoted to noting the special characters of good examples of adaptation to these situations.

Fruits.—What is sought at this stage is not a scientific classification according to structure, but rather a recognition of the different means of dispersal, ensuring the continuance of each species. Hence particular attention should be given to the parts specially adapted for this purpose, *e.g.*—

- Winged fruits and seeds ;
- Seeds jerked from fruit by wind ;
- Explosive fruits scattering seeds ;
- Fruits dispersed by animals, actively and passively.

A beginning should, however, be made in following the development of the fruit observationally in familiar cases to show its relation to the parts of the flower. Good examples for this purpose are Gooseberry, Strawberry, Buttercup, Bramble, Pea.

Leaves.—Revision of points made clear in previous course. Study of a typical foliage leaf ; its shape ; surfaces, how lighter below, meaning of surface gloss ; veins ; simple experiments to illustrate the passage of moisture through the leaves, and other leaf functions. Drawings of leaves

upon plant to illustrate relation to each other and to the light. Some clear cases of leaf mosaics, *e.g.* Nettle, Plantain, Daisy. Simple illustrations of leaf arrangements on the stem. Leaf forms.

Recognition by leaf of familiar plants, *e.g.* Dandelion, Dock, Sheep Sorrel, Daisy, Primrose, Celandine, Clover, Wood Sorrel, Oak, Beech, Poplar, Lime, Sycamore, etc.

Relation of leaves to buds on the stem. Recognition of leaves by their position as well as by form.

Simple modifications of leaves, *e.g.* spines and tendrils.

Storing leaves. Detailed examination of a bulb. Value of reserve stores to a plant.

Some clear cases of leaf development after flowering, *e.g.* Coltsfoot and Butterbur. Significance of this.

Study of autumn leaves. Comparison of leaves of same type of tree but at different stages. Comparison of leaves of different kinds of trees. The commoner colours and their distribution on the leaf. General appreciation. Drawing, painting, and making collections.

In the foregoing plant studies the principles which should be set forth for recognition by the pupils are:—

The diversity of forms adapted to similar ends (seen in flowers and in leaves); the wealth of Nature's forms;

The biological significance of flowers, and their value in human life; this latter is an illustration of secondary values acquiring great importance;

The prime labours of the plant—food making and seed producing illustrated in the work of leaves and flowers respectively;

Competition amongst plants for room and light.

II. ANIMAL LIFE :

In connection with flower studies there should be given a series of lessons upon four common types of insects visiting flowers :—beetles, flies, bees and wasps, butterflies and moths. Recognisable distinguishing marks should be noted and the relations to the flowers visited made clear. Note should be made specially of those insects with short jaws (beetles and flies mostly), with jaws of medium length (bees and wasps), with long jaws (butterflies and moths). What the insects get in each case, and how they serve the flower.

Study of the main activities in a bee-hive. Life history of humble-bees.

Rearing of insects in school—observational work on their habits and life histories. The following types make profitable subjects of study, viz. :—

Butterflies and Moths—various species.

Beetles—procure “Meal-worms” (larvae of *Tenebrio molitor*) from bird dealers and rear in bran.

Crane Flies—rear larvae in soil, feed with grass roots, or sow corn and allow them to feed on the roots. This can be done in a box.

General facts learned from the study of insect life :

Complex inter-relations seen in structural adaptations between flowers and insects; between the members of a bee colony, illustrating the principle of division of labour. The same principle illustrated differently in insect life-histories—the larval period for feeding and growth, *i.e.* the individual interest; the adult period, usually short, for race interest, *i.e.* the continuation of the species.

General Lesson List

from which selections may be made according to circumstances, season, etc. The list of course is only suggestive.

Structure and habits of Earthworms.

General structure of Insects.

Life Histories of Insects (insects reared in school).

Insects from Aquarium—habits and structural adaptations.

Structure and Life History of Crab.

Common Animals of the Garden, with facts regarding habits and life histories.

Slugs and Snails.

Shells, interpretation of their markings, studies in form.

A talk about Pearls.

The structure of a Fish; how a fish swims.

Life History of the Eel.

Frogs, Toads, and Newts; life histories and habits.

The Covering of Birds; talks about feathers.

A lesson on Eggs of Fish, Frog, and Bird.

Talks about migration and other habits of birds.

Characteristics of twenty common birds.

Common Mammals: Lessons on structure and habits—

Stoat and Weasel;

Rabbits and Hares;

Mole and Hedgehog;

Bats, etc., etc.

General facts learned from these studies:

A gathering of nature lore of interest and practical use;

Realisation of inter-relations and adaptations illustrating the struggle for existence.

Aquarium Studies :

Continuation with more precision of the Life Histories of the commoner inmates, Frogs, Newts, Gnats, Water Beetles, Water Bugs, Pond Snails, etc. Observational exercises on their behaviour, accompanied by drawings illustrative of typical habits, etc., *e.g.*—

- The respiratory, locomotor, and feeding habits of Larval Gnat ;
- Stages in the life-history of the Gnat ;
- Changes in the respiratory methods of the Tadpole.
- Changes in size and external form of Tadpole ;
- Larval and adult form of Newts ;
- Carnivorous habits of Water Beetles ;
- Adaptive features in Water Beetle for locomotion, and for respiration ; etc.

The properties of the surface film and the animals which use it.

The conditions of life in an aquarium or fresh water pool.

III. WEATHER STUDIES :

Practice should be given in the reading of instruments and in the recording and charting of the readings. Distinguishing the various cloud forms, and direction of wind should also be practised. Further work under this head is included in the general scheme for Nature Calendars. Pupils at this stage should be beginning to show some capacity for appreciating the connection between the appearance, luxuriance, and decline of life upon the earth and the seasons, *i.e.* the weather. See also Physical Study, p. 39. It should also be borne in mind that one of the chief interests in weather study lies in comparisons which

may be made, *e.g.* as between the different months of the year, the same months in different years, neighbouring counties or districts of different altitude or configuration, and so on. Teachers in differently situated localities might supply each other with their weather records for comparison. The pupils should be taught to make graphs to illustrate such points as these.

IV. KEEPING OF CALENDARS :

Pupils of this grade to share in the general work of reporting observations for insertion in the calendars kept in school and details of which have been already outlined.

V. GENERAL :

Throughout, practice in description should be given, verbally and by means of writing and drawing; the teacher should take every opportunity by quoting from nature literature of the best kind and by causing suitable selections to be learnt by heart to enrich the memories of the pupils with lofty sentiment and to cultivate an appreciation of the aesthetic aspects of nature. It will be suitable also at the close of this stage that the teacher should summarise with the pupils the more important generalisations in Biology which have been prominently illustrated in the studies of the previous years. (For these see conclusions formulated at the end of the several sections in the foregoing Courses.)

COURSE IV.—*Senior Pupils.*

The principles laid down for recognition in the previous course will now receive further illustration and amplification. Pupils will now be better able to realise seasonal influences, and this factor therefore receives more prominence. Within the seasons the studies are in the main arranged with some attempt at logical continuity of theme rather than under the distinct sciences, botany, zoology, etc. It is intended that this arrangement should be followed; so far from causing confusion, it will help towards a much desired realisation of what has been so fitly termed the "web of life," as well as of other interrelations of the nature complex.

SPRING COURSE.

This course may begin very appropriately with the study of early flowering plants. Pupils who have gone through the lower courses will already be familiar with a good many types. It will be found, however, that the interest of finding anew and examining old friends is unflagging, and further, that new facts continue to emerge. Work on the following lines should be carried out:—

OUTDOOR STUDIES.

Flowering Plants.—A list to be made of the flowering plants growing wild in the district. The date of first time seen in flower and situation to be noted in each case. In order to illustrate the special relation to spring of the plants found, some grouping should be attempted on these lines:

- (a) Hardy, flowering all the year or nearly so—*e.g.* Groundsel, Shepherd's Purse, Daisy, Chickweed;
- (b) Hardy, flowering early—*e.g.* Gorse, Purple Dead-nettle;
- (c) Provided with special reserves of food store over winter—*e.g.* White Butterbur, Coltsfoot.

This will entail a close and discriminative examination of each kind of plant which cannot but have instructive results.

Appropriate literature reference: Wordsworth's "To the small Celandine," to be read or learnt by heart. Note the message of the early spring flowers:

"Telling tales about the sun,
When we've little warmth, or none."

Trees.—This stirring of dormant life, sign of spring's appearing, is also to be followed upon the trees. A definite course of study upon trees continuous through the year should be undertaken, of which the following may be taken as the portion appropriate to spring.

Keep a watch and record the order of unfolding of buds of all the common trees in the neighbourhood. A continuous record of this for successive years to be kept in school.

Note and record those whose flowers appear before their leaves. Give dates of appearing of flowers.

Animal Studies.—Note further spring awakenings:—Insects appearing; some from winter sleep, *e.g.* queen humble-bee; various caterpillars, some from winter chrysalids; look out for first butterflies and moths.

Awakening of hibernators:—Bats, hedgehogs, squirrels, field voles.

Only some of these awakenings may possibly come under observation. But there is no harm in recounting others.

Return of migrant birds—mating and nesting.

If near a river, look out for the march of the elvers (young eels).

Note the re-peopling of the fresh water pools—gnat larvae, water fleas, etc. Stock the school aquarium. See p. 182 for details of lessons.

Collect frog spawn.

Much of the work noted here will consist of records for the Nature calendars (see p. 7). The pupils should be led to realise the seasonal importance of these observations and the *necessity for their being accurate*. But the teacher will utilise the opportunities afforded by the observations made out of doors by the pupils and by the materials collected to formulate definite school studies.

Now is the time to make spring phenological observations. A watch should be kept for the first flowering of particular plants, the arrival and song of birds, etc. See p. 110.

Fact emphasised: Spring is a season of awakening life.

SOME INDOOR STUDIES :

1. Flowering plant identification and examination. For detailed study during the three months of spring, a selection should be made.

The entire plant should be examined in each case. Note:
Adaptations to spring flowering (as already suggested);

Adaptation to situation (Wood Anemone, Lesser Celandine, Golden Saxifrage, Scurvygrass, Whitlowgrass, etc.);

The more obvious characters distinctive of the Natural Order in each case.

2. Trees and Shrubs. Recognition and examination of twigs.

Draw stages of opening of buds. Pupils must not be allowed to wantonly tear branches from trees. The teacher should bring in twigs, which should be placed in water; pupils should make daily observations. Note the effects of sunshine and heat.

Study a section of a twig, *e.g.* Horse-chestnut, interpreting the parts as regards use.

Look for seedlings of trees; bring in early, *e.g.* those of Sycamore, and note all stages of development for some weeks. Draw stages.

Study some catkins, *e.g.* Hazel, Alder, Goat Willow, Birch, Oak, distinguishing male and female; draw; note visits of humble-bees to willows, find the nectaries within the flowers.

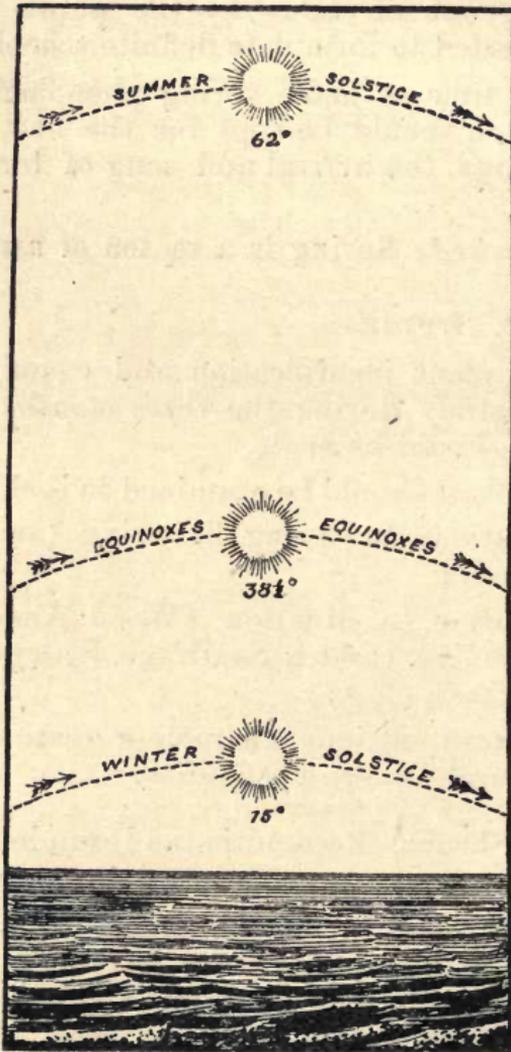


Fig. 2.—Altitude of the Sun at the latitude of London, in different seasons.

Detailed examination of Flowers of Elm, Beech, Gooseberry, Currant.

3. Germination of Beans, Cress, Wheat, etc.*
4. Examination of Pupae ; drawing and colouring.
5. Physical study : Cause of the Seasons.

After the pupils have realised the close dependence of life upon the seasons, a study as to their immediate cause is appropriate. The following should be made clear :—

The sun is the source of heat upon the earth.

Owing to the inclination of the axis of rotation of the earth the distribution of solar heat upon the earth varies at different times, thus producing the seasons.

Exactly how this is brought about should be demonstrated upon the school globe ; observations should be made on the sun's altitude now and at each season. Show the effect of obliquity on the sun's rays, *e.g.* when this is great the heat is spread over a larger area, a greater depth of atmosphere has to be traversed, and thus more heat is absorbed (see Fig. 2). A comparison of the average temperature (taken from the school records) of the three months of winter with the three months of spring should be made, and the fact that more heat is now being received from the sun should be demonstrated in this way.

6. Meteorological studies : Various Charts. See p. 317.
7. Animal studies : see list in the previous course ; it will probably be found that the aquarium will provide abundance of material for animal studies at this season of the year.

* Teachers who wish to carry out experimental work on seeds and seedlings will find many useful suggestions in Cavers' *Plant Biology*, or in the same author's *Life Histories of Common Plants* (Clive).

SUMMER COURSE.

As already indicated, the aim of the courses outlined in this work is to maintain a real correspondence between the work organised as Nature Study as a school subject and the more or less conscious impressions received by the pupils from Nature direct. If in the spring the dominating impression is that of awakening, may we not say of summer that it speaks of growth, vitality, abundance of life?

Opportunities for study crowd upon us now, and it is insistent that as many as possible should be taken advantage of. Consequently, as already stated, it is most strongly advocated that time-tables should be drawn up allowing for more work in Nature Study in summer. It is not suggested that the time be taken from other work, but that more work be apportioned to summer and correspondingly less to autumn and to winter. This scheme is drawn up on this basis. It is not likely that the whole of the scheme here suggested can be undertaken in any one case, but the contents will permit of choice. Similarly local circumstances may determine the inclusion of some things not here set down.

OUTDOOR OBSERVATIONS :

A summer course ought to lay great stress upon outdoor observations. As already laid down, it is not necessary that numerous organised rambles be undertaken. In the school garden opportunities will be afforded for outdoor class work, and they should be utilised to the full.

The following specific observations are suggested :—

- (a) The usual weather records (charting, making of averages, etc., to be included under indoor studies).
- (b) Recording the dates of agricultural operations on observational farm.

- (c) Other observations of value in weather study, e.g.—
- | |
|--|
| First flowering of horse-chestnut (<i>Aesculus hippocastanum</i>). |
| " " hawthorn (<i>Crataegus oxyacantha</i>). |
| " " white ox-eye (<i>Chrysanthemum leucanthemum</i>). |
| " " dog rose (<i>Rosa canina</i>). |
| " " black knapweed (<i>Centaurea nigra</i>). |
| " " hare-bell (<i>Campanula rotundifolia</i>). |
| " " greater bindweed (<i>Convolvulus sepium</i>). |
- Swallow (*Hirundo rustica*), first seen.
 Nightingale (*Daulias luscini*a), first heard.
 Flycatcher (*Muscicapa grisola*), first seen.
 Orange tip butterfly (*Anthocaris cardamines*), first seen.
 Meadow-brown butterfly (*Epinephile janira*), first seen.
- (d) List of flowering plants in the neighbourhood (see note under spring list).
- (e) List of ferns and mosses.
- (f) List of weeds of the garden.
- (g) List of weeds of cultivated fields.
- (h) List of mammals, birds, insects, etc.
- (i) List of animals of garden, classified as beneficial, indifferent, harmful.
- (j) List of wild animal visitors to cultivated fields—beneficial and harmful.
- (k) General nature notes of particular interest.

INDOOR STUDIES :

Weather.—The daily observations upon the weather will in the first instance be recorded in tabular form (see table, p. 319) ; from these records a chart in graphic form should be prepared to show daily temperatures, maximum and minimum, and weekly averages. Monthly diagrams of the wind direction should be made, and from these in course of time the direction of the prevailing winds for the district should be made out. Directions for this work are given in the chapter on Weather Observations. See also p. 33.

Plant Studies.—It will be understood that in the making of the list suggested [see (d), p. 41] opportunities will arise for notes and habitat, structure, etc., of the plants found. Besides these, lessons should be given on selected species to illustrate the aspects enumerated on p. 30.

Insects visiting flowers should be noted, and some good cases, *e.g.* primrose, violet, clover, pea, and their insect visitors should be clearly understood. Some attempt might be made at the grouping together of flowers visited by the same kind of insect, *e.g.* butterflies and moths, and the situation of their nectaries compared with that in flowers visited by other insects, *e.g.* beetles and flies. A grouping of insects visiting flowers according to the length of their feeding apparatus might also be made. Flies and beetles have short mouth appendages, in bees we have an intermediate graded series, whilst in moths and butterflies the appendages are relatively long.

Rearing of Insects.—All stages in the life history of the various types of insect which are reared should be closely followed and drawn. Careful and complete lessons upon the structure of caterpillar and butterfly or moth should be given. Lessons upon the commoner types of insect structure, *e.g.* bee, fly, butterfly, beetle, grasshopper, are appropriate to the present season. A particular case to be demonstrated is that of the bee, whose special adaptations for the collection of pollen and honey and the making of wax are of interest. See lesson, p. 171.

Other Animal Studies.—Some cases of insects visiting field or garden plants should be observed and understood. The life histories of aphides (green fly), magpie moth, V moth, currant saw fly, crane fly, and turnip beetle are examples from which a choice may be made.

The life of slugs, centipedes, millipedes, earwigs, woodlice, and their relation to cultivated plants might be followed.

Aquarium Studies.—The more advanced lessons stated under this head should be given. See p. 183.

General fact to be emphasised.—Summer is the season of growth, activity, and abundance of life.

AUTUMN COURSE.

The season in which the fruits of the summer's wealth of life and energy are reaped. Harvesting and preparation for winter generally are the dominant activities.

I. PLANT STUDIES :

Fruits.—Revise facts noted in previous course.

Interpretation of parts of the fruit in relation to the flower.

Definition of Fruit: "All the parts around the seeds which have undergone modification with the fertilisation of the ovules."

Distinctive characters of Berry, Drupe, Nut, Pod, etc.

Classification of these.

Collection and study of Wild Fruits.

Grain: Fruits eaten by man.

Special note of adaptations for distribution.

Seeds.—Their dispersal. Some note of numbers in relation to modes of dispersal and other factors, *e.g.* the "waste" of seed—Nature "knowing that of fifty seeds she often brings but one to bear."

[Practical studies in germination to be carried out in spring.]

Leaves in Autumn.—More detailed study. Children will gather leaves and bring them to school.

A general examination, children's preferences as regards colour to be noted—Arrange according to tree—Compare trees as to time and order of shedding leaves—Study of colours of each kind of tree—Yellows, Browns, Reds—Mode of change—Causes—Distribution of colour on the leaf—Mechanism of fall—Relation to seasonal agencies.

Drawing and colouring of different kinds.

Some studies of late summer flowers, or of garden flowers.

In schools situated by the seashore sea-weeds might be collected, named, and pressed. Drawing and colouring of

these should also be done. Elementary facts of life histories explained.

Classification of the regions for storing reserves in plants: tubers, roots, bulbs, rhizomes, etc. Clear recognition of the true nature of the organ in each case.

II. ANIMAL STUDIES:

Examples appropriate to autumn are—animals which harvest and store—Squirrels, Foxes, Field Mice, Rats, Voles, Bees (Hive), Ants, etc.

Migration of Birds: Review of the facts known, with classification of Birds (quoting as many instances as possible of each kind) into residents, summer visitors, winter visitors, birds of passage, stray visitors.

Slugs, spiders, and other small animals which may be available. Study of structure and general habits.

Craneflies are in evidence at this season—their general structure should be gone over and questions asked as to the meaning of their remarkable form. Review also their life history.

House flies may be captured, and if suitable conditions can be arranged for their preservation, these would form an interesting autumn study. It has recently been shown that these flies may be got to hatch out even in winter. See Local Government Board Report* for details of the experiments, which are not beyond the powers of an enthusiastic teacher. Such a study of course is easily performed in summer, but it may well be deferred to the autumn when less material is available.

Insects generally are scarcer, but winter pupae, *e.g.* of cabbage butterfly, may be collected, drawn, and set aside for hatching in the following year. These might be kept under various conditions as to light and heat and the effect noted in the times of hatching and possibly in the colouration or markings.

* *Report to the Local Government Board on Public Health and Medical Subjects* (New Series, No. 5, 1909), price 2d.

- III. WEATHER STUDIES as for the other seasons. Here some of the comparative studies suggested at p. 33 might be carried out.
- IV. SUITABLE CALENDAR RECORDS, *e.g.* harvesting operations; fall of leaf, giving trees in approximate order; migratory movements of birds, etc.
- V. PHYSICAL STUDIES, *e.g.* Equinoxes, Measurement of the Sun's Altitude at September 22nd, Study of the Moon's phases, Characteristics of the Harvest Moon.
- VI. STAR STUDIES as in Winter Course.

WINTER COURSE.

From the nature of the work for this season it is not convenient to set it out under separate heads of indoor and outdoor. It will be seen that the logical continuity is best maintained by following the lines adopted below.

We pass naturally from the Fall of the Leaf (Autumn Study) to a study of

LEAF MOULD, in connection with which a demonstration on *Processes of Decay* should be given (see p. 277). Devise experiments to show the action of Bacteria. Grow moulds experimentally. Study Mushrooms and Toadstools—their mode of growth, structure, and their means of dissemination. Dry and char some toadstools. The residue is mainly carbon. Enquire as to whence it comes and what becomes of it.

Note the formation in soil of Humic Acids, CO_2 , and disappearance of carbon from the soil except as carbonate, which remains longer. Incidental to the experimental demonstration of the presence of Bacteria in the Air, give a talk on the Hygiene of Fresh Air in relation to disease-producing germs.

From leaf mould we make the transition to SOIL contents generally. Classify these.

I. Vegetable Matter :

Dead : yielding Humic Acids, CO_2 .

Living : $\left\{ \begin{array}{l} \text{Seeds.} \\ \text{Bulbs.} \\ \text{Rhizomes, Roots.} \\ \text{Tubers, Corms.} \end{array} \right.$

Lesson : The plant world in winter. Where stores are kept.

Lessons on characteristics of the above.

II. Animal Inhabitants :

Earthworm.

Mole.

Hibernating Mammals : Hedgehogs, Shrews, Voles.

Hibernating Reptiles : Lizards and Snakes.

Hibernating larvae and pupae.

Beetles, Bees, and Wasps.

Ants.

Centipedes, Millipedes, Spiders.

Wood lice.

Slugs and Snails, etc.

Burrowers $\left\{ \begin{array}{l} \text{Rabbits.} \\ \text{Badgers.} \\ \text{Foxes.} \end{array} \right.$

A general lesson on the Winter Life of Animals ; also detailed studies of particular examples of the foregoing, particularly those materially affecting the soil, *e.g.* Earthworm and Mole. See pp. 131, 176.

This classification of vegetable and animal constituents should be worked out on blackboard and in note-books by teachers and pupils as a study in itself.

III. Earthy or Mineral Constituents :

(a) *An inquiry as to the origin and some changes undergone :*

Experimental study of Denudation :—

Enumerate first the commoner agents forming soil—
Rain, Frost, Running Water, Wind, Vegetation, Animals.

Explanation of mode of action of these.

Examine the extent of weathering on old buildings and tombstones, the dates of which are known.

Note crumbling of stone walls and growth of moss and lichen on these.

Note also the farmer's operations, Ploughing, etc., seeking the assistance of Nature in the work of further disintegration.

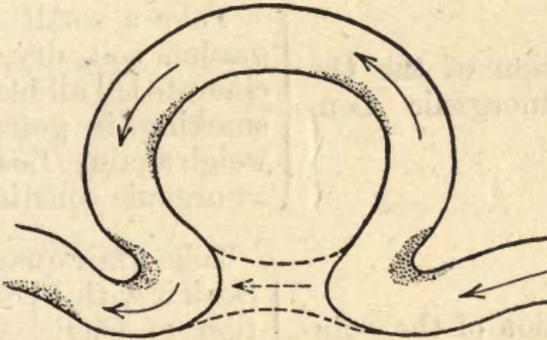


Fig. 3. River-Loops in an Alluvial Valley. The dots mark points of deposition.

An Illustration : The Work of Running Water :—

Some things to be done and observed are: Examine streams swollen after rain, take samples in a glass vessel, note the muddy condition, set aside and record the time taken for the water to become (relatively) clear. Note the different layers of sediment, and their times of settling.

Estimate the rate of flow of the stream. This may be done *roughly* by timing floating objects in, say, the middle of the stream, covering a distance measured from the bank. By this means discover how far the different layers

are likely to travel.* Keep for use at other times sealed samples of the stream in different conditions.

Note the formation of alluvial plains, if such occur in your district.

Study and make sketches of river bends, noting how islands are sometimes formed (Fig. 3).

Action of sea—eating away of cliffs, blown sand, and action of sand-binding grasses illustrate changes on the sea-shore.

Fact to be grasped by pupils : Denudation is a reality.

It has gone on for innumerable ages : appeal to sedimentary rocks which by elevation may have become exposed to view.

(b) *Simple Analyses :*

- | | | |
|--|---|--|
| 1. Separation of the Organic and Inorganic Constituents. | { | Take a small quantity of garden soil, dry, weigh, incinerate till all blackness and smoking is gone, cool and weigh again. Loss of weight = organic constituent. |
| 2. Separation of the Soluble and Insoluble Constituents. | { | Take a fair quantity of soil. Soak it with 1 per cent. solution of Citric Acid, whose action may be regarded as equivalent to that of the root-let sap upon the soil. Filter and evaporate the filtrate. |

The filtrate contains the readily soluble mineral matter which may be regarded as available for plants.

* The results obtained in this way are only roughly approximate, since we are assuming the rate of deposit in still water to be the same as that in running water. But our main point is to emphasise the *fact* of transport.

3. Mechanical by means
of sieves.

Mechanical analyses may be made by means of sieves (2 millimetre) for the rougher particles, and by sedimentation in water for the finer. But *exact* experimentation of this kind is rather outside the limits of the elementary school course.

(c) *Identification of Commoner Mineral Constituents :*

Quartz,	Mica,
Felspar,	Sandstone,
Limestone, etc.	

Study of their distinctive characteristics (see p. 282).

Name the rocks of your own district.

PLANT STUDIES :

Lessons on Evergreens, *e.g.* Spruce Tree, Holly, Snow-drops, Christmas Roses, Mistletoe.

WEATHER STUDIES :

Continue the work prescribed for the other seasons of the year. Incidentally, Snow Crystals should be studied and from these the transition to a study of Crystals in general may be made. See p. 64.

STAR STUDIES :

Indoors the teacher should figure the constellations most readily observable at the time of study and pupils should be encouraged to identify these at night. As an aid to teachers, Philip's "Planisphere" will be found of value.

RURAL COURSE.

For those teachers who are required to conduct nature studies which shall have some bias towards the agricultural industry, the following subjects are suggested. The Course is drawn up for senior pupils, since only in the higher grades is it desirable that specialised studies be submitted. What is given here need not of course constitute the whole course. There should be added studies for the seasonal groups given under Course IV. The details necessary for the lessons will for the most part be found in subsequent chapters.

- I. **Weather Studies** (as already detailed for other courses, emphasising dates of agricultural, etc., operations).
- II. **Calendars** (see p. 7).
- III. **Study of the Soil.** See details in Winter Course for Senior Pupils (Course IV.). Identification of the chief mineral ingredients. History of some common rocks.
- IV. **Study of Farm Crops.** Life histories.
- V. **Study of Common Weeds,** and their mode of propagation.
- VI. **Simple Cross Breeding Experiments** by artificial pollination, *e.g.* with Sweet Peas. (Enquiry: Verification of Mendel's Law.)
- VII. **Insects in Relation to Plant Life.** Cross pollination of flowers. Study of Pea, Violet, Primrose, etc. Useful and injurious insects: Life history—relation to plant and animal life of the farm, *e.g.* Crane Fly, Wireworm, Flea-Beetle, Carrot Fly, Ox Warble Fly, Sheep's Nostril Fly, Surface Caterpillars, etc.

- VIII. The economy of a **Beehive**. A school observational hive might be kept. Lessons on Insects and other animals of the garden.
- IX. Characteristics of five **Common Insect Orders**: Lepidoptera, Coleoptera, Diptera, Hymenoptera, Orthoptera, studied on common examples of each kind.
- X. Study of twenty common **British Birds** of direct importance in agriculture and horticulture, etc. The following are suggested:—Rook, Jackdaw, Magpie, Starling, Blackbird, Thrush, Cuckoo, Swift, Chaffinch, Bullfinch, Yellowhammer, Skylark, Swallow, Lapwing, Wood Pigeon, Black-headed Gull, Green Linnet, Blue Tit, Kestrel, Sparrow Hawk, Owls. Notes on their identification marks, feeding, nesting, and other habits.
- XI. **Life and Habits** of Field Mice, Rats, Voles, Moles, Hedgehogs, Weasels, Stoats, etc.

CHAPTER IV.

NATURE STUDY IN THE TOWN.

It will probably be felt by town teachers that some of the suggestions given in this work, whilst capable of being acted on in the country, are not appropriate to town conditions. There is much force in this objection. The teacher in the town school labours under disadvantageous circumstances as regards this subject. There is no doubt, of course, that the teacher who is personally well equipped can and does overcome his adverse surroundings, often with remarkable ingenuity and success. But we must think of the individual who is more or less of a beginner at this work.

In the first place it may be laid down as a general principle that the governing bodies of city schools must make reasonable provision in the matter of school equipment. The teacher should not be asked to make bricks without straw; he should not be reduced to that most pitiable condition of teaching lessons on flowers, birds, or beasts, and such like, by an appeal to the imagination alone. Nor is that state of affairs an ideal one in which the teacher under town difficulties lives, as it were, from hand to mouth, in the matter of class supplies.

Many teachers cheerfully find the necessary materials, but many on the other hand cannot spare the time required to collect such. The practice of finding supplies through the medium of the pupils may work satisfactorily in the country; it has undoubted limitations in the town. It is not suggested that the teacher should stand aside and do

nothing. An enthusiastic teacher will never lose a good opportunity of finding lesson material, and the best lessons will always be taught from that which has cost some trouble. At the same time official assistance is an absolute necessity for first-class work in the vast majority of cases.

To meet the difficulties of town schools the following suggestions are made:—

1. The Making of Collections.

Natural History collections should be gradually built up. Country teachers can to some extent assist their town brethren in such matters, and School Boards should be approached for the means to provide others. For a list of useful objects see p. 335.

2. Aquarium Studies.

In spring several glass jars should be stocked with fresh water animals, which will provide studies for a considerable part of the year.

3. Birds of the Town.

The birds of the town should all be identified, and their life history and habits investigated. Winter feeding affords an excellent opportunity.

4. Flower Cultivation.

On the plant side a fair amount of flower cultivation in boxes or in pots can be engaged in at small cost.

5. The use of Public Parks, etc.

Something should certainly be done in the way of visits to parks in the city, and occasionally to suitable places near it. In each district there are local natural features which the teacher ought to make his or her business to be intelligently familiar with; pupils should be taken to these at the most suitable times of the year. Coast towns, for example, are favourably situated for the study of marine

life; in other places the geological features may supply the subject-matter. But the teacher must be careful here not to attempt anything of a difficult nature.

With reference to the public parks, an arrangement between the park authorities and the schools for the supply of leaves, twigs, etc., for detailed study is quite practicable and should be come to. Large supplies are not needed at any one time in a school, and they may be made to serve several classes. The study of trees in some towns can be made a special feature.

6. Weekly Wild Flower Studies.

At least a single wild flower might be studied each week of the spring and summer. Pupils and teachers alike can share in the finding of these.

7. The School Garden.

Practically all difficulty with the town school is overcome if a garden is attached. Not many town schools have these, although they may be set down here as an ideal to be aimed at. But even a single plot may be of great service if the teacher but know how to lay it out to best advantage.

8. Weather Study.

The school should be supplied with instruments for the study of the weather (p. 337); in the town also something can be done with star studies in winter.

9. Calendars.

The making of Calendars, too, will prove a potent factor in developing the interest of the town pupil in the wider fields of Nature.

In town, too, it will be found that the spring and summer yield more opportunities than the autumn and winter. Time-tables of nature work should be drawn up with this in mind. There is no reason for adhering to a routine

arrangement of a uniform amount of time each week throughout the year; on the other hand it will be found more satisfactory not to do so.

The foregoing hints need not be regarded as exhaustive. Other points will occur to thoughtful teachers. There are many aspects of nature noticeable in a town which are special to it, such as the stones with which its houses are built and its streets are paved, or the soil beneath these. There are the domesticated animals upon the streets and in the houses, articles for sale in shops, and even the fog which sometimes hides the sun at noonday. But we have avoided reference to these, which, though admittedly capable of yielding studies of great interest, in that some at least are special to the town or to artificial conditions of life, need not find a place amongst studies designed specially to interest the pupil in the free and open fields of Nature rather than in the town. But a wise judgment will save the teacher from making any serious mistakes either way. Everything here will depend upon the manner and spirit in which the lessons are taught.

Whilst freely acknowledging the special circumstances of the town teacher, and submitting the foregoing hints to meet these, it is hoped that a careful study of the Courses outlined in this work will prove suggestive and helpful. From these, together with the lesson hints to be found throughout the book, most town teachers should find it possible to frame satisfactory schemes of work such as will tend towards the realisation of the best ideals in Nature Study.

CHAPTER V.

COLOUR, FORM, AND MOVEMENT.

A SIMPLE LESSON ON COLOUR.

LET this lesson be, in the first instance, an appeal to the innate appreciative faculty in the child for colour.

Do we need to ask whether they prefer things plain to things coloured? Some preliminary questions may be asked as to things liked by the pupils on account of their colour. Flowers will almost certainly be placed first, then perhaps fruits, *e.g.* rosy apples, cherries, strawberries, etc. (We need not stop to inquire into the complex of qualities, of which colour is only one, which may really determine the ultimate choice of any of these things. It is sufficient to exercise for a little the child's discriminative faculty amongst coloured objects falling within its experience.) Pictures, toys will be in the list, and the teacher will more than likely get surprises.

Next we may ask for some general colour impressions.

1. The Seasons.

Winter	...	White.	
Spring	...	Green.	
Summer	...	A wealth of colours.	
Autumn	...	Brown	} Earth ; Leaves. Fruits. Golden grain.
		Red	
		Yellow	

There should be some talk as to the reasons for the colour chosen. (This point arises in connection with the making of illustrated nature calendars, p. 9.)

2. Living Things.

Vegetation.—Green; assented to universally. Chlorophyll may be spoken of to the senior pupils.

Animals.—If we wish to get a parallel to chlorophyll, we must guide the pupils away from the thought of externals, and suggest a vital substance, which in all higher (vertebrate) animals is of the same colour, Red (*i.e.* blood). The colour is due to Haemoglobin.

3. The Sky.

Blue; again a universal assent. It may not be possible to give a reason to pupils, but it may stimulate the imagination if it is stated that fine dust in the air has to do with it. To those who understand that white light is composed of a number of colours, it may be possible to explain that the fine dust particles are able to scatter more of the blue rays than of the other colours owing to their shorter wave lengths, and that hence the sky appears blue.*

THE NATURE OF COLOUR.

To what is colour due? If circumstances prevent a full answer we can still give a partial one. We may begin by showing that white light can be made to yield a series of colours—red, yellow, green, blue, violet. This may be done by means of a glass prism or by an appeal to the rainbow. From this we may pass to the statement that white light is not simple, but a combination of different kinds of light (Fig. 4).

Objects appear coloured to us when they absorb some of the rays of white light and reflect others. The greenness of a leaf is due to the substance absorbing all the rays of the spectrum except green. If no rays are absorbed but all reflected, then the object appears white. Examples of such objects are snow, white hair and feathers, powdered glass. In all of these cases a gas of some kind is enclosed between the constituent particles.

* Recent researches appear to suggest that the dispersal is due to molecular movement.

At this point pupils might be asked to name common coloured natural objects, whose colour is due to these objects absorbing certain rays of light and reflecting others: Examples: Flowers, vegetables, fruits, butterflies, feathers, birds' eggs, etc.

Amongst the examples given there are likely to be some whose colour is due to the structure of the object on which the light falls. In this case the colour will vary as the object is moved in the light (it varies with the angle of incidence of the light). This will be best understood by

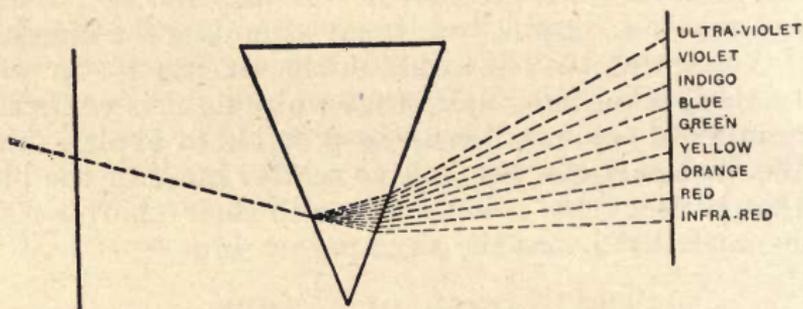


Fig. 4.—White light passing through a prism is broken up into its constituent elements.

citing more examples and comparing with those already quoted: Pearls or mother of pearl, many feathers, *e.g.* the tail feathers of the magpie or breast feathers of the starling, the metallic colours exhibited by many beetles, the cuticle of an earthworm, the iridescent scum upon a stagnant pool.

It will not be difficult for the pupils to understand that in some cases the colour of an object may be due to both causes combined, *viz.* a substance absorbing certain light rays and at the same time, owing to the structure of its surface, producing a play of colour by means of the rays which are reflected. Some of the instances quoted, *e.g.* feathers showing reflections (starling, magpie), are of this nature,

Sum up all by again commenting on the variety of colour in our surroundings, *i.e.* in nature. Run over with the pupils the colours in the landscape as seen from the school doorway or window, or in any suitable view, and give the pupils some practice in naming the colours of different objects around them.

In all descriptive exercises pains should be taken to make the records of colour as precise as possible. This is admittedly not always easy, as the beginner will find who tries, for example, to describe in detail the plumage of a bird or the colour of birds' eggs.

SYMMETRY IN NATURE.

SUGGESTIONS FOR LESSONS ON FORM.

We commence with a simple classification.

The pupils' attention has probably first been drawn to the subject by noting the symmetry of flowers. But we shall begin this really important subject more simply with the familiar grouping of all things mundane as vegetable, animal, or mineral. Pupils will assent to this classification.

The next step is more difficult. Our question now is—with regard to the form of the bounding surfaces of objects belonging to these groups—What fundamental agreements or differences are observable? Take concrete illustrations, say a flowering plant, an animal, and a piece of granite. The answer of course is that the organic—buttercup and weasel—are our examples—is bounded by curved surfaces and the individual constituents of the granite by straight lines. Try to educe this difference from the pupils. If only a partial assent is given we may proceed.

There is not much difficulty with the organic. Plants and animals are bounded by curved surfaces, and the human mind in infancy finds gratification in this, probably before it appreciates straight lines.

The Symmetry of Flowers.

Let us take easy examples. In flowers the bounding lines are symmetrical. That is to say, there is (nearly) always one line which drawn through the flower divides it into two parts which are counterparts of each other; one is the mirror image of the other. Commonly in flowers there is more than one such line. In our buttercup there are five.

Draw a buttercup on the board viewed from above, and pass a straight line across the middle of a petal and along the space between the two petals opposite. You see that this can be done five times always with the same result—two and a half petals on one side, and two and a half exactly similar petals on the other. (For sim-

licity's sake we neglect all reference to other parts, stamens, etc. We are dealing with the plan of structure.) Such symmetry as is here illustrated may be termed Radial Symmetry (actinomorphic of botanists), and as stated above it is the commonest form of flower symmetry. Examine a few flowers with regard to their symmetry.

Now take another example, this time a Violet flower. Draw a surface view, or, what is perhaps better, a floral diagram (Fig. 5). We see at once that in this case there is one line only which can divide the flower into two counter parts. When such is the case we speak of Bilateral Symmetry (zygomorphic of botanists).



Fig. 5.—Floral Diagram of Violet. The line of bilateral symmetry is the line passing across from the spur to the odd sepal at the top of the figure.

Test this rule upon one or two cases, *e.g.* Primrose and Wallflower. The former shows radial symmetry. What of the latter? Draw the floral diagram of the Wallflower (Fig. 6). This presents an interesting case. A line drawn so as to divide the two groups of long stamens and have a short stamen on each side (A B in Figure) gives the true line of bilateral symmetry, and no other line gives the

same kind of division. But a transverse line still gives a division into two equal parts (the line CD). It divides each of the two stamens into two parts, and separates the two groups of long stamens, see Figure. But the two halves thus got are not similar to the halves got in the first division. We may call this latter dividing line a secondary halving line. The Wallflower shows bilateral symmetry. Note that we must reckon with the stamens in this case as they enter individually into the plan of the flower. This is not the case where the number of stamens is indefinite.

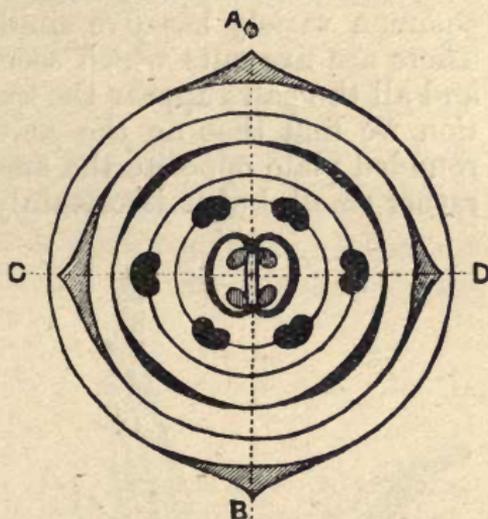


Fig. 6.—Floral diagram of Wallflower.

The Symmetry of Animals.

Let us turn now to animals. All higher animals exhibit bilateral symmetry. They have right and left sides. Think, for example, of Mammal, Bird, Frog, Fish, Insect, Crab, etc. Get examples of animals from pupils. Animals far more than flowers show bilateral symmetry. The animals which show radial symmetry, *e.g.* jellyfish, sea anemones, starfish, are lower in the scale of being, and there is good reason in this for believing that the bilateral symmetry is the higher type. For with the bilateral symmetry in animals is associated always a definite brain of some sort, marking out the head end.

It has been suggested with some show of truth that the appearance of varieties of life amongst radial forms, *e.g.* perhaps certain lowly types of worm, which exhibited one part of their radial margin more sensitive than the rest led the way to forms in which this small beginning developed into a brain—a definite ascent.

The Case of the Starfish.

The starfish deserves further notice. An example of the common variety has five similar rays regularly arranged. There are five cuts which seem to give an equal division, and all the pairs appear the same. But on close examination we find that on the central disc there is a definite rounded plate opposite the angle between two rays. It is rather small, but it is certainly not trivial; it is a definite

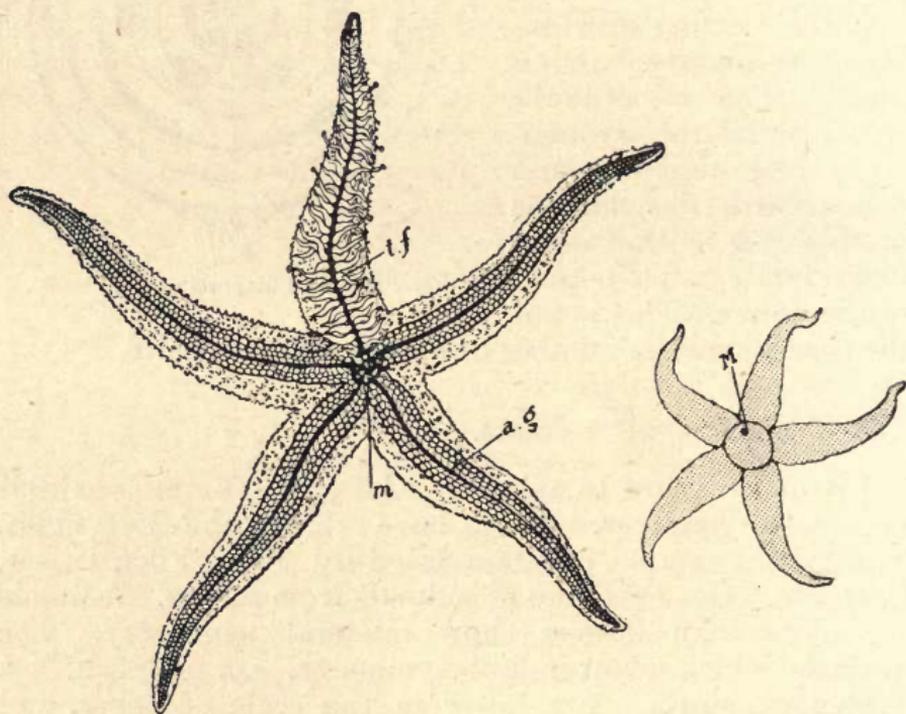


Fig. 7.—Starfish. The larger figure shows the under, the smaller the upper side. *M*, the madrepore, the spot referred to in the text which gives the line of bilateral symmetry. Other references are *m*, mouth; *t.f.*, feet; *a.g.*, the ambulacral groove on underside of the ray.

organ leading into the water system of vessels, and it destroys after all the radial symmetry. A line through this plate and through the odd ray opposite gives the true dividing line of bilateral symmetry. But while emphasising a point like this, we need not minimise the undoubted

fact that the starfish is *radial in form*. It behaves as a radial animal. Whether this radial form has in the course of evolution been superimposed upon a bilateral type is a difficult question, the answer to which cannot be discussed here (Fig. 7).

Unsymmetrical animals are rare. There is the familiar snail, carrying its shell containing many important organs upon its right side. We cannot divide this animal by a single straight line into two symmetric halves. But the snail in this feature exhibits a turning back. It is at bottom bilaterally symmetrical, but this symmetry has been lost

Symmetry of the Inorganic.

We have already suggested that the contrast in surface bounding lines between living matter and mineral is that of curved lines and straight lines. We go on now to state the difference more exactly. Geologists recognise that matter—apart from organic matter—exists in two main conditions.

(a) *Amorphous*, having no definite internal structure, and consequently no characteristic external shape of its own, but taking the form of the cavity or space in which it originated. This is not the place in which to consider the causes leading to matter appearing in this condition, but it may be pointed out that in some cases the assuming of the amorphous state is due to the conditions of formation (*e.g.* too rapid cooling), and is not an inherent property of the substance itself. Examples of amorphous matter are natural glasses, *e.g.* obsidian and pitchstone.

It has been suggested that amorphous bodies are really made up entirely of matter in the condition of irregularly arranged crystals of microscopic size.

(b) *Crystalline*, where the substance has a definite internal structure, which usually finds expression in a definite external form, which is not lost unless the substance be subjected to external forces. One reason why

crystals are not more obvious to the ordinary observer than they are is that they are so frequently broken by mutual pressure, etc.

We have taken a piece of granite to exemplify the condition of mineral matter, and in it we may see crystalline structure. Not, certainly, in the simplest form in which it might be seen; still a close examination will reveal the straight lines of innumerable crystals inextricably mixed up.

If our pupils wish to see a simpler case, it may be possible to exhibit a large quartz crystal which has had room to grow, and consequently displays its angles and faces perfect. In this connection we may appeal for a closer examination of the fern-like tracery of the frost figures on the window pane, or an examination of the snowflakes as they fall upon us out of doors. And above all we must give effective point to the lesson by growing crystals.

What are the simpler characters of crystals which may be pointed out to our pupils?

1. They are bounded by straight lines, not curves.
2. They have flat surfaces, termed faces.
3. In crystals of the same substance the angle between corresponding faces is constant, whether the crystal be large or small.
4. There are different types, distinguished by the number, length, and position of their "axes."

Some Common Crystals and their Appearance.

1. *Snow*.—Snow crystals have six rays. They consist of "solid rods or flat scales, each with six sides, others are six-sided pyramids, the most common are six-pointed stars." The six rays constitute three lateral axes, and there is a very short vertical axis in the centre. They are white because of the large amount of air enclosed between their numerous points (Fig. 8).

An ordinary snow flake consists of many of these crystals in a loose entangled mass. They are delicate and are



Fig. 8.—Examples of snow crystals.

frequently broken in their fall through the air; yet although they melt quickly as we examine them closely, it is not difficult to get a view of perfect examples.

2. *Quartz*.—Quartz crystals consist of six-sided prisms, topped by six-sided pyramids. They are known as rock crystal; perfect examples are found where they have grown in cavities. The number and arrangement of the axes is the same as in the snow crystal (Fig. 9). Quartz occurs in granite and sandstone, but perfect crystals cannot be seen in these; it is the commonest mineral in the earth's crust.

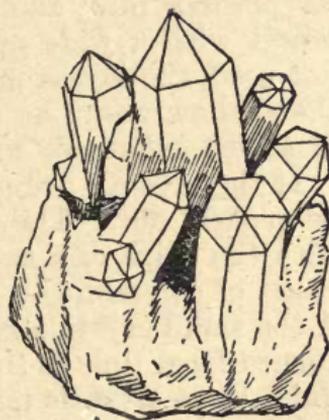


Fig. 9.—Piece of Quartz showing crystals.

3. *Alum*.—Alum crystallises in regular octahedra. There are three axes of the same length, intersecting each other at a right angle. Exhibit a crystal or draw one.

4. *Common Salt* crystallises in cubes. Here the number and arrangement of the axes is the same as in alum. This should be demonstrated by means of a diagram.

5. *Copper Sulphate*.—In this type of crystal all the axes are unequal and are placed obliquely to each other.

Growth of Crystals.

The experiment of growing crystals should be performed. The teacher should make a saturated solution in water of any of the three foregoing substances or of any other he may find more serviceable to his purpose, by dissolving as much as the hot water will take up. Keep the water near boiling point, continuing to add more of the solid as it dissolves. In the case of common salt a very large quantity of substance will dissolve in this way, but as it is readily available in quantity it should be taken for this experiment.

When the solution is saturated, which will be indicated by the liquid ceasing to dissolve any more solid, it should be poured into another clean vessel. A quite shallow vessel with a wide opening is best, and if all the liquid is not used the excess may be put aside for future use. In the shallow vessel as cooling and evaporation proceed the dissolved substance will reappear in crystalline form.

If the crystals are not too crowded, perfect forms may be picked out. They may be separated from each other with the point of a needle. In this way small but perfect cubes of common salt will be got. In the case of the alum, if the small crystals can be kept apart from each other and turned from time to time so that the faces may grow equally quite large crystals may be obtained. So also with copper sulphate, but this substance being poisonous is not so convenient for school use.

If these experiments are successfully performed, and with care and patience they may be, it will be well in conclusion to compare the growth of a crystal with that of a plant or animal. The teacher should make clear the fact that

although crystals grow they do so by the addition of particles of the *same substance* to the outside—*growth by accretion*—whereas plants and animals grow by the addition of substances which are *dissimilar* and by addition from the inside—*growth by assimilation*.

Summarise the studies on form by appealing for appreciation of nature type forms, particularly animal and plant. But scenery should not be neglected. This appreciative spirit should run through all nature studies—its development tends to the culture of aesthetics.

THE SWIMMING FISH.

A STUDY OF MOVEMENT.

We have before us in a large glass bowl some golden carp. Let us watch them for a little. As with the bird in the air, so with the fish in the water, we cannot but admire the ease of movement, the mastery of the medium in which the creature lives. Our fish may not be the best to typify the various activities of fish in general which we might have, but at the moment they are the most convenient. The gold fish are slow, trout in captivity even show more activity; for dash and perfect grace of movement the salmon or any of the more active sea species, *e.g.* the spotted dogfish, afford in their natural haunts a very fine sight.

Let us, however, watch our gold fish. Lazily they move, sometimes suddenly dashing forward, at other times they poise stationary, they rise, they fall. We become conscious that movement is effected with slight effort. What are the special adaptations fitting them to live in water? And while we seek to enumerate some of them we shall think not only of the gold fish before us, but of fish in general.

- We note (a) their form—spindle or wedge shape,
 (b) their surface—smooth,
 (c) specific gravity—that of the water,
 (d) great muscular development,
 (e) fins,
 (f) air bladder.

Form.—We shall study this in some detail.

Draw the outline of a fish as seen from above.

It is a double wedge, with the broadest part a little way behind the front (Fig. 10A). The head forms a short blunt

wedge in front, and the body a long tapering wedge behind. It is not unlike the general shape of a bird's body. A consideration of the fish shape with reference to the inward pressure of the water upon the body will show that this tends to push it forward on the slightest muscular effort (see Fig. 10).

The pressure on the long wedge tends to produce forward slipping, whilst the small wedge presents a cutting edge, removing the resistance which would otherwise be offered in its absence (compare A and B).

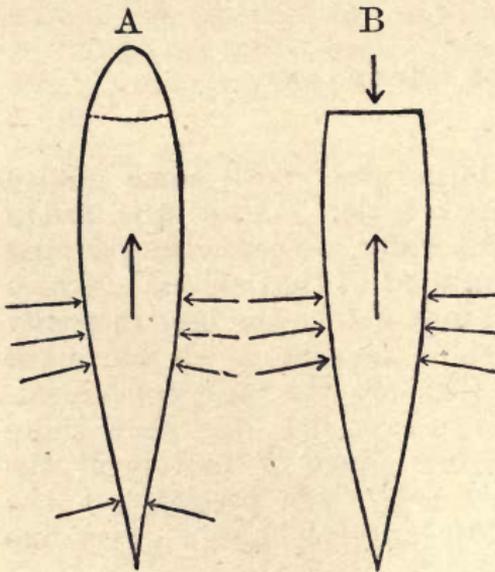


Fig. 10.—Diagram to show the effect of the pressure of the water upon the body of a typical fish. The median vertical arrows indicate the direction of the resultant pressure. See text for full explanation.

Note also the absence of all projecting parts or breaks in the even continuity of the body outline. And here it is of interest to recall how animals of fundamentally

terrestrial structure which have taken to the water approximate to the fish form. All stages are observable. Compare, for example, with regard to loss of neck constriction, reduction or loss of ear pinna, modification or loss of hind limbs, the following series:—Water Vole, Otter, Seal, Dolphin or Whale.

In all of these the neck is thickened, and there is practically no constriction. In the water vole the ear pinna is covered with rather long hair and lies flat against the head; in the otter the pinna is greatly reduced in size, and does not project upon the head; in seals, dolphins, and whales it is entirely absent. As regards hind limbs, in the semi-aquatic forms these limbs are of normal size; in seals they are directed backward in the line of the body and are most useful as swimming organs; in the others—entirely aquatic mammals—they are lost, save for vestiges concealed within the body.

Surface.—Though scaly, the body presents a smooth surface. Mucus glands are present in the skin, and in some fishes it is kept in an extremely slimy or slippery state by the products of these glands. An excellent example of this is the small “butterfish” so common in the pools around our shores, although here the slipperiness has the additional protective value of rendering the fish extremely difficult of capture. It is worth while here also comparing the “set” which is assumed by the hair upon the aquatic mammals, *e.g.* otter and seal.

Specific Gravity and Centre of Gravity.—It is well known that dead fish float. Their specific gravity is about equal to that of water. Their centre of gravity is high up on the body a little way behind the head. These points might be verified on a dead fish. Bearing this in mind, it will be readily seen that, were it not for the action of the fins, the balance of the fish would be easily upset. But with balance maintained, the result of these arrangements is that a minimum of effort is sufficient to effect movement. The support given to the body is such that fish of this shape do not require to lie down in resting. A little watching of the fish will help to make these things clear.

Muscles.—The proportion of muscle to the total body weight in a fish is considerable. The amount of space occupied may be demonstrated by pointing out that if we except the cavity on the lower side of the body containing the viscera, and the backbone and fins, practically all behind the head consists of muscle. The outline of these muscles may be seen through the skin in some fishes, *e.g.* the haddock. That fishes are capable of long-continued muscular effort we know from what has been learned regarding their migrations; for example, those of the eel (see p. 73).

Fins.—The fish should be carefully and patiently watched, and an endeavour made to interpret the action of the several fins. To begin with let us enumerate these. Distinguish median fins in the middle line of the body, dorsal, ventral, and tail. Fill these in upon your drawing. The

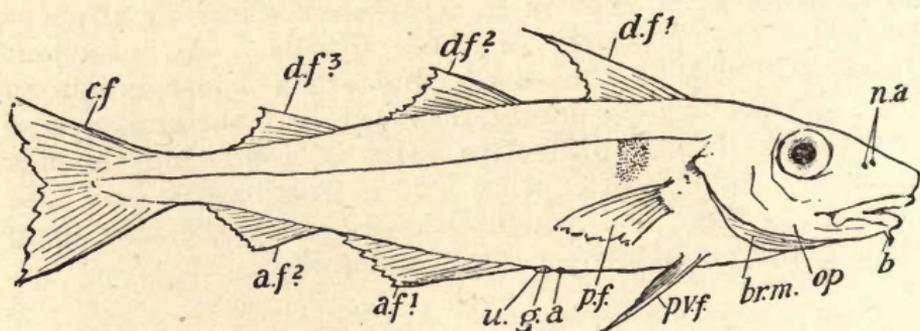


Fig. 11.—Diagram illustrating the externals of a Fish (Haddock).

n.a., nasal pit; *b*, barbule; *op.*, operculum or gill cover; *br. m.*, branchial membrane, lower part of gill cover; *pf.*, pectoral fin; *pvf.*, pelvic fin; *u.g.a.*, body apertures; *d.f.*^{1,2,3}, dorsal fins 1. 2. 3; *a.f.*^{1,2}, ventral fins 1 and 2; *c.f.*, tail-fin.

number, size, and position of dorsal and ventral fins vary in different types of fish. (See description of a fish, p. 77.) There are also two sets of paired fins. These are comparable to the two pairs of limbs in higher animals.

Consider the dorsal and ventral fins. We recall the unstable equilibrium of the fish and note that these fins will help to maintain an even balance. As we watch the fish

we see that they are raised and lowered at will. These fins have been removed from fishes, when it has been found that a straight course could not then be followed. In some fishes, *e.g.* pipe fishes, sea-horses, and sticklebacks, the dorsal fin by means of rapid undulations along it is used to propel the fish.

Tail Fin.—The action of this fin should be closely studied. It should not be difficult to note that this is the propelling organ. Two principal movements can be observed—the bending of the tail to the side preparatory to the making of the stroke, and the backward effective stroke. In fishes with a large lobed tail fin, one can readily see that in the bending preparatory stroke the fish by a graceful undulatory movement of the fin presents its edge to the water suggestive of the feathering of an oar. In the extending stroke, on the other hand, the flat surface is presented to the water and effective propulsion is the result. In the two movements there is in effect a slipping through and a gripping of the water.

An excellent illustration of the force there is in the stroke of a fish's tail is seen when the fish in a nearly vertical position by a single movement of this organ throws itself out of the water, *e.g.* the trout after fly, flying fish when chased by their enemies, or salmon in climbing weirs, etc. No better testimony to the effectiveness of the stroke of a fish's tail can be got than this last. Salmon of very large size are known to readily effect a six-foot leap.

Besides propulsion the tail fin is on occasion, by bending to the side, made to act as a rudder.

It is of interest here to note two common recognisably different tail forms.* There is the type seen in bony fishes in which the upper and lower lobes are of the same size, and that occurring in sharks and dogfishes in which the upper lobe is much the larger. This latter type of tail is the more ancient.

* This does not exhaust the list of tail types, of which there are four amongst living fishes.

Paired Fins.—There are two pairs of these, and we may note in passing their interest as the precursors of the fore and hind limbs of other vertebrate animals. They are placed, one larger pair upon the sides near the head and the other smaller pair further back and lower down on the body.

In some fishes, *e.g.* members of the cod family, the hind pair has been transferred to a position in front of the fore pair. This arrangement doubtless assists in keeping up the head end, which is necessary owing to the position of the centre of gravity and which is one of the uses of the pectoral fins.

Both pairs also act as side keels, maintaining steadiness and preventing overturning. This is not difficult to understand in the light of what we now know of the other adjustments in the fish body.

Another important service performed by these fins, which may be discovered by watching the fish, is that of steering. It will be noticed how frequently the fins of one side act independently of those of the other. A backward stroke of a pectoral fin turns the fish towards that side, and other turning movements are similarly effected. Lastly they are in some cases used as propelling organs. Sticklebacks may be observed using their pectoral fins for this purpose.

Air Bladder.—An interesting structure possessed by many fishes is the air bladder. This sac lies below the backbone; it is very variable in form and size; it may open into the gut or be closed. It is undoubtedly a hydrostatic organ in the first instance, though in many cases it has other functions.

Its use seems to be to adjust the specific gravity of the fish to that of a particular plane in the water, which is called the plane of least effort. If the fish rise far above this plane, or go far below it, special effort will be required to maintain the new position until by an internal adjustment of the amount of gas in the bladder a new specific gravity is attained, and the bladder is contracted or distended. This adjustment is effected by blood glands in the air bladder, and also by the duct liberating gas in

those which are open. The air bladder is probably of use in the longer migrations, when it may help to keep the fish relatively at the same depth in the course of the journey.

Throughout, the attempt should be made to maintain this lesson on observational lines, by, as has been suggested, close watching of the different movements made by the fins, and noting the result of these movements ;

- e.g.* raising and lowering of median body fins ;
- action of tail fin ;
- action of paired fins, together and separately.

MIGRATIONS OF THE COMMON EELS.

As a particular illustration of the powers of fishes, the lessons on the swimming fish might be followed by the teacher recounting the outstanding facts narrated below regarding one of the most familiar of fishes occurring in fresh waters.

Until a few years ago it was necessary in speaking of the life-history of the common eel to refer to it as a mystery. To-day much of the mystery has been removed, and in its place we have a tale of remarkable interest.

The "march of the elvers" or young eels up the rivers from the sea in the spring or early summer has long been an event of interest and wonder. It is an event to be looked for by those within reach of the banks of a river or smaller stream. The time varies with the stream, but in general it is later in the south than in the north.

The young eels on leaving the sea spend their time in the fresh water, feeding and growing, sometimes leaving the water and crossing the fields to another stream ; in this way they live for about four or five years, when a return migration down the streams to the sea takes place.

It is a matter of some importance to note that eels at this later stage have assumed a different appearance from the ordinary. They present a silvery metallic appearance. Their eyes are larger and are placed closer to the top of the head ; their sense of smell has become more acute, as is

evidenced by the greater development of the smelling organ. Another sensory organ whose development is accentuated is the lateral line, a structure whose function appears to be of the nature of a chemical sense or to have something to do with the appreciation of pressure in the water. Further, there is much fat accumulated on the body, the muscles are exceptionally well developed, and the breast fins are increased in size. Notwithstanding these changes, very suggestive of the fish being in the pink of condition, the eels are not mature.

What do these changes signify? The eel is starting upon a very long journey, upon which it does not stop to feed. Many of the characters assumed are those of deep sea fishes, *e.g.* the large eyes or well-developed lateral line. The eel is in reality a deep sea fish and this migration is a return to the ancestral home to spawn.

The journey is not simply to the sea. The eels of the streams and rivers of the east coast of Great Britain, for example, do not spawn in the North Sea nor in the waters of the Baltic. No eggs, nor young, nor mature eels have ever been found there. Nor do any fully grown eels ever return to the fresh waters. The spawning beds of the eels of the north-west of Europe are situated in the North Atlantic at one thousand fathoms depth and at least one thousand miles from fresh water.

The eels travel at the rate of eight to ten miles per day, at which rate it will be seen they must spend several months on the journey. By the time they reach their journey's end they have become mature, and the eggs are probably spawned in the spring time. From these there develop after more than one larval period the elvers which appear the following spring in our rivers and which therefore must be a year old. The parent eels are believed to die after spawning.

The migrations of the eel illustrate a remarkable instinct. They are difficult to explain, except on the ground that the migrations have been evolved in the past through changes in the distribution of land and water, in which the fresh waters to which the eels had betaken themselves for feeding have through the ages been further and further removed

from the spawning place. If this be the case, then the eels have inherited the double instinct of returning to their ancestral home to spawn and die, and what must be regarded as the more remarkable one of the young elvers, of finding their way to the fresh waters many hundreds of miles away along a route of which they have no previous knowledge.

It will be well also to refer to the migrations of the salmon, which are exactly opposite in character, since the salmon frequent the fresh waters to spawn and return to the sea, in which their principal growth takes place.

Compare the journeys of migratory birds.

By way of further development of the study of movement the teacher should map out comparative studies on the powers and modes of movement of some common animals. Information which may be utilised in this connection will be found in the Chapters dealing with Birds, Frogs and Toads, Moles and Bats, Snail, and Earthworm.

CHAPTER VI.

EXERCISES IN DESCRIPTION.

THE fundamental exercise in indoor nature study is description. It sets the seal in a precise way to observation, and pupils should frequently be set tasks of this kind when sufficient specimens are available. The pupils, at the commencement at all events of such work, should receive some suggestion as to the order in which to proceed. As a rule, both with plant and animal specimens, a description should commence first with a statement of the size, general form, and colour. Subsequently the various parts should be taken in order and described in detail. We give here a description of a fish such as has been studied alive in a previous lesson.

Illustration of a Description.

EXAMPLE.—A Carp, black variety.

This specimen is about five and a half inches long, the form somewhat spindle-shaped—tapering gradually to both ends, laterally compressed, thicker anteriorly, more flattened in tail region. The trunk and tail are covered with soft overlapping scales. Along the dorsal region of the head and trunk the colour is blackish, laterally bronzed, and ventrally, yellowish white. Head, trunk, and tail regions are recognisable, but there is no neck.

The head is short, deeper than broad at its widest part, tapering bluntly. At no part is it so broad as the anterior region of the trunk. The roof of the head is the darkest

in colour of the whole body, and the whole head is scaleless. The mouth-opening is terminal, and when closed is crescent-shaped; the nostrils, paired and valved, are situated anterior to and about the level of the dorsal border of the eyes. These are black, with iris pale, slightly bronzed, and tinged with amethyst. There is a row of [sensory] spots on the under side of the lower jaw. Behind the eyes are the relatively large, somewhat convex and composite gill-covers, beneath which may be seen the gill-arches. The ventral portion of the gill-cover on each side is supported by a few curved bony rods.

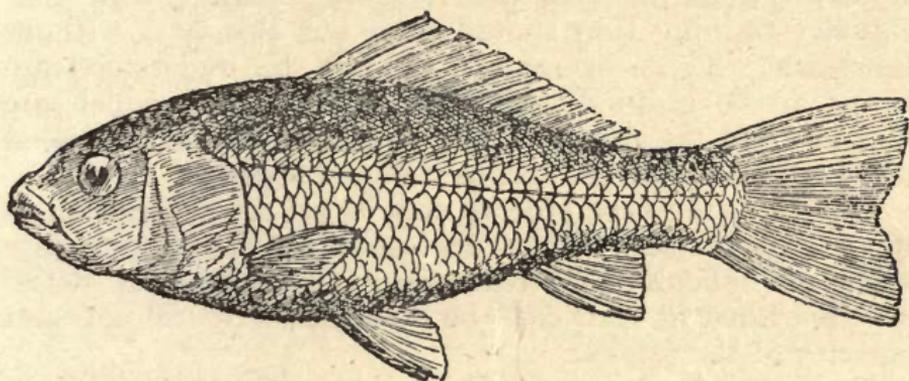


Fig. 12.—The Carp (*Cyprinus*). Compare with Haddock (p. 70) as regards number and arrangement of median fins, and position of paired fins.

The trunk is about three and a half inches long, its greatest vertical depth, which is just behind the head, is one and a half inches, and its least, at the junction with the tail, about half an inch. The scales have a rounded free border, and are always more darkly pigmented on the exposed part. One taken from the side of the body is bronze, dotted over with minute black specks, the covered part is silvery white, and the innermost border is wavy in outline. A distinct line of modified scales, running along each side of the body and curving upwards anteriorly, is observable. (This indicates a lateral sensory line.)

There is a median dorsal fin about the middle region of the trunk, and a median ventral, smaller, both terminating about the same distance from the caudal fin. Close to the

free borders of the trunk anteriorly, and near the ventral side, are the paired pectoral fins [equivalent to fore-limbs] somewhat fan-shaped. On the sides of the ventral line, half-way between the head and the ventral fin, are the pelvic fins [equivalent to hind-limbs], like the pectoral in shape, but smaller. In all these fins the first ray is stronger and firmer than the others. The anal aperture is just in front of the ventral fin. The tail fin is relatively large and symmetrical, with a rounded, broadly bilobed, terminal border (Fig. 12).

It is desirable that pupils should have frequent practice in descriptions such as the foregoing. After their preliminary training they should carry out this work without assistance. These exercises it should be understood are meant to be quite distinct from descriptions which are elicited from the pupils in the course of an observational study such as is given, *e.g.*, in the next chapter.

The following type objects may be set for description as opportunity arises. They are arranged in approximate order of difficulty of treatment; the degree of detail required must in each case be determined by the age and capacity of the pupils.

Plants.

Leaves.—These will call for verbal descriptions of size, shape, colour, and texture. Not until the pupils have grappled with the difficulties of finding terms to correctly indicate different shapes of leaves should the teacher supply the recognised nomenclature, and this should for the most part be done with the older pupils only.

Fruits.—Descriptions should include reference to size; shape; colour; nature of surface; consistency (*i.e.* whether fruit is hard, soft, pulpy, leathery, etc.); odour (pleasant, if any associations suggested, etc.); taste, if edible.

Flowers.—Note size, giving approximate measurement across top of flower, also length if this is marked; shape, with particular reference to symmetry; colour of individual parts; arrangement of component parts; odour.

Entire plants.—Pupils' descriptions of such are given by way of illustration at p. 203.

Twigs.—For a description of a twig see p. 253.

These exercises may quite suitably be made the means of gradually building up a knowledge of botanical nomenclature on the part of the pupils as far as descriptive terms are concerned. This is probably the best way in which to communicate such knowledge.

Animals.

Shells.—The usual order should be followed here also: size; general shape; colour outside and inside; general build, such as thick, thin, strong, fragile, etc.; nature of surface details, such as markings outside and inside.

Eggs.—These form excellent tests of colour description.

Animal Types.—Examples of all the five chief vertebrate groups should be included. The following are suggested:—A gold fish, a frog or toad, a newt, a lizard, a snake, a series of birds, all the ordinary domestic mammals as well as any others which may be available, *e.g.* hedgehog, mole, bat, squirrel, water vole, hare, rabbit, stoat, weasel. Since these exercises are primarily intended to develop the pupils' observational powers, it will of course be understood that these subjects are suggested only if the appropriate material is available. The small examples, fish, frog, etc., will readily be found, and the live animals should be utilised for the purpose. In all instances of dealing with live animals, it need scarcely be pointed out, the greatest care is necessary in ensuring their comfort and in avoiding anything likely to encourage carelessness or cruelty on the part of the pupils. For exercises on birds and mammals stuffed specimens may be used, and in the country, at all events, dead examples of both these types are at times available, and such opportunities should not be lost.

CHAPTER VII.

FROGS AND TOADS.

OBSERVATIONAL STUDY OF A TOAD.

THE toad may be kept under observation in a glass vessel, say under an inverted tumbler, or, better, a bell-jar. It may be allowed to crawl some distance without any likelihood of its escaping, and be again placed under the bell-jar. It is much more manageable when subjected to study than the frog. But the teacher should handle these animals quietly and with confidence, when it will be found that either frog or toad may be managed without difficulty.

We begin by sketching the animal, drawing it natural size and representing it in various attitudes. As we note its form, we recall Milton's simile

"Him there they found
Squat like a toad."

And to emphasise the attitude, if a frog is available the contrast in the resting position should be clearly noted. Next we may liberate the toad for a little in order to see its mode of locomotion. It may leap or it may crawl. We find, in captivity at all events, that it prefers to crawl. A sketch with the leg extended as in crawling should be attempted (Fig. 13).

Note next the colour. The skin is pigmented. The colour may vary in different individuals, or in the same

individual under different conditions. These animals possess some power of colour change. This may be proved by keeping toads in light and dark places in turn, when some response to the difference in the surroundings can generally be made out. Think of the natural environment of the toad, on the moor or amongst stones or grass, and recall how in general it harmonises with its surroundings. But the toad has very few enemies likely to devour it, and is further protected against interference, as we shall see.

As we look at the toad resting in front of us, before going on to study details, we may ask the question: What



Fig. 13.—The Common Toad (*Bufo vulgaris*) in the act of crawling.
A figure to suggest movement.

is our general impression of this creature? Do we think it is unattractive, awkward? What is the justification for Shakespeare's "toad, ugly and venomous," or is there any? Is anything in nature ugly, in its own place?

Let us study the toad a little more closely. We take it in the hand. How does it feel? First, we observe it is cold. Think of the impression received when we hold a live bird as we may at some time have done. The one is cold and the other warm—cold-blooded and warm-blooded. We have other impressions, the skin feels clammy, not so much so as in the case of the frog, but still distinctly clammy. Exactly what is included in this expressive term? Cold, moist, slightly sticky.

Feel the rough or warty surface of the skin. These warts are the seat of a bitter substance which is poured out by the toad when it is taken in the mouth of any animal. Snakes do not appear to heed this, but most animals reject the toad because of this acrid secretion of the skin, which the toad can pour out at will. This is its most effective means of protection. If you look at the sides of the toad's head behind the eyes you will see a pair of thickened ridges like long pads beneath the skin. These are specialised regions of the skin for producing this protecting fluid. Organs which produce special substances for the use of the body are termed glands. Hence we may note the skin of the toad as a glandular skin.

Further, it is of some importance to note that on this skin there is no kind of covering or protecting growth. This character is noteworthy, since if we look around us we observe that backboned animals with naked skins are remarkably rare. Of the animals likely to be familiar to pupils, only relatives of the toad (*e.g.* frogs and newts) and the river lamprey can be placed in the category of naked skinned vertebrates. (Incidentally we might here digress to name different kinds of skin outgrowths—hair, spine, bristle, feather, scale, with examples.)

Next, gently lift the toad by the skin of the back, noting how loose is the attachment to the underlying parts. This feature is much more marked in the frog. Beneath the skin are large spaces filled with lymph fluid, and in the frog at the hinder end of the body may be seen the beating of a pair of "lymph hearts," where the lymph fluid passes into the veins.

One of the striking features of the Amphibian Class is the various changes undergone in mode of breathing. Early in the course of their life-history Amphibia breathe by means of their skin, and notwithstanding the acquisition of other respiratory organs they continue to some extent to make use of their skins for this purpose. In hibernation the lungs are not used for breathing. Although by a mere examination we cannot demonstrate the respiratory character of the toad's skin we must note this as one of its functions.

Before leaving the subject of the skin of the toad, we summarise its numerous properties:—

- | | |
|----------------------|------------------|
| (1) Cold. | (6) Nauseous. |
| (2) Moist or clammy. | (7) Pigmented. |
| (3) Naked. | (8) Loose. |
| (4) Warty. | (9) Respiratory. |
| (5) Glandular. | |

We now examine the body in some detail. Commencing at the head, we may describe it as in outline almost an equilateral triangle, with the triangle rounded in front. For such a large head, the vertical depth is small. What are the outstanding features?

First, of course, the large mouth. It stretches almost from ear to ear; its large size is probably originally an adaptation to the habit of taking insects on the wing, although toads take a good deal of "creeping" food. The tongue is fixed in front, but has probably not the same free movement of eversion that the frog's tongue has (Fig. 14). Toads feed largely on creeping insects, wood lice, slugs, worms, etc. They have no teeth.

Note next the respiratory movements, the opening and closing of the nostrils, the falling and rising of the floor of the mouth, the pulsation of the sides of the body. These movements occur in an orderly series. Endeavour to follow it. Note that the mouth is kept quite close in breathing.

Two things are worth noting in the eye. There is the delicate transparent membrane which from time to time sweeps across it from below. The ordinary eyelids are mere ridges, this is the true functioning eyelid. Then we note the golden red iris with the dark pupil. We recall, of course, Shakespeare's reference to the toad, "which . . . wears yet a precious jewel in his head."

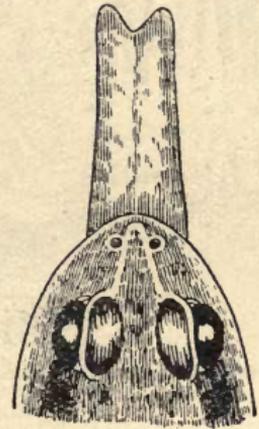


Fig. 14.—View of roof of Frog's head, with tongue protruded.

If we could see inside a toad's mouth we would realise how bulky the toad's eyes really are. They are the biggest organs in its head. Make an outline drawing of a toad's head, fill in circles to represent the eyes, allow a little space in front for the smelling organ, and a small space for the hearing organ at each side behind the eyes, and you will



Fig. 15.—The edible Frog (*Rana esculenta*).

discover how little room is left for the brain of a toad or frog.

Behind the eyes are the large glands which form the noxious substance which really protects the toad from interference. On a dead toad this substance may readily be made to flow out if the gland is compressed.

Try to find the drum of the toad's ear—a small circular disc above the angle of the jaw. It is readily seen in a frog, and easily missed in a toad. The drum of the ear is at the surface of the head.

The head merges directly into the body without any neck constriction intervening. The body is usually plump and shows a very slight hump on the back. In the frog this hump is very marked. This is the place where the hip

girdle is attached to the back-bone. Its peculiarity consists in its being placed so far forward on the body, but this position is of very great service in enabling the frog or toad to leap when on land.

The fore limbs of a toad are short and weak, so are those of the frog. On the other hand, the hind limb is remarkably long and strong. The length of the hind limb should be measured and compared with the total length of the body. Note that four divisions are recognisable in a toad's hind limb.

Count these on the resting toad. There is the thigh directed forward, then the leg turned backward. Next downward or forward the very much lengthened ankle, giving much added power to the leap; lastly there is the foot with its five true toes and an extra nodule on the inner side of the foot termed the "calcar." You will notice that there are no claws upon the fingers or toes of these animals, that the toes are webbed, and that the fourth toe is the longest.

Take a good look at the toad and then draw it from memory.

Make a tabular comparison between frog and toad.

TOAD.	FROG.
Body plump, hump not prominent.	Body less plump, hump is prominent.
Skin warty.	Skin smooth in comparison.
Glands, large, on body, irritant (producing "phrynin").	Glands small, only slightly irritant.
Toothless.	Teeth in upper jaw and in roof of mouth.
Web of hind foot slight.	Web of hind foot marked.
Largely terrestrial in adult state.	Frequents wetter places than toad.
Spawn in a slender gelatinous cord, which swells in the water.	Spawn not in a cord but in irregular masses.
Tadpoles black.	Tadpoles brownish with small golden specks.

Toads and frogs hibernate in the mud of ponds and ditches, waking in the spring, after which they spawn. They then leave the waters. The male frogs croak noisily, the sound emitted by the toads is more plaintive.

EXERCISE.

Contrast a newt, both young and adult, with frog or toad.

Make a detailed study of a newt on the lines suggested above for the toad.

HOW TO STUDY THE FROG'S LIFE-HISTORY.

For this study the following points should be attended to:—

Spawn should be collected in the early spring, as soon as it appears. If frogs are collected before spawning, there is a possibility that, though spawn is got subsequently, it may not develop.

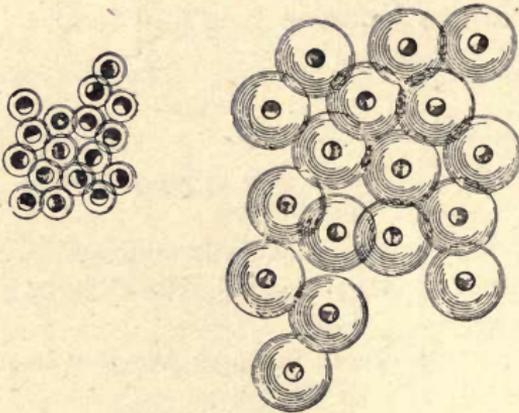


Fig. 16.—Spawn of Frog, newly shed, and a short time afterwards.

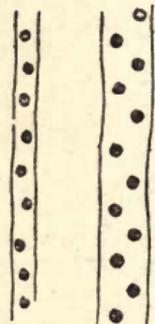


Fig. 17.—Spawn of Toad, newly shed, and a short time afterwards.

Keep in a moderately warm place in a good light. Place some healthy water weed in the same vessel as the spawn. Call pupils' attention to all changes observed.

Note *e.g.* the rapid swelling of the jelly around the egg. If got quite early pupils should be asked at once to examine and draw the eggs, noting

1. The dark end, the animal pole or living end.
2. The white end—the yolk substance which is to be used in the building of the tadpole's body.
3. The jelly, which keeps the eggs apart, preventing collisions perhaps when the rough March winds ruffle the pool, which certainly saves the eggs from being eaten by all birds, save broad-billed ones, and which may have other uses (Figs. 16 and 17).

The following stages should be watched for and dates of their appearance noted. A record should also be kept for comparative purposes in successive years of the external conditions as regards exposure, light, temperature, and food supplied. A strict account of the mortality might be attempted so as to arrive at some notion of the proportion reaching the frog stage:—

Stage I.—The mouthless stage. This is first definitely marked when the head



Fig. 19.—Tadpole with internal gills.



Fig. 18.—Tadpole with external gills.

and body can be made out clearly. Note that now, just as in the egg stage, breathing goes on through the skin.

Stage II.—Appearance of external gills (Fig. 18).

Stage III.—Disappearance of external gills. The internal gill stage (Fig. 19). Note the spout opening on the left side. The tadpole is now fish-like in many important structural and functional characters.



Fig. 20.—Tadpole with hind limbs. It shows also the "spout" opening on the left side.



Fig. 21.—Tadpole showing fore limbs beneath the skin.

Stage IV.—Appearance of hind limbs (Fig. 20).

Stage V.—Appearance of fore limbs. Note that the spout opening is quite visible until the fore limbs begin to bulge. With a good lens the fore limbs with outspread toes may be seen under the skin (Fig. 21).

Stage VI.—Tail entirely gone. Frog stage is reached.

Make a series of drawings to illustrate the gradual disappearance of the tail (Fig. 22).

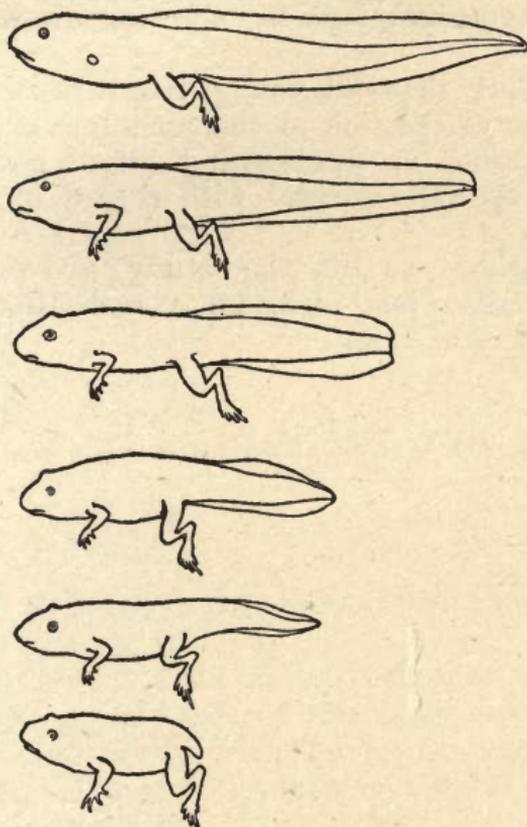


Fig. 22.—The tadpole in six successive stages showing the gradual absorption of tail.



Fig. 23.—Tadpole showing the left fore limb as it appears at first when pushed through the spout opening.

Verify the following:—

The left fore limb breaks through the “spout-like” opening (Fig. 23).

The head is actually broader before the fore legs have come out than it is after they have appeared.

The mouth is still small after both pairs of legs have appeared.

A tadpole with four legs and tail leaps at a quite early stage in contrast to a newt (similar in form), which crawls. Explain this.

Carry out experiments in rearing under different conditions as to food (giving very minute particles of fish, meat, bread, etc., respectively to different lots. Avoid contaminating the aquarium jars by allowing excess of food to decompose).

It is very important that all young frogs reared in school should, on the completion of their metamorphosis, be taken to the marshes or ditches and set at liberty. Teachers should be specially careful with regard to this point.

Endeavour throughout to lift the study above the commonplace, to awaken and maintain a realisation of the wonder and mystery of Life.

CHAPTER VIII.

SOME SUGGESTIONS FOR BIRD STUDY.

GENERAL BIRD LORE.

COMMENCE with recognition marks in Plumage, Song, Nest, Egg of birds of the neighbourhood, gathering and recording the information by degrees. Note the time of appearance of migrants—Summer, Winter. With the assistance of the pupils general lore will be accumulated gradually. Boys, *e.g.*, who know something of this subject should be asked to tell the class or given the option of writing accounts of habits of different species. Seek as far as possible verification. Enter the facts which seem of seasonal value in the Nature Calendar.

The teacher will find a field-glass of material assistance in this study, especially in watching the feeding both of adults and of nestlings.

Important birds of the neighbourhood should be studied specially, *e.g.* gather facts about habits of at least twenty birds.

The methods for detailed study of particular subjects connected with bird life are given at length in the remainder of this chapter.

STUDY OF BIRDS' EGGS.

This subject may of course form part of a series of lessons on eggs of different animal types or form a lesson by itself. As birds' eggs show quite distinctive features they deserve a series of lessons by themselves.

At the commencement it is well to strike a note of discouragement of the practice of egg collecting amongst pupils. Lessons such as these should aim at being effective in creating an intelligent interest which is content to view the eggs undisturbed within the nest. Where schools are already provided with a supply of birds' eggs, these of course will be available for use. Many different kinds are not required in any case; the lessons will stimulate the pupils to observe for themselves in the proper quarters.

Whether we examine a general collection or appeal to individual pupils as to what they already have observed, it will not be difficult for the class to agree to one or two general propositions. We appeal as far as possible to experience.

(a) Birds' eggs are mostly coloured. This is in marked contrast to those of the only other vertebrate group which has shelled eggs, viz. reptiles. Some of the pupils may have found the eggs of snakes or of lizards, and some may have seen (*e.g.* in a museum) those of a turtle or of a crocodile. These all have white eggs.

(b) Some birds have white eggs, *e.g.*

Sand martin.	Dipper.
House martin.	Owls.
Kingfisher.	Wood pigeon.

How many of these lay their eggs in holes or concealed places? The wood pigeon is the only one whose nest may be said to be "exposed."

(c) In many cases the colour renders the eggs difficult to observe. To appreciate this fact one must view the eggs in the nest in their natural surroundings. Objects such as bright blue eggs which look conspicuous in the hand may be readily overlooked in the confused light and shade of a thick hedge. Further, there are some clear cases in which the eggs closely resemble their immediate surroundings. Examples are those of the terns, which resemble the pebbles of the beach amongst which they are laid, or the plovers whose olive-green eggs speckled with brown are like the ground on which they lie. Both these birds nest in exposed places.

(d) We also notice in many groups of birds a kind of "family resemblance" in the colour of the egg. Take, for example, the crow family—Raven, Carrion Crow, Hooded Crow, Rook, Jackdaw. The eggs of these birds laid side by side are seen to be but variants of a greenish tint with light brownish speckling or blotching.

The members of the Gull family have eggs of different shades of olive green with brownish black blotching. The hawks exhibit a brick-red pigment in varying quantities upon a light-coloured egg.

The various species of Tits have white eggs with reddish spots. And other cases might be quoted, *e.g.* breeds of domestic fowl. Investigation has suggested that the colouring matter is derived from the blood, and is of the nature of a waste product. If this is so, the family resemblance which is recognisable in many cases is not difficult to understand. The colour of the egg in such a case may be regarded as a matter of family constitution. But perhaps with our pupils it is best to be content simply with a clear recognition of the facts.

(e) Note lastly that in some cases there is very great individual variation in the matter of colouring, *e.g.* Guillemot. (Incidentally note the marked constancy of shape of this bird's egg.)

Before passing from this subject, the appearance of a few of the commonest eggs of birds should be noted.

Exercises in description of eggs where these are available form excellent tests of the pupils' powers of colour description. The eggs should be drawn and coloured. Where clay modelling is practised this might be attempted. The models should be covered with white enamel paint, and the ground colour and markings painted over this.

STUDY OF AN EGG IN DETAIL.

Take an ordinary fowl's egg. Note the following points. The shape; it is quite distinctive. We find it described in books as "ovoid," that is, egg-shaped. Usually an egg has one end broader than another, but some eggs, *e.g.* those of some owls, tend to be almost spherical. The shell consists of carbonate of lime, phosphate of lime, and animal gluten. Some eggs are smooth in texture, *e.g.* those of aquatic birds. Such eggs do not wet readily. A fowl's egg is coarser grained. The shell is porous, admitting the passage of oxygen inward and of carbon dioxide outward for the respiration of the growing bird. Evaporation of the contents also goes on through the pores after the egg is laid.

The size of an egg generally has some relation to the size of the bird laying it, but there are some interesting cases. The cuckoo, a bird about twelve inches long, lays a small egg scarcely an inch in length. The guillemot, a bird about the size of a rook, has an egg about three inches in length, whilst the apteryx, a flightless nocturnal bird of New Zealand about the size of a small fowl, lays an egg about the size of that of a goose.

What is the weight of an ordinary hen's egg? About two ounces, but pupils might be asked to guess by testing in the hand.

Within the egg, just beneath the shell, lie the shell membranes. Pupils will be familiar with one membrane, perhaps not so familiar with the fact that there are two. Demonstrate at the broad end of a hard boiled egg the two membranes, one against the shell, the other lying against the white of the egg. Note the "air space" between. Shell and membranes protect in part what lies within from

interference from without, but chiefly serve to maintain heat within and to regulate evaporation.

The colourless almost fluid substance which coagulates to a white solid on boiling consists of albumen, a substance containing six chemical elements, Carbon, Oxygen, Hydrogen, Nitrogen, Phosphorus, Sulphur. It is in three layers, which may be observed flaking apart on cutting a hard boiled egg. Within the albumen we are familiar with the yolk enclosed by a delicate membrane from which there passes towards each end of the egg a thickened twisted cord of albumen. The cords or chalazae which end in the

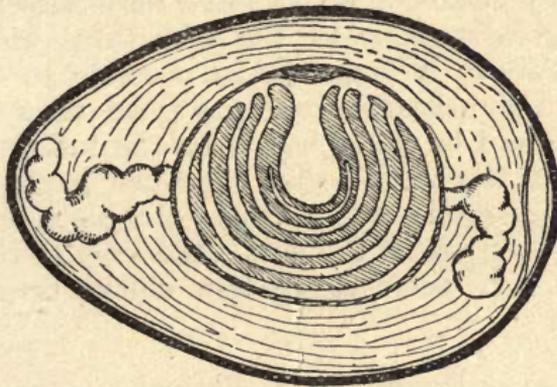


Fig. 24.—Diagram to show the parts of a fowl's egg as seen in longitudinal section. The parts represented are the shell and its membranes, air space, albumen in which may be seen the thickened cords (chalazae), yolk in layers with the position of the germ indicated by the dark patch at the top.

middle layer of albumen, suspend the yolk; they prevent it spinning rapidly when the egg is rolled or turned quickly, and they act as buffers to the yolk in the event of its receiving sudden jolts.

The yolk, golden yellow in colour, which consists of several organic substances, serves to nourish the developing bird within the egg. It is not of uniform composition, the inner contents being lighter. Just above where this lighter mass comes to the surface of the yolk, there lies the germ. Owing to this arrangement, no matter how the egg lies, the yolk rotates on the chalazae so that the

lightest part with the germ above lies towards the upper side, that is nearest to the warmth of the hen's body during incubation (Fig. 24).

At this point it is well to emphasise the distinction between the *germ* on the one hand—microscopic, living, *essential*; on the other—all the rest, bulking large, but after all, not living, *accessory*.

Lastly, a brief note might be added on the breathing of the chick within the egg by means of a special structure which lies against the shell, on the use of the air chamber where the chick first fills its lungs preparatory to "breaking out" and on the "egg tooth" (a limy nodule on the tip of the bill) by means of which some birds effect their exit.

In calling attention to the structural arrangements enumerated above it ought to be possible to educe from the pupils their significance in a good many instances. Questions should be asked, *e.g.* upon the following points:—The use of the shell—why eggs are narrower at one end—why egg-shells are porous—the uses of the shell membranes—the use of the yolk—the uses of the chalazae—why hens turn their eggs—how chicks breathe within the egg.

STRUCTURAL STUDIES.

For senior classes the adaptational features in a bird's body will be found to yield an admirable series of lessons. For this purpose the pupils under the guidance of the teacher should mount upon a card examples of different types of feather from various regions of the body. Cards of the plumage of different kinds of birds should be made as opportunity arises, and the best of these retained for the school collection. A series of different types of bill and foot might also be got together in course of time.

A preparation of the wing of a bird, say of rook or wood pigeon or of any small bird available, should be made in the following way. On a flat board stretch the fresh wing out fully, inner side downward. Endeavour to keep the feathers unruffled and in their natural positions. A small staple should next be driven through into the

board around the bone of the uppermost part, and also near the free end. The small "thumb wing" should be drawn outward and a tack placed so as to keep it in the outward position. The wing may be left to dry and stiffen. In a week or two it may be removed from the board, when it will be found ready for use. Care should be taken in removing the wing from the body to remove the bone of the upper arm entire, and to cut away any free flesh adhering to the wing.

All clean bones of birds—not cooked bones, as they are apt to be oily and discoloured—which can be obtained should be kept to illustrate lessons. In fact an entire skeleton of a moderately large bird such as a rook, pigeon, or fowl is desirable, and dealers supply these beautifully cleaned and set on stands at a reasonable price. Failing an entire skeleton, the teacher should endeavour to possess some or all of the following bird bones:—

A Breastbone.

Bones of the wing, fastened together in correct positions

Bones of leg.

A Backbone.

Adaptations.

In all our structural studies our point of view is that of adaptation or fittedness of the whole and of its parts to the conditions of life under which the organism is placed. That is to say our inquiries are directed towards noting the suitability of the parts examined to the uses to which they are put or to the conditions under which they act.

It should be understood that whilst in many cases we are able to apply the principle of adaptation with great clearness, we cannot always do so. This is probably mainly because of our ignorance of all the facts bearing on the point. Sometimes it is because we are apt to forget that organisms have all a very long past history and what we see at present can only be correctly interpreted by remembering that it has a meaning with reference to the past as well as to the present. This past history is often the explanation of a seeming want of adaptation, and it should be borne in mind.

External Features.

With this preliminary caution we may proceed to examine the body of a bird for adaptational features. Birds are creatures of the air. Their bodies are heavier than air, yet they maintain themselves in it, often for very long periods, with grace, ease, and comfort. Recall the long migrations performed in amazingly short periods of time. It is well to recall these things with the children before familiarity with aeroplanes has killed all wonder and done away with the mystery of the birds' mastery of the air.

What is the shape of a bird's body? Look at the birds perched on the fences or trees. If a stuffed bird is available, examine it closely. Best of all try to catch glimpses of a bird from below as it sails gracefully overhead. Watch the gulls wheeling above you at the estuary, on the rocks, or around the ploughed fields; or the rooks with heavy flap of wing high overhead wending their way home at even. Here a fieldglass will help you to answer with conviction the question: What is the shape of a bird's body? A bird's body is spindle or torpedo shaped. It is long, rounded, tapering evenly to both ends. Here you may enlarge on the suitability of such a form to rapid and easy progress in air, how it is calculated to reduce friction and offer a minimum of resistance. At this point refer to remarks in lesson on the Swimming Fish (p. 67).

Feathers.

Note next the covering of the bird's body. You may have in your hand a freshly killed bird, which may have been the occasion of your taking a bird's body as your theme, or a stuffed specimen may stand in front of you, or a live bird in a cage. Of course you will not talk about details without the material at hand for examination and verification.

Birds are feathered. This feature alone separates them from all other types of life. Feathers are outgrowths of the epidermis. Feathers are light, proverbially so; they

keep up the temperature, being bad conductors they retain the body heat; they give an even contour to the body which is of service in flight. They usually contain colouring matter, and are often iridescent as well. White feathers have no pigment, but contain gas in their internal spaces.

Separate lessons should be given on feathers.

LESSON I.—The *kinds of feathers* found on an ordinary bird, *e.g.* Pigeon. We may divide them into two large groups in the first instance.

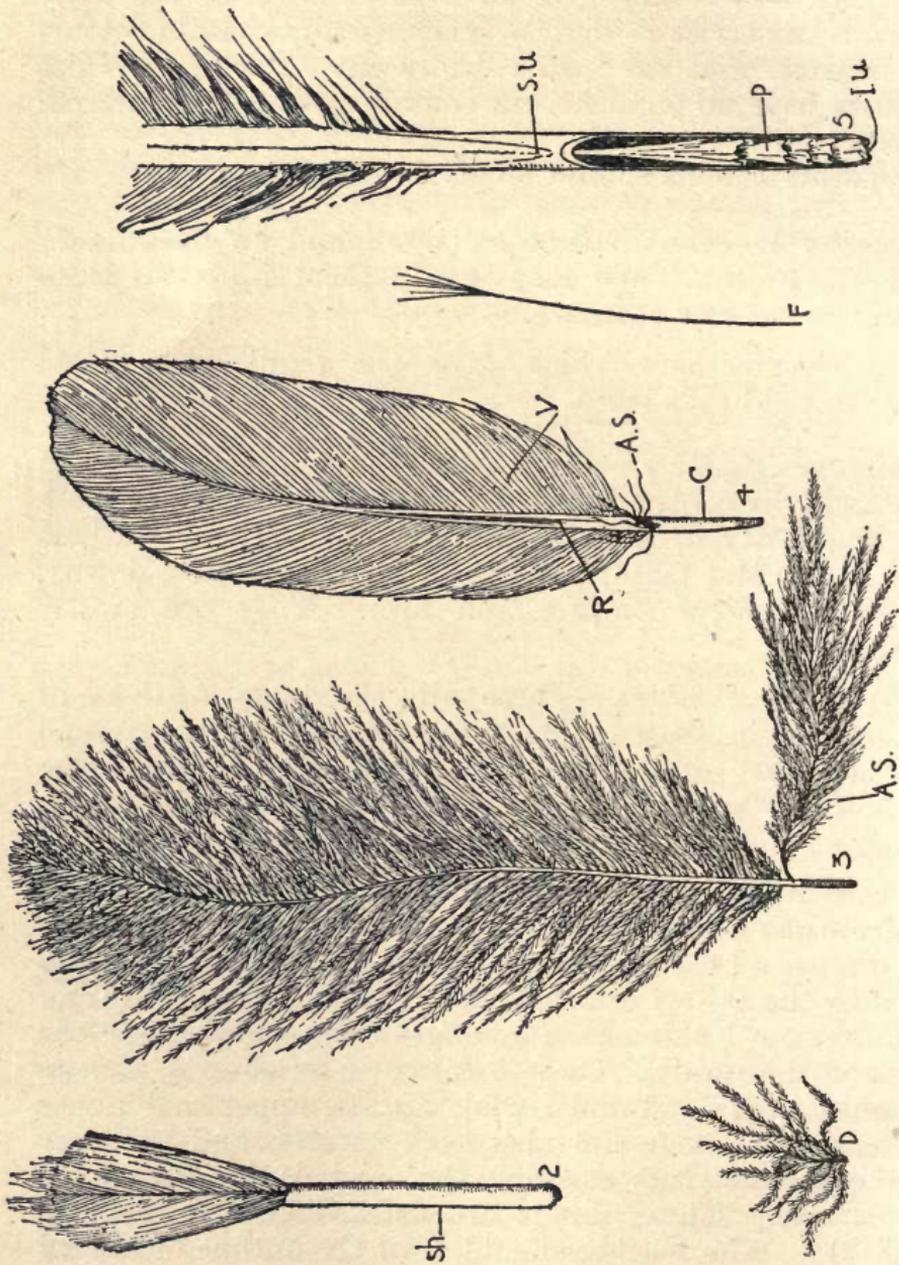
(a) The feathers which give the regularly rounded shape to the bird's body.

Contour Feathers.—Emphasise the appropriateness of this name by contrasting the contour of a live bird with the angularity of a dead plucked one. These feathers vary in size and texture, some are soft and almost downy, others are more compact and firm. They are mostly curved.

(b) *Quill Feathers.*—These are the large feathers of importance in flight. The "rowers" of the wings, and the "steerers" of the tail. Make use of the spread wing to show the "rowers"; expand the tail to show the quills clearly.

There are other types to be found on closer study.

Meantime we return to the contour feathers. We shall not discuss all the grouping of these on the body as recognised by the skilled ornithologist, beyond noting the larger and stronger looking ones amongst them which cover the bases of the quills. These are known as coverts, and we recognise upper and under wing coverts, upper and under tail coverts. There are also back coverts, and in many birds a distinct tuft covering the ear-hole, known as the ear coverts. These things are marked on the diagram (Fig. 31). The teacher should draw the outline of a bird upon the board and fill in the details as they are verified. A knowledge of these simple terms will be found useful in writing out descriptions of birds.



D, Down feather. 2, Young feather, within sheath (*sh*). 3, Covert of Heron, showing aftershaft (*a.s.*). 4, Quill feather (secondary) of Pigeon: R, rachis or shaft; V, vane; C, quill; A.S., reduced aftershaft. 5, Portion of quill: *p*, pith; *lu* and *su*, lower and upper openings. F, Filoplume.

Fig. 25.—Types of Feathers.

Further reference to the quill feathers may be omitted at this stage. They are dealt with later in a study of the wing.

When the body of the pigeon is divested of the contour feathers, we discover beneath them a set of very delicate hair-like feathers. These are so small that they cannot be plucked by hand. The familiar practice of singeing a bird—passing it through the flames after plucking—has for its object the removal of these hair-feathers or “filo-plumes.” The filo-plumes have a delicate tuft at their tips (Fig. 25 F).

Besides filo-plumes young feathers in various stages of growth within a sheath will be found. If these are removed a semi-fluid substance, perhaps mixed with blood, will be found oozing from the base. This is the nourishing substance from which the feather is built up. Compare the dry base of the fully grown feather.

The general development of a feather might be outlined if not considered too difficult, but that is best considered after the structure of the fully developed feather is understood.

Although down feathers do not occur on the pigeon, for the sake of completeness they ought to be mentioned (Fig. 25 D).

LESSON II.—*The Wing of a Bird.*

On the wing of a bird we can feel three divisions. When the wing is closed these three parts lie folded closely together, arranged like the parts of the letter Z. If a fresh wing is available it should be spread out and closed in turn until the relations of the parts are clearly grasped. Next the pupils may be asked to note the three divisions of their own arm. These are the upper arm (above the elbow), the lower arm (from elbow to wrist), and the hand. Pupils should endeavour to fold their arms as a bird does its wings—upper arm downwards, lower arms upward alongside, hands downward. This last cannot be done, but the exercise will help to make clear some points of interest.

A bird's wing consists of upper arm, lower arm, and hand. (Both birds and human beings have got a wrist in

addition, but reference to it is omitted for the sake of simplicity, as the bird's wrist is reduced and cannot be demonstrated as a "region" by the method of external examination alone.) It is true that the bird's "hand" looks very unlike the hand of man. In the bird the hand is adapted for bearing the strong quill feathers of flight. Two of the fingers have disappeared, two have become united beneath the skin, and the third, the "thumb" reduced in size, remains free. Repeat the attempt to fold the arm after the manner of a bird, and note now how the thumb points outward from the hand. Examine the wing at this place and discover the bird's thumb, feel close down to the base so as to find the bone, and note the tuft of

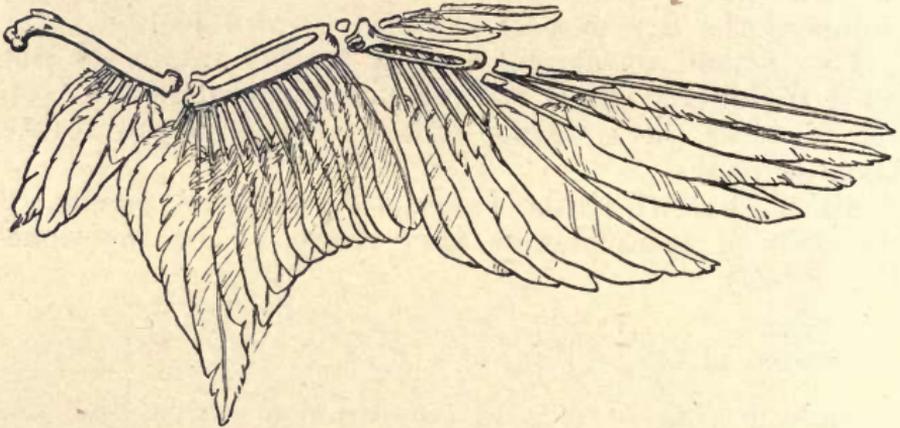


Fig. 26.—The wing of the Pigeon, showing the bones and the principal feathers.

feathers borne on this part. This tuft is termed the "thumb wing."

The teacher might here tell the story of the extinct bird *Archaeopteryx*, which had separate fingers with claws as well as feathers upon its wing; that the thumb of birds often bears a claw, or that the fingers of the unhatched ostrich are clawed.

Examine again the outspread wing, feeling the skin across the bend forming the elbow joint. This skin forms a kind of web, giving an outspread surface enlarging the area upon which the feathers are spread. Note the upper and under coverts of this area, and also upon the upper arm.

Note next the quill feathers. On the pigeon's wing there are twenty-three. Eleven of these rest upon the hand. They are unsymmetric, the outer web of the vane being narrower than the inner. The remaining twelve are termed secondaries. Their bases are supported by the stronger of the two bones of the lower arm (the ulna). They are mostly symmetrical.

Lastly, note the lightness of the whole wing. Move the dried expanded wing swiftly through the air and note the resistance given to the stroke. Draw the figure of a wing, with and without the feathers (Figs. 26 and 27).

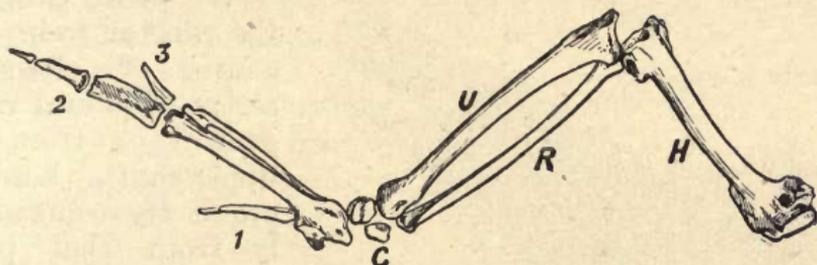


Fig. 27.—The bones of a bird's wing.

H, Humerus; R, Radius; U, Ulna, it supports the secondary quill feathers; C, Carpus, of which there are only two free elements, the remainder having fused with the fingers; 1, 2, 3, Bones of the fingers.

LESSON III.—*Study of a Quill Feather.*

Each pupil should be supplied with a good sized quill feather from a fowl or other large bird. Notes should be made upon its lightness, and any special feature of colour or iridescence.

Distinguish shaft or central axis and the vane. Draw the shaft, noting the translucent, hollow, more or less cylindrical lower part, the quill; and the somewhat quadrangular, tapering, opaque part surrounded by the vane. These facts of shape, etc., should be elicited observationally from the pupils. Let them draw quill and upper shaft in cross section.

Find next the opening at the base of the quill, through which the nourishment passed to the growing feather (the

so-called inferior umbilicus). Within the quill can be seen the shrunken pith. If a feather be carefully slit along the quill this pith will be found to be arranged in a series of cones overlapping each other (Fig. 25, 5).

At the base of the vane will be found a few detached straggling barbs. They are apt to be overlooked, or at all events regarded as of no significance. But in some feathers these form a definite second shaft with vane, which is sometimes, *e.g.* in the Emu, as long as the main feather. This is called the after-shaft. Note the after-shaft of the Heron's covert shown in Fig. 25, 3. Other birds which show the after-shaft clearly are Parrots and Gulls.

We come now to the vane or web. It consists of a close-set series of lateral rays growing out from the upper shaft. Let the pupils discover exactly from what part these lateral rays arise. They are termed barbs (Fig. 28). Pupils will add a set of barbs to their drawing of the shaft, filling them in at intervals sufficient to

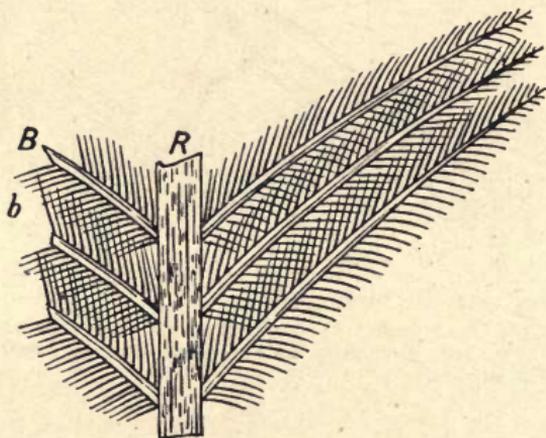


Fig. 28.—Portion of a feather.
R, shaft; B, barbs; b, barbules.

give the correct outline to the whole feather. Let them examine the barbs closely, using a pocket lens if such is available. They will note of course that in a quill feather the barbs are not free, that in fact the adherence of the barbs of the quill to each other is the property which gives to the feather its effectiveness as an instrument for striking the air in flight.

A close examination shows that the barbs have themselves lateral offshoots, repeating the structure of the main feather. Pupils will fill in these lateral offshoots on some of the barbs in their drawing. How do these barbules, as the secondary barbs are termed, adhere to each

other? We cannot with the naked eye see what the arrangement is, but from the result, *i.e.* a coherent web, we must conclude that the barbules are hooked and that the hooks of adjacent barbs are linked together (Fig. 29).

Note how by pulling gently the hooks release their hold and the feather tears. Note also how we may imitate the action of the bird when it draws the feather through its bill and relinks the hooks again. We may do this by passing the severed part between the thumb

and forefinger, when it will be found that the feather can be repaired.

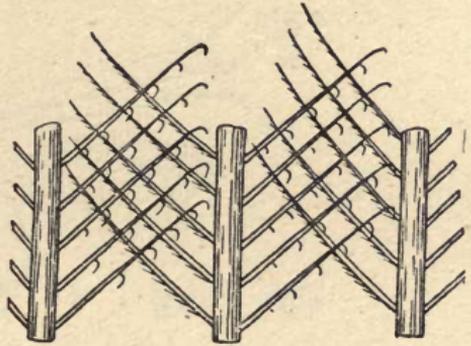


Fig. 29.—Diagram of barbs and barbules with hooks.

Other External Features of Note.

Bill.—Birds are toothless, but it may interest the pupils to learn that this was not always so. A further reference to *Archaeopteryx*, which was toothed, may be made, or to *Hesperornis*, a North American toothed fish-eating bird, long since extinct. The function of the lost teeth is in part fulfilled by the horny sheath which covers both upper and lower jaw. Some note should be made of adaptations in the bill to different types of diet. That of the Hawks, *e.g.* is strong, sharp-edged, notched, and hooked (Fig. 30), suited for the tearing and cutting of flesh. Other types which might be noted in relation to the principal items of diet are, *e.g.*, those of the finches and similar birds, short and conical, or of insect-eating birds like swallow and swift, short and broad, or broad and flat as in the ducks, and so on.

Nostrils.—These are small openings near the base of the bill. In the pigeon they are slit-like.

Cere.—This is the soft whitish fleshy patch behind the nostrils. It is an organ of touch, and is of interest in

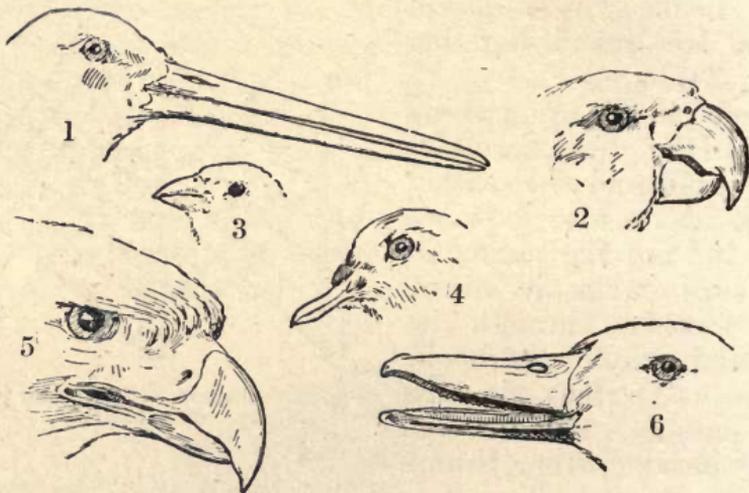


Fig. 30.—The Beaks of Birds.

1, Stork ; 2, Parrot ; 3, Sparrow ; 4, Pigeon ; 5, Eagle ; 6, Duck.

being the only soft part of the body of a bird which is exposed, except the eyelids.

Eyes.—Of interest is the third eyelid, the membrane with which the bird cleans its eye ; it passes down over the eye beneath the outer eyelids (Fig. 32).

Ears.—Concealed beneath the feathers just behind the eyes are the quite large ear openings. There is no outer lobe, but in Owls the openings are not only very large, but their edges are raised into a kind of ear lobe. The hearing of owls is very acute.

It is of interest to note that all the specialised sense organs of birds are located in the head.

Feet.—A pigeon has four toes, and no bird has more than four, though some have fewer. Some attention should be paid to the ways the toes are arranged in birds of

different habit. Usually the first toe is turned backward,

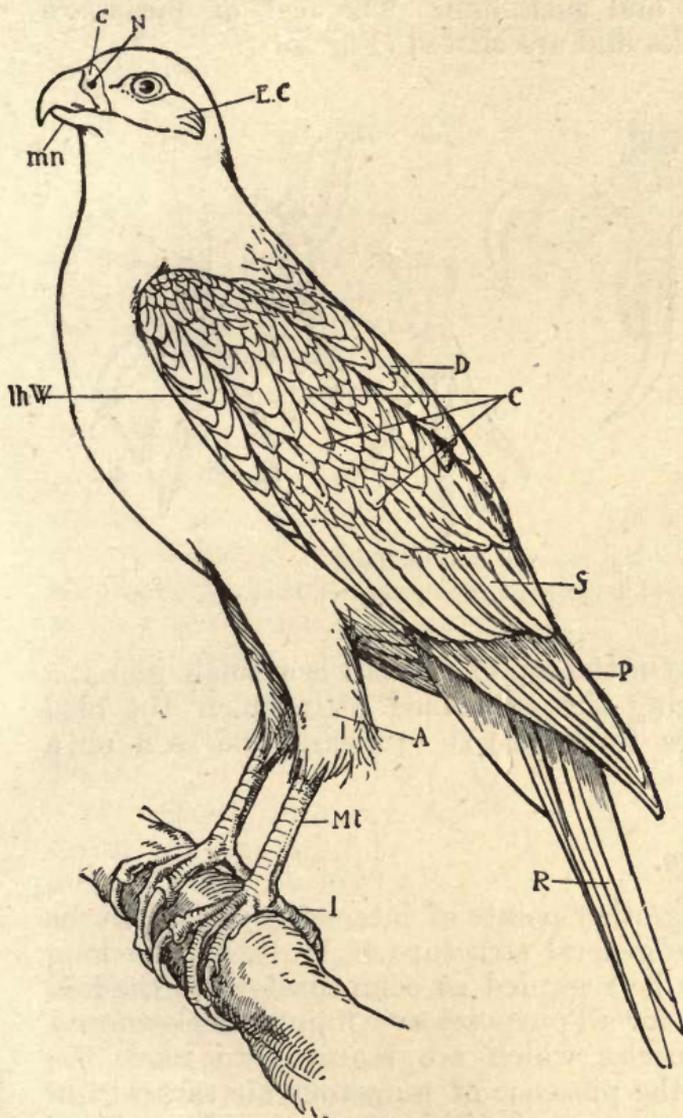


Fig. 31.—Diagram of externals of a Falcon.

mn, mandible; *c*, cere; *N*, nostril; *E.C.*, ear covert; *lh.w.*, thumb wing; *d*, back coverts; *C*, wing upper coverts; *S*, secondaries; *P*, primaries; *R*, rectrices (tail quills); *A*, ankle; *Mt*, tarso-metatarsus; *I*, first toe.

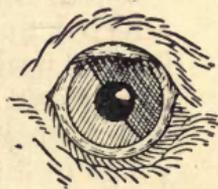


Fig. 32.—Eye of a Bird, showing the Third Eyelid.

but sometimes also the fourth, *e.g.* Owls, Woodpeckers, Cuckoo. In the swifts, whose feet are very short, all four

toes are turned forward. They walk badly, but can cling readily to walls and such like. The feet of birds are covered with scales and are clawed (Fig. 33).

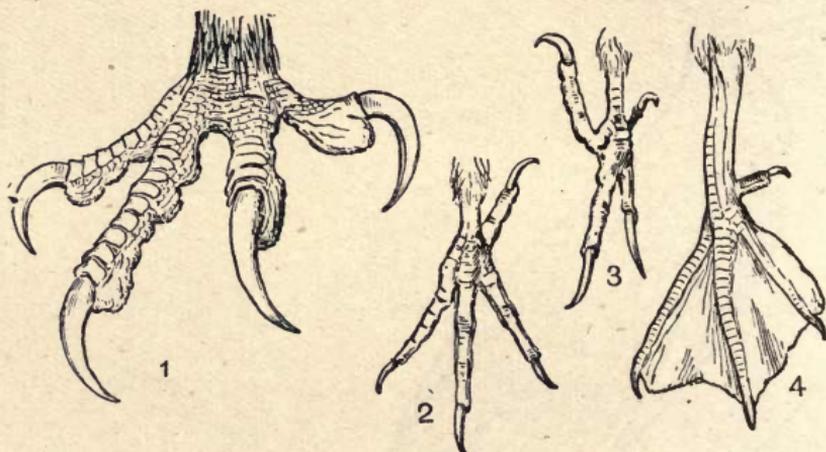


Fig. 33.—The Feet of Birds.

1, Eagle ; 2, Pigeon ; 3, Woodpecker ; 4, Duck.

Preen gland.—On the top of the tail is a small gland, a structure producing the substance with which the bird preens or oils its feathers. It can easily be seen on a plucked bird.

General Structure.

There are many other points of interest which might be referred to in the general structure of birds, *e.g.* the long flexible neck may be regarded as compensatory to the loss of the fore limbs for all purposes save flight ; the large and heavy breast muscles which are required to move the wings in flight ; the presence of numerous air sacs within the body, and in some cases within the bones (humeri) of the wing, greatly contributing to thorough efficiency in respiration ; the high temperature probably related to this ; the arrangement of the heavy organs within the body so that the bird is very stable in the air as well as on land ; and numerous skeletal peculiarities, some of which are stated below.

Skeleton of Birds.

Note and verify as far as possible the following points:—

(1) The bones are light, being hollow or of spongy texture.

(2) Where rigidity is required, parts which are free in other animals have been united in birds. Examples of this are seen in the following:—

(a) Backbone, which behind the shoulder is practically rigid throughout. This obviously gives leverage to the wing stroke which an ordinary flexible back could not supply.

(b) Hand portion of the wing, separate fingers are not required, rigidity being of more service. The thumb is distinct, and photographs of birds in flight show that some of them make independent use of the thumb wing.

(c) Ankle and foot. Rigidity here again in birds is of more value than flexibility.

(3) Loss of parts. The loss of fingers in the wing has already been referred to.

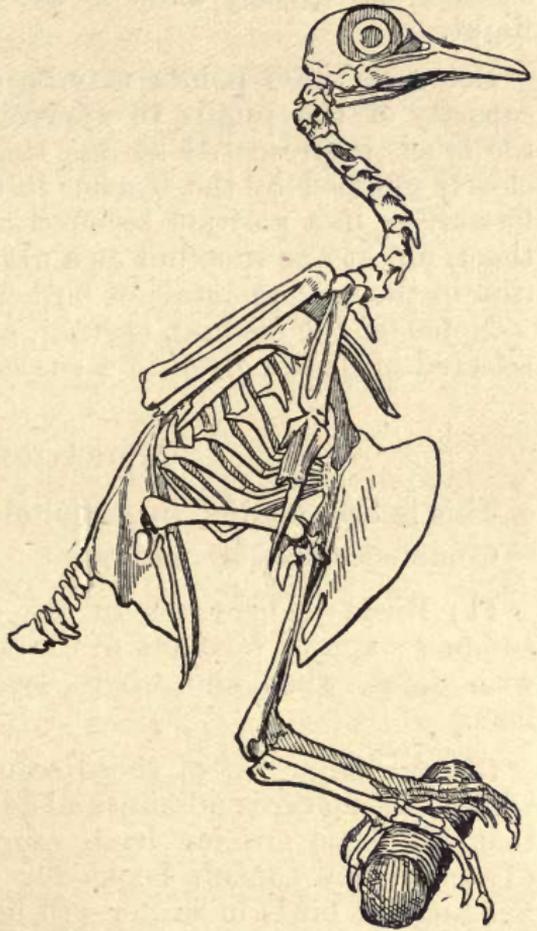


Fig. 34.—Skeleton of the Pigeon.

(4) Breastbone in flying birds is prominently keeled. This gives a large surface for attachment of the big muscles of flight.

(5) The shoulder girdle rests upon the breastbone. This arrangement gives resistance to the downward wing strokes and greatly adds to the stability of the body in flight.

Some of these points may be regarded as beyond the capacity of the pupils to appreciate. This will be so if too much is presented at one time. But they should be clearly grasped by the teacher in the first instance so that he may be in a position to effectively apply some or all of them, not at one time but as a gradual process of instruction in the fundamentals of bird life.

Notes on the feeding, nesting, and other habits of a few selected birds are given in a succeeding section.

MIGRATION.

This is best studied in school observationally.

Commence, *e.g.*, by noting :

(1) Birds in evidence in the district throughout the summer ; appeal for facts to the scholars. Draw up a list with dates, when and where seen, etc. (Compare plant lists.)

(2) A similar list of those seen in late autumn and in winter, noting birds missing and additions. Do not assume that all those missing have *migrated from this country*. (Teacher may consult books for well ascertained facts.) Feeding the birds in winter will help in this work.

(3) A spring list of *new appearances*: note dates and average temperature for week and month each year.

(4) Meanwhile ask some simple questions as to what birds get and do in summer and winter while in this country. Elicit in particular two areas for a large number.

A Northern Colder area for Breeding.

A Southern Warmer area for Feeding and Growth.

(5) We may now group the birds found in our islands as

Residents.—Even amongst these there is much migration of a kind. The redbreast, for example, migrates from one part of the country to another. Blackheaded gulls breed on inland marshes and migrate to the sea-shore in winter. The curlew and dunlin perform a similar movement. Oyster Catchers move from river to shore and *vice versa*. And there are many other less definite comings and goings. Thrush, Blackbird, Tits, Hedge-sparrow, Sparrow, Linnet, Bullfinch, Yellow Hammer, Chaffinch, Starling, Crow, Jackdaw, Magpie, Skylark; Barn, Long Eared, and Tawny Owls; Sparrow Hawk, Merlin, Kestrel, Lapwing are amongst the commonest of our smaller resident birds.

Summer Visitors.—Redstart, Nightingale, Spotted Fly Catcher, Swallow, Martin, Sand Martin, Swift, Cuckoo, Wheatear, Corn-crake are some of the most familiar.

Winter Visitors.—Fieldfare, Redwing, Snow Bunting, Woodcock, Jack Snipe, Little Auk are the most familiar members of this group. Many members of the duck tribe are also winter visitors. There are various other birds which may strictly be described as resident in the North, but which are only winter visitors in England.

Birds of Passage or Migrational Visitors.—These are birds passing northward or southward and visiting the British Isles on their way. They belong chiefly to the family of Waders, *e.g.* Turnstone, Sanderling.

Stray Migrants or Wanderers.—These are birds not regularly visiting our islands, but which appear irregularly from time to time, *e.g.* White and Black Storks, Pallas's Sand Grouse, Crane.

(6) *Times of Coming and Going.*

If the pupils are being taught to report the outdoor occurrences observed, records will be got of the times of appearance and departure of the more familiar of our

migrants. A comparison of dates in successive years will throw light on the interesting question of their punctuality, which is said in many cases to be marked irrespective of unfavourable weather conditions. So also with regard to place; it is well established that, in spite of the very long distances travelled, the same birds come back in successive years to the same nesting place.

(7) The distances travelled cannot of course be verified.* But some well certified facts may be quoted, *e.g.* the swallow may come to England from Natal in ten days, the Sanderling migrates from Iceland to Cape Colony; the Knot travels from the Arctic Circle to Australia; the Turnstone from Greenland to Australia, New Zealand, and to South America; the Golden Plover is known to have travelled 1,700 miles at a stretch.

The order of travel is interesting. In spring, the adult males arrive first, followed by the females, and last of all the young. In autumn, the order of departure is reversed, the young going first. An exception to this is the case of the Cuckoos, whose young are left to follow alone. From the fact that the young are able to do this, there seems little doubt that migration is at bottom an instinct, an inherited faculty. That this instinct may be aided by the intelligence of the birds, or by their possessing an extra sense, *i.e.* a "sense of direction," is, however, very probable. It is also likely that the reasons for its performance are bound up with the past history of birds themselves in relation to climatic changes upon the earth.

* In this connection, however, it might be suggested that those who have opportunity might assist in a work designed to throw light upon bird migration problems generally. Professor J. Arthur Thomson of Aberdeen University is conducting an inquiry by means of placing numbered rings upon the feet of birds captured and set free again. The hope is that if large numbers are ringed, an appreciable proportion will be heard of again from other parts of the world. Any one willing to ring birds (*e.g.* nestlings) is invited to apply to Professor Thomson, who will gladly supply rings for this purpose.

SOME COMMON BIRDS.

Appended are brief notes upon a few common birds, selected mainly on account of their relation to agricultural life. These notes are not exhaustive descriptions of the birds; only the most outstanding structural characters are named. But it is hoped the notes on feeding habits will be of some value, since definite information of this kind is exceedingly scarce. Lessons may quite readily be given upon those birds which are known to the pupils observationally in the neighbourhood of their homes or of the school. Such lessons should be taught orally, by question and answer, if specimens of the birds are not available, and the knowledge of the pupils supplemented by such information as is given below. The aim should be to stimulate observation of the habits of the birds under consideration.

In the following notes the letter R. denotes *Resident*, and the letters S.V. denotes *Summer Visitor*.

ROOK (R.). The rook is readily distinguished in the adult condition from the other members of the crow family by the abraded condition of the part of the head around the base of the bill and of the throat. The male is about $19\frac{1}{2}$ inches from tip of bill to tip of tail, female about $18\frac{1}{2}$ inches. The colour is black, with purple and steel blue reflections. The young are without the bare patch, and less glossy. Rooks are gregarious, living mostly in large companies, nesting together forming rookeries. They feed mostly on land under cultivation, and it continues to be a debated question as to whether their feeding habits are mainly inimical to the interests of the farmer.

There appears to be no doubt that they levy a more than fair toll upon seed corn, potatoes, and turnips, pecking holes in these last and rendering them unfit for use. Sometimes they take fruit, *e.g.* apples and pears. But it must be borne in mind that these attacks are limited to parts of the year only, while on the other hand the rook is a persistent feeder upon insect life, very largely of the injurious

type, throughout the whole year. Their chief diet consists of crane fly larvae ("leather jackets"), wireworms, chafer grubs, etc., and the young are fed chiefly on suchlike fare. The young hatch early in April.

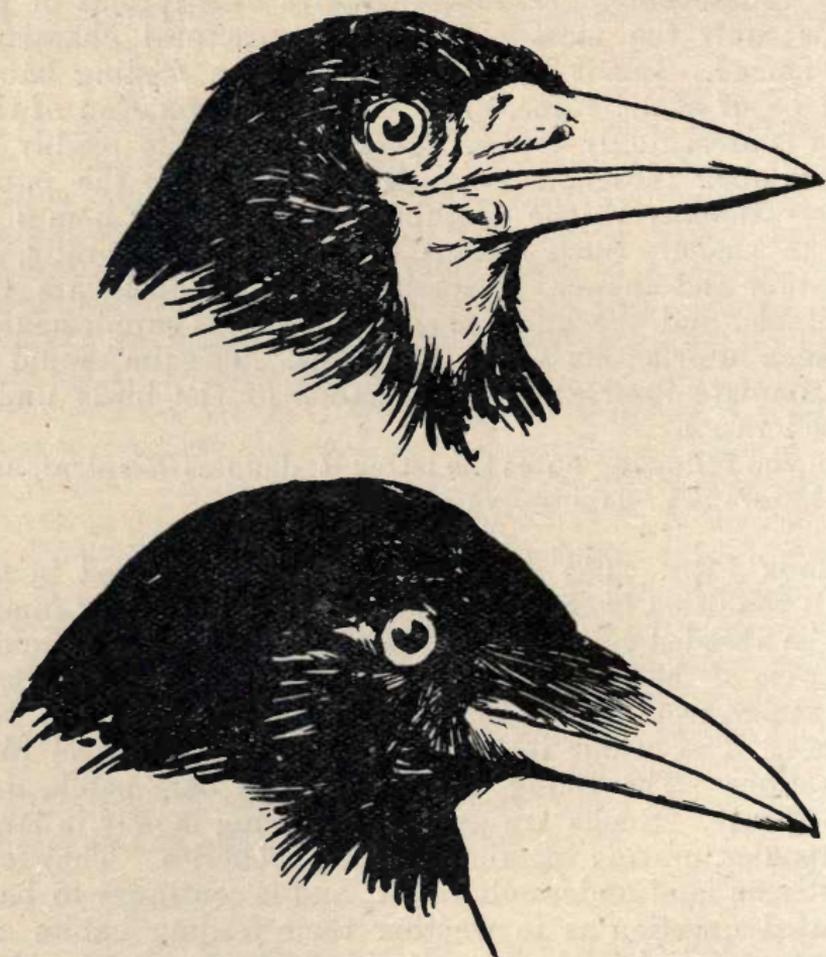


Fig. 35.—Heads of Rook (above) and Carrion Crow (below).

Nest in trees, composed of sticks lined with fibrous roots, bulky. Eggs four or five, nearly two inches long, light greenish blue, spotted brownish.

The rook should be identified in the fields by means of the naked patch under the bill (Fig. 35).

CARRION CROW (R.). This bird is frequently confused with the rook. It is a slightly larger bird, without the abraded patch under the bill. The bill has bristly feathers along its base above. The plumage is very glossy black, reflecting purplish above, greenish below. In contrast to the rook its habits are more solitary, although it is occasionally gregarious. It builds a rather bulky nest in trees or on rocky places. The eggs are about $1\frac{3}{4}$ inches long, light bluish grey, spotted brownish, four to six in number. In habits the carrion crow resembles the raven rather than the rook, frequenting moors, hilly pastures, seashore, and occasionally the fields. It feeds on small birds and mammals, worms, insects, mollusca and carrion generally. "It is a great poacher of game and poultry, and will even attack lambing ewes" (Aflalo). (Fig. 35).

Make a drawing of a rook's head and a crow's head, side by side.

JACKDAW (R.). This member of the crow family measures about 14 inches long, is greyish black in colour, grey at the neck. The head, wings, and tail are dark and glossy. Bill and feet are black. Jackdaws generally nest in companies, favouring old buildings, towers, etc., about which they spend much of their time throughout the year. They are fairly noisy birds, with quite distinctive "caw." They feed chiefly on insects—"wireworm" and "leather jackets"—but sometimes take eggs or fruit. The nestlings are fed on insects. On the whole they are generally regarded as beneficial birds.

Eggs four to seven, an inch and a half long, bluish white with small round dark brown spots.

MAGPIE (R.). A bird of about 18 inches in length. Head, neck, and forepart of breast black, glossy, with but slight reflections. Back black, interrupted by a greyish band in front of the rump. Hinder part of breast is white, the legs and feet are black. Wings with a large white patch next the body, secondaries with marked purple and green reflections, primaries brown on outer and white

on inner margin. The tail, which is 9 to 10 inches long, shows very fine green and purple reflections.

This bird is "extremely shy and vigilant when molested, it is much less so in unfrequented places. It walks like the crows, but occasionally leaps in a sidelong direction, emits a chattering cry when alarmed, flies rather heavily, and nestles in trees or bushes, forming a large nest of twigs, covered over or arched, with an aperture on one side. The eggs, from 3 to 6, $1\frac{5}{12}$ inch long, $\frac{1}{12}$ in breadth, pale green, freckled with umber brown and light purplish grey, but varying in their tints." (MacGillivray.)

It is very destructive to eggs and young birds, levying its toll upon the game preserves. Newstead (*The Food of some British Birds*) reports:—"7 contained insects of the injurious group; 4 beneficial group; 4 indifferent group; 1 wheat and oats; 1 acorns; 1 a holly berry; 1 a field vole; 2 pellets of sheep's wool. . . . I saw this species rob the nest of a song thrush of its young, but I cannot say if this habit is at all general. The young thrushes were only a few days old, and were carried off in the direction of the magpie's nest and were probably fed to the young ones." The bird is sometimes tamed; it has a great weakness for carrying off glittering objects.

SONG THRUSH (R.). This bird is about nine inches long, yellowish brown above, the head faintly reddish, neck and breast yellowish white, feathers of breast tipped with a triangular brownish spot. It feeds on snails, insects, worms, but is also a great destroyer of fruit. A resident bird and a delightful songster. Lines its nest neatly with mud. Eggs generally five, about $1\frac{1}{4}$ inches long, blue, sparsely spotted with blackish brown. Spots large or small or almost absent.

BLACKBIRD (R.). In the male, which is about 11 inches long, the bill is yellow, and there is an orange-coloured ring around the eye. Colour black. The female is slightly smaller, bill dusky, plumage brownish above and lighter below. A persistent robber of garden fruit, but takes also worms, snails, etc. Song rich and mellow, may be heard from early spring to middle of July. Nest

of fibres and grass lined with mud, usually placed in a hedge. Eggs about $1\frac{1}{4}$ inches long, five in number usually, pale greenish blue, speckled with light brown, sparsely, or so thick as to obscure the ground colour.

STARLING (R.). This bird is about 9 inches long, dark in colour, with marked purple and blue reflections. In the male the feathers on the head and neck are very narrow and tapering. On the other parts all the feathers are tipped with a triangular greyish speck, which in the male is small. The bill is long, pointed, and angular, pale yellow, the feet are reddish brown. In the female the feathers are broader, with broader specks at tip. The bill is dull coloured. The nest is placed in various odd situations, disused chimneys, under eaves, crevices in rock, holes in turf or in trees, etc. The eggs, four to six, are about $1\frac{1}{4}$ inches, narrow and somewhat tapering, pale blue. Starlings are gregarious; they feed chiefly on a varied insect diet which includes all the more important agricultural pests, "daddy long legs" larvae, wireworms, etc., also worms and snails. Their nestlings are fed almost entirely on insect diet.

The following record of observations by Newstead are of great interest. At intervals during several days he watched a pair feeding their nestlings. "During a total period of 17 hours, representing approximately the hours of one day during which food was collected for the young, 169 journeys were made to the nest. It may be interesting to note that three birds (two males and one female) were seen on four occasions to bring food to the young. Of this I am absolutely certain, as all three birds arrived at the nest almost simultaneously. As a rule, however, the birds paid alternate visits, and there was an irregular interval between them.

"An approximate summary of the food brought in during the 17 hours may be tabulated as follows:—269 insects of the injurious group; 4 of the beneficial group, 2 of the indifferent group; 30 earthworms; 14 slugs and snails (molluscs); 1 centipede; 1 wood louse; 2 harvest spiders (Phalangids); 23 lots of bread; 19 lots of

garbage (?) from kitchen midden; 10 lots of unidentified insects."

On the other hand, it is clear that starlings do considerable harm to fruit when ripening, *e.g.* cherries, apples, and pears. They also are blamed for destroying young wheat, and in winter they may do considerable damage to stacked corn. On the whole, however, these birds must be considered of a decidedly useful type from the point of view both of forestry and of agriculture.

BLUE TIT (R.). A small bird, $4\frac{1}{2}$ to $4\frac{3}{4}$ inches long. The bill is short, black, and pointed. The crown of the head is light blue, encircled with a white band. Nape and shoulders a darker blue, with two bands of the same colour passing, the upper one across the eye, the lower around the neck, and forming a triangular patch almost black beneath the bill. The cheeks are white. The back is yellowish green, flushed with blue, with a whitish patch behind neck. Wings bluish, with a white transverse band. The breast is pale yellow, mixed with whitish, with a blue patch in middle. The tail is bluish; narrow. Female duller than male.

The Blue Tit feeds on small insects such as green fly and scale insects; the young are fed on grubs and caterpillars. It attacks fruit buds and is very fond of pears. On the whole, though destructive to certain kinds of fruit, blue tits are serviceable birds in the garden, keeping down the smaller types of insect pest.

This bird, if supplied with a lump of suet or coco-nut suspended from pole or tree, to which it comes readily in winter, makes an interesting study. It frequently makes use of nesting boxes placed in the garden; ordinarily it nests in holes of a tree, wall, etc. The eggs, which may be over ten in number, are about $\frac{5}{8}$ inch long, whitish, speckled with light reddish brown, which may be mostly massed at the broad end.

There are six different species of Tits occurring in Britain and all are useful as destroyers of garden insect pests, especially of the smaller forms and their eggs, which are apt to be overlooked by larger birds.

BULLFINCH (R.). This finch is about 6 inches long, rounded and plump-like in body. The bill is black, very short, and slightly hooked above. The male bird is glossy black on top of head, the black continued from the outer margin of the eye around the bill on to the throat. The wings, upper tail coverts, and tail are of a similar colour; the back is slaty grey; the rump is white; throat, breast, and sides brick red. In the female the back is greyish brown, the under parts greyish red. The young resemble the female.

The bullfinch feeds on the seeds of various weeds (self-heal, dock, composites, nettles, etc.), but is also very destructive to fruit buds in orchards and gardens.

The nest, of twigs, fibre, and moss, is built on a bush or tree. The eggs, about $\frac{3}{4}$ inch long, are pale greenish blue with reddish brown or purplish grey speckling at the broad end. The speckling is sometimes in the form of a ring, a not uncommon feature in the eggs of various species.

LINNET (R.). This species is about 5 inches long. The male is yellowish brown above streaked with dark brown, the upper part of the head is crimson in summer, duller in winter; the rump, under parts, and sides of neck are carmine in summer, rump duller in winter. The female is without crimson on the rump; in summer the fore part of the head is crimson. The linnet nests in bushes, utilising twigs, grass, moss, hair, etc. The eggs, four to five, $\frac{3}{4}$ inch long, pale bluish green, with brown spots at the broad end.

The linnet is a gregarious bird, forming sometimes enormous flocks in the winter, when it feeds largely upon seeds of weeds upon cultivated lands. Charlock, self-heal, composites, dock, and dandelion are amongst its diet, especially the first-named. It also visits the farm-yard and the vicinity of towns. In summer it occurs more commonly in wilder parts, *e.g.* hilly regions or waste ground. It is the sweetest songster amongst the finches.

CHAFFINCH (R.). This attractive little bird is about 6 inches long. The male is reddish brown on the back, greenish on the rump. The neck and top of the head are

greyish blue. The breast is reddish. The female is lighter in colour, dark greyish above, light grey on the breast. The male "in the breeding season has the black of the forehead and the greyish-blue of the head, unmixed, the red of the back brighter, and the breast of a much lighter tint. The bill, which in winter is pale reddish brown, also becomes of a fine leaden blue" (MacGillivray).

The Chaffinch appears to be maintaining its numbers, and is not uncommon in the outskirts of towns. It feeds largely on seeds of weeds in winter and on more mixed diet in summer. The nestlings are fed upon insect diet. The nest is a small, extremely compact, and neat structure composed of moss and lichen, lined with feathers, wool, etc. It is placed in a low tree or bush. The eggs, 4 to 5, are $\frac{3}{4}$ inch long, greenish blue with brown spots and streaks. The spots are generally paler at the margin, becoming reddish and spreading diffusely. The egg is sometimes covered with this reddish brown tint so that the ground colour is obscured. Sometimes the egg is pale blue without any spotting.

SKY LARK (R.). The Lark measures about 7 inches in length. The bill is nearly half an inch long. The top of head, back, wings, and tail are dark brown, well streaked with light reddish brown. There is a light band over the eye. The throat is whitish, speckled with small brownish spots, the breast is pale reddish with strong brown streaks, abdomen whitish. The claws are strong, that of the hind toe longer than the toe itself, curved and sharply pointed. The lark is well known for its power of rising to a great height whilst pouring out its delightful song, which is of remarkable duration.

Larks feed chiefly on seeds in winter, often gathering in large flocks on the stubble fields. In summer the diet is more mixed, including insects.

The nest is formed on the ground in open pasture or amongst corn or hay. It consists almost entirely of withered grass loosely put together. The eggs, 4 or 5, are about $\frac{5}{8}$ of an inch long, greyish, thickly speckled with light brown, variable in size and colour.

CUCKOO (S.V.). A bird about 14 inches long, of slender and shapely build, bluish grey above, front and sides of the neck lighter, under parts of the body bluish-white with narrow transverse bars of brown. Quills brownish, inner webs barred with white, tail feathers dark grey spotted along the shafts and on the inner web, white at tip. The bill is slender, with a slight downward curve. This bird arrives in this country in the end of April and leaves in July or August. Its cry, "coo-coo," is well known, as is also its habit of depositing its egg in the nest of another bird.

Some notes with regard to its egg-laying habits may here be given. Its egg is small in proportion, being scarcely an inch in length. It is greyish white, reddish white, or very pale light green with greyish brown; sometimes it is plain blue without speckling. It is in fact somewhat variable as regards colour. The egg is laid on the ground and carried in the bill to the nest of some other bird. This nest is frequently that of the Meadow Pipit, Hedge Sparrow, or Bullfinch, but a great many different birds are victimised.*

In the Fenton Collection of Eggs at Aberdeen University 101 different clutches occur in which a Cuckoo's egg has been found, and in these 57 different kinds of birds are represented. These include Song Thrush, Blackbird, Redbreast, Garden Warbler, Swallow, Skylark, Goldfinch, Wren, Hedge Sparrow, Meadow Pipit, Bullfinch, etc. An analysis of this collection shows:—

(1) The Cuckoo's egg has considerable range of colour variation, *i.e.* in a series. There is also what may be termed discontinuous variation, *e.g.* the plain blue egg. While this is so, there is some evidence to show that the eggs of individual cuckoos probably do not greatly vary.

* In certain localities the Cuckoo shows a preference for certain birds' nests, probably because these are numerous and readily found. Mr. Fenton informs me that "in Pomerania the common wren is the usual victim; at Evesham, in Worcester, the reed warbler; at Clitheroe, the yellow wagtail; and in the western islands of Scotland, the twite."

(2) Sometimes (in 24 cases) the normally-coloured Cuckoo's egg resembles generally the egg of the foster bird. It is, however, usually easily recognised at first sight by the size.

(3) In 12 cases extreme variants of the Cuckoo's egg resemble the foster bird's eggs. This includes one blue egg in a Redstart's nest.

(4) 65 cases are indifferent: that is, there is no noticeable resemblance between the Cuckoo's egg and those of the foster parent.

The egg is laid early in the incubation period and the foster parents hatch it out. The young Cuckoo early (on the second day) ejects the other occupants of the nest, eggs or young. The foster parents feed the intruder, continuing to do so sometimes to the point of sheer exhaustion, so exacting are the demands of the big, black, repellent-looking creature. The young Cuckoos are left behind by their parents and follow them, migrating in October.

The adult Cuckoo feeds on caterpillars, *e.g.* those of the tiger moth and magpie moth.

SWALLOW (S.V.). This summer visitor is a small bird of about 8 inches in length. The throat and front part of head above the bill are deep rusty red; the top of head, back, and shoulders are steely blue; quills of wings and tail bluish green, but with concealed white patches on inner sides of all the tail feathers except the central pair. Front part of breast metallic blue, hinder parts rusty white. In the female the red above the bill is less marked and the breast lighter. The tail also is shorter. In the male the two outer quills are prolonged about an inch and a half beyond the others. The bill is short with wide gape; the feet also are short.

The Swallow nests about buildings, under a ledge or projection of some kind, sometimes in chimneys, and it is said even exceptionally in the forks of trees. The nest is shallow, open above, consisting of mud, straw, and feathers. The eggs are 4 to 6 in number, $\frac{1}{2}$ to $\frac{4}{5}$ inch in length, white,

spotted with brown. There are two broods in a season. The northern range of the swallow may extend as far as Iceland, Spitzbergen, and Northern Russia. In winter it is found in India, Burma, Malay, and Africa. The young birds migrate from this country about September, and are followed later by the old birds.

The diet of the Swallow consists of insects caught mostly on the wing. They devour large numbers of moths, crane flies and other diptera.

The number of swallows appears to be decreasing, and this is attributed to their slaughter in S. Europe for millinery purposes and to the ousting habits of the sparrows, which drive them from their accustomed nesting places.

MARTIN (S.V.). This bird is frequently confused with the Swallow, whose habits and time of appearance in this country are similar. It is of quite distinctive appearance, and may readily be distinguished on the wing by its showing the dash of white on the rump as it flashes past beneath the level of the eye. It is about $5\frac{1}{2}$ inches long. The upper parts of the body are of a glossy steel blue, the rump is white and also the under parts of the body. It is feathered to the toes. The



Fig. 36.—Male Swallow, and tail of female.

fork of the tail is not so marked as in the Swallow. The nest is placed in the upper corner of a window or similar sheltered situation, and is composed of mud, grass, and feathers. Unlike the Swallow's, it is built close up, with only a small hole left for entrance and exit. The eggs, 4 to 5, are pure white, about $\frac{3}{4}$ inch long.

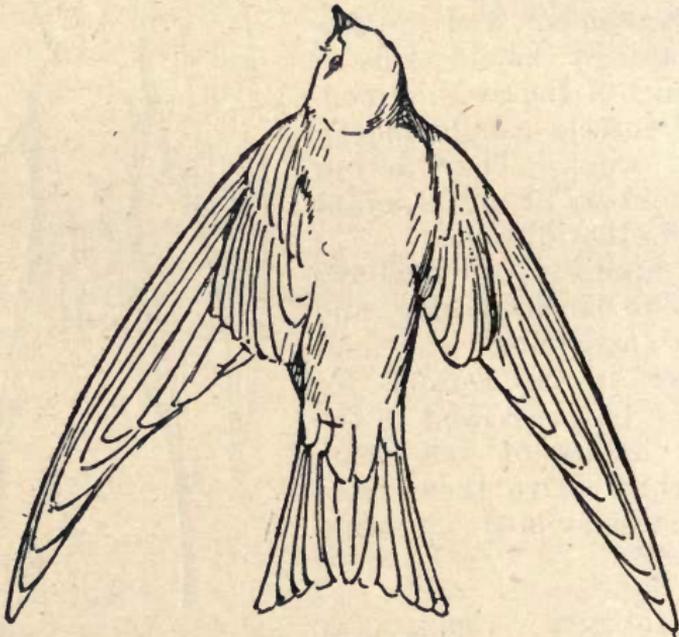


Fig. 37.—Figure of Martin, to show proportions of wing and tail, also type of bill.

The feeding habits of the Martin are similar to those of the Swallow, and the remarks made with reference to their decrease in numbers apply here also.

The Sand Martin, which nests at the end of burrows in sand banks, is rather smaller than the foregoing. Its distribution is more local. It is greyish brown above, brownish white below. Eggs rather smaller, also white.

SWIFT (S.V.). This summer visitor, recognised by its sweeping flight, long scythe-like wings and screaming voice, is about $7\frac{1}{2}$ inches long, from tip to tip of wing

about $16\frac{1}{2}$ inches, is brownish black in colour with a slight dull greyish white patch at the throat. Swifts are insect feeders. They arrive about the beginning of May and leave about the end of August. They nest in holes under eaves of houses, in towers, steeples, etc. The eggs are pure white, about one inch in length, two or three in number.

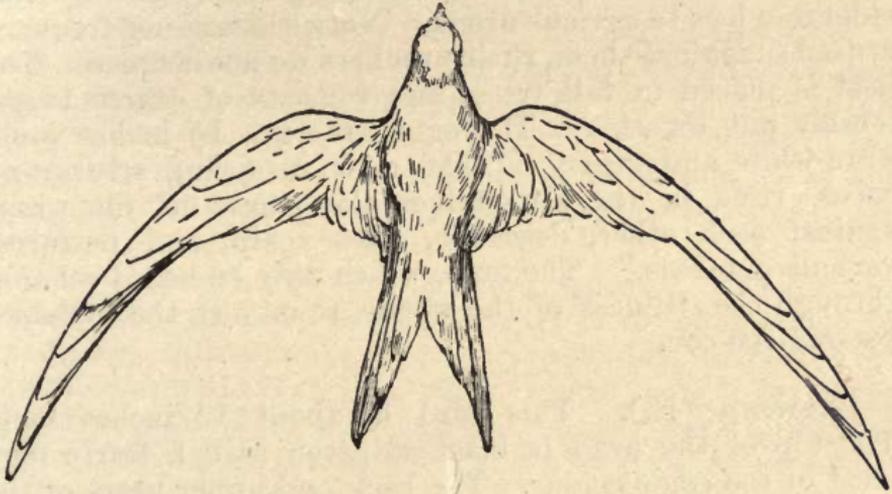


Fig. 38.—Swift. Note the very long scythe-like wings.

The Swift is readily distinguished even on the wing from the Swallow by the great sweep of the scythe-like wings and the uniformly dull colour (Fig. 38).

Make drawings to show the outline of Swallow (male and female), Martin, and Swift. Note the general resemblance in the shape of bill.

WOOD PIGEON (R.). This bird, which is known under a variety of names, Ringdove, Cushat, etc., is about 18 inches long. The head and fore part of neck is slaty blue; neck at back greyish with green and purplish-red reflections; on each side of the neck is a large whitish patch. The back is greyish brown anteriorly, slaty behind. Breast reddish, abdomen light coloured, wings brownish to slaty

with white longitudinal stripe anteriorly, primary quills with narrow white outer edge. Tail greyish, black at tip with broad white band below.

This bird occurs in large numbers over wooded and cultivated regions, and the numbers are largely augmented by visitors from the Continent in autumn. They feed almost exclusively upon grain, peas, grasses, clover, turnip leaves, beech mast, and acorns, causing each year very considerable loss to agriculturists. Notwithstanding frequent crusades against them, their numbers do not decrease. The nest is placed in tall trees, and consists of coarse twigs, loosely put together. The eggs are two, $1\frac{1}{2}$ inches long, pure white and glossy. "The male in spring struts and cooes, rises in the air, strikes the points of his wings against each other, descends, rises again, and performs various gambols." The note, which may be heard echoing through the stillness of the woods, resembles the syllables coo-roo-coo-coo.

LAPWING (R.). This bird is about 12 inches long. The top of the head is blackish green with a fairly long crest of the same colour. The back and upper parts of the wings have metallic green reflections on the upper fore parts of wings. The tail has three broad bars, chestnut at base, white next, and purplish black at tip, except the outer feathers, which are white. Outer wing quills like tip of tail, outermost with whitish patches near the tip. Under parts of neck whitish, chest greenish black, breast white.

A common bird in Scotland and Ireland, less so in England. It nests on the ground in fields in any natural hollow in turf, simply adding some grass, etc. The eggs are four, sometimes five in number, about $1\frac{1}{2}$ inches long, olive greenish, with dark brown blotches. April and May are the usual incubation periods. "The female runs silently from her nest when approached, and it is the male which indulges in such frantic swoops and twirls, accompanied by noisy cries; though when the young are hatched, both parents practise every artifice to allure man or dog from their brood. The 'false' nests often found are

scraped out by the cock in turning round, when showing off to the female."—(Saunders.)

This is one of the most useful birds frequenting cultivated lands. Its food consists in great measure of "wire-worms" and crane-fly larvae.

BLACK-HEADED GULL (R.). This Gull is about 16 inches long. The back and wings are of a light slaty-grey colour, the under parts white. In winter the head is greyish, with a black crescent in front of the eye and a dark grey patch behind it. In summer the head and throat are deep sooty brown, the under parts rose-tinted. These seasonal changes take place in the feathers themselves and are not the result of moulting. The bill and feet are red.

This bird occurs along the shore, especially at estuaries, and is common also inland, where it feeds abundantly on crane fly, wireworm, and other insect diet, disposing of enormous numbers of these agricultural pests. In spring they frequent inland marshes, where they form "gulleries," breeding in large companies. The nest consists of rushes and sedges. The eggs, two or three, about two inches in length, olive green to light brown with dark brown blotching. When the young are able to fly they migrate with the old birds to the sea shore.

THE SPARROW HAWK (R.). A bird of somewhat varying plumage, in general recognised by the marked length of the foot (metatarsus), which is yellow in colour, the middle toe long and slender, and by the lightish under parts barred transversely with reddish brown. The upper parts are bluish; tail has from three to five dark bars; the wings are short. The cere is greenish yellow and the eyes orange. The male is about 12 inches long, female about 15 inches. The Sparrow Hawk is widely distributed, nesting in trees, building a nest of its own or in some cases utilising the discarded nest of another bird, *e.g.* Wood Pigeon, adapting it to its own purposes, especially when rearing its young. The eggs, 4 to 6 in number, about $1\frac{1}{2}$ inches long, pale blue, almost white, blotched and smeared with reddish brown.



Fig. 39.—Sparrow Hawk.

The Sparrow Hawk feeds on small birds, devouring them upon the ground, usually in the shelter of a hedge. It is a troublesome enemy of young game and poultry (Fig. 39).

KESTREL (R.). This is the commonest of the British birds of prey, occurring all over the United Kingdom. In



Fig. 40.—The Kestrel.

Scotland in winter numbers migrate southwards into England. It is frequently termed the Windhover, from its practice of hovering almost motionless in the air, head

to wind. The plumage differs in the two sexes. In the male the back is light reddish with small black markings; the other upper parts bluish grey. The under parts buff with black markings, tending lengthwise. The wings are relatively long. The cere and feet are yellow. Length about 13 inches. The female is darker above with black transverse bars. The tail has several black bars, the last of which is broader than the others. Length about 15 inches.

The Kestrel does not build a nest, usually depositing its eggs about cliffs, hollow trees, or in the discarded nest of other birds such as the Crow or Wood Pigeon. The eggs are about $1\frac{1}{4}$ to $1\frac{1}{2}$ inches in length, often so deeply covered with reddish brown as to conceal the pale ground colour below.

The feeding habits of the Kestrel have been the subject of much controversy, but there is now no doubt but that as far as game and poultry are concerned the Kestrel is practically harmless. It feeds largely upon mice, young rats, beetles, and other insects, and is therefore a bird of distinctly useful type, which should on this account, if on no other, be left unmolested (Fig. 40).

CHAPTER IX.

SOME COMMON MAMMALS.

NOTES FOR SCHOOL STUDIES.

THE MOLE.

MOLES are frequently abundant in certain districts, and are not difficult to obtain. When the opportunity arises a lesson should be given upon the mole's adaptive characters. Moles are burrowers; we are familiar with the earth thrown up by them, *i.e.* "molehills," in the course of their excavations.

With a dead mole before us we notice, as we draw it through our hands, its remarkable approximation to the cylindrical form. There are here none of the undulations which mark the contour of mammals in general. By contrast we think of the arched back of the mouse or squirrel, the sinuous curves of the weasel or the stoat, and note that the mole—fitted to life in cylindrical burrows—has a body of a similar shape.

We stroke the fur of the mole, noting its greyish-black colour; we feel its delicate, oily-like softness. So marked is this that we look at our hands again to make sure that the fur is not oily. The mole's fur has been described as soapy to the touch, and the value of this property is that, though rubbing continually against the soil, the latter does not adhere. The fur, so long as it is dry, remains clean.

We also notice, as we turn over the fur, that it does not possess the property known as "set." That is, it stands almost straight out from the body, and brushes readily in any direction. It is not difficult to understand the meaning of this in a creature moving constantly in a narrow

burrow. A "set" to the fur would be altogether unnecessary. The structure of a mole's hair is unusual (Fig. 41).

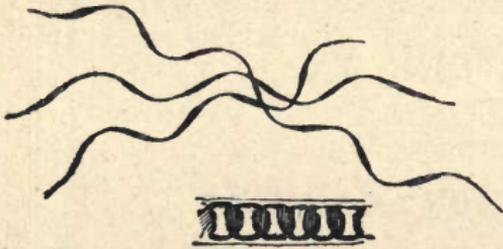


Fig. 41.—Hairs of Mole, showing the regular variations in thickness. A magnified portion of a hair is shown below.

The cylindrical body has deprived the creature of a neck. The head tapers almost suddenly in front of the body; it exhibits

several peculiarities of interest. The snout, tapering downward at the tip, is long. Within there is an extra bone strengthening it, as it assists the claws in pushing the earth aside. The mouth below is suitably some distance behind the tip. It is like a long narrow U, the margins are thin, and that of the upper jaw forms a close covering to the teeth, an effective curtain shutting out grit.

The teeth are sharply pointed, the canines in particular are long and sharp, and well adapted to dealing with the wriggling earthworm upon which the mole feeds. The tongue is long and narrow like a strap, very useful also we imagine in dealing with the earthworms. Around the snout there are numerous sensory bristles, both above and below. All these things should be pointed out to the pupils.

Our next interesting quest is for the mole's eyes. By blowing aside the fur, we disclose the tiny jet-black eyes. The mole is not blind, though its vision is blurred. It can see moving objects, if it does not see them clearly. The mole depends on its other senses more than upon its eyes.

The ears are without an external lobe, and, further, are situated at the end of quite a long narrow tube. By blowing aside the fur which conceals it, this tube may be seen.

A pin should be inserted by the head end so as to show its length. There is no doubt that the hearing organ is thus specially protected from contact with the soil. Moles hear very acutely ; as Shakespeare has it :

“Pray you, tread softly, that the blind mole may not
Hear a foot fall !”

But it is extremely probable that the sensitiveness of the mole is in great measure due to its feeling the vibrations of footfalls through the solid earth.

Perhaps the most noteworthy modification of the mole's body to suit its subterranean life is that of its fore paws. The whole fore limb looks extremely short, yet it is set so closely to the head that when the limb is stretched forward it reaches in front of the snout. It is turned outward more than downward. These limbs do the excavating—not the sensitive snout, which probably simply pushes aside the

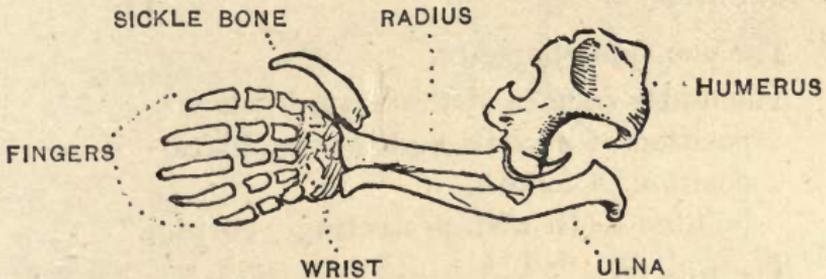


Fig. 42.—Fore limb of Mole.

broken earth. The upper region seems buried in the body, it is very short, and the bone within it (humerus) is greatly flattened and otherwise altered in form to allow of attachment of the excessively developed muscles required for the hard work of excavation (Fig. 42).

The paw itself is broad and flat, the palm very tough and leathery, and its inner margin is extended and strengthened by the presence of an extra bone not found in the fore paws of other animals, which on account of its shape is known as the “sickle” bone. The claws of the five digits, which are

nearly all of the same length, are very strong and sharp. Altogether the limb shows remarkable adaptations to the special work it performs, and all these points should be verified by the pupils.

In this connection it should be mentioned that the breastbone is ridged, thus supplying additional surface for attachment of the strong muscles which move the limbs. We recall of course the keel in the breastbone of flying birds, which serves the same purpose. The great development of this fore limb is further emphasised when we note the slenderness of the hind limbs of this remarkable creature.

The mole has a short and somewhat insignificant-looking tail.

The teacher who is interested in the subject might endeavour to procure a skeleton of a mole, the further study of which will reveal other peculiarities.

Pupils should be asked to make drawings illustrative of the following:—

The shape of the body.

The under surface of the head, to show
 position of nostrils and sensory hairs,
 position of mouth,
 pointed teeth with protecting "curtain."

The fore paw.

BATS.

There are twelve species of Bats occurring in the British Isles, and at least two others are reputed to have been found here. All the bats of this country are insect feeders, but the larger species occurring in tropical regions, such as India and Madagascar, are fruit-eating. Bats are for the most part nocturnal or twilight animals; they hibernate usually in large companies in church towers, old ruins, and other deserted places, generally hanging by the feet with head turned downwards. Their sleep is deep, and they

often die if awakened out of it. They sometimes waken and fly abroad in mild weather, but this does not appear to happen often.

A teacher friend has sent me a long-eared bat. It is one of the commoner species, and I have had it drawn and figured (Figs. 43, 44). Let us examine it. What is a bat?

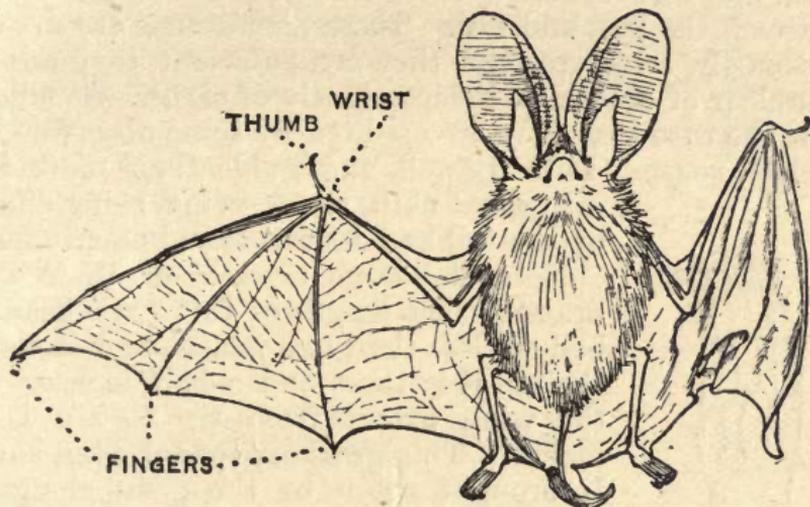


Fig. 43.—The long-eared Bat.

Let this be our first question. A live bat held in the hand is felt to be a warm-blooded, furry animal. We know that they bring forth their young and suckle them with milk. Bats are therefore mammals. Zoologists place them in an Order of mammals to which the name *Cheiroptera* is given (*Cheir* = hand; *Pteron* = wing). They are mammals with hands modified to serve as wings.

Our bat has extraordinarily long ears, thin, translucent, and transversely folded, extremely delicate and sensitive structures. No doubt its hearing is extremely acute. Bats are great moth-hunters, and it is quite possible they may detect the sound of the fluttering of the moth's wings. The membrane of the ears is doubtless extremely sensitive. Some bats have folds upon their noses (nose-leaved bats)

greatly resembling in structure the ears of the long-eared bat, and these also are highly sensitive.

The most remarkable structure about the bat, however, is undoubtedly the flying apparatus. Let us unfold the so-called "wing." Its delicacy is remarkable; exquisitely soft to the touch and folded in innumerable creases is the flying membrane stretched between the bones of the hand, arm, and leg. There is also a similar membrane stretching between the legs and tail. These membranes are so extraordinarily sensitive that they are sufficient to guide the bat clear of obstacles, independently of sight. So much is this the case that they are credited by some observers with a sixth sense. Bats fly well, and guide their movements with great skill, the steering being effected by the tail and its associated membrane.



Fig. 44.—The Bat's foot, showing the toes of equal length and with long claws, by means of which the animal suspends itself when sleeping.

Note the large expanse of these membranes. The length of this bat's head and body is less than two inches, and if we add the tail it is three and a half inches. But the wing extent from tip to tip is ten inches. This great expanse of wing surface is brought about by the great elongation of the bones of the arm and fingers, which serve as supports or act as a kind of framework upon which the flying membrane is stretched. Four of the fingers are involved as well as the arm bones. And the membrane stretches across the inner bend at the elbow, just as the skin is stretched in the same place in a bird's wing.

The "wing" serves not only as an organ of flight, and as a sensory apparatus, but is used as a wrap or mantle in which the bat sleeps and in which the female holds and shelters her young. And some bats use the membrane between the hind limbs as a kind of sac into which they strike the moths during flight. The bat's thumb is free and carries a strong claw. It is used in walking and in climbing, and proves serviceable also when bats fight, as they not uncommonly do. How does the bat dispose of its wings when walking?

There are five toes in the hind foot; they are all of the same length, and have sharp claws, bent like hooks. The bat suspends itself by these when it goes to sleep or hibernates (Figs. 44, 45).

These things should all be pointed out to the pupils. They should draw a wing and a hind foot.

The voice of this bat has an interesting peculiarity. It is singularly high pitched, so that it is audible only to certain individuals.

The structure of the Mole and the Bat illustrate well the principle of adaptations. They are modifications towards opposite extremes in relation to specialised modes of life of the ordinary terrestrial mammalian type.



Fig. 45.—The Bat at rest.

STOATS AND WEASELS.

Of the British wild beasts, applying the term in the restricted sense to the terrestrial Carnivora only, Stoats and Weasels are probably the best known. This is because they are the commonest. Specimens are not difficult to procure; they may be obtained from keepers, who mostly regard it as their business to keep the numbers down. Except that the Weasel is absent from Ireland, they occur throughout the British Isles.

We shall here write down some notes which may be utilised as lesson points.

We have not many wild animals in our islands. Let us name them. After the Stoat and Weasel, we may think of the Pole Cat and Pine Marten. These may be but names to most of the pupils, they are so rare. The Badger is more familiar, but probably only by hearsay. The Otter is commoner; it is of course semi-aquatic. The Fox will be well known, but he too would undoubtedly be scarce were he not preserved for sporting purposes. We finish

our list with the Wild Cat, which is slowly but surely being driven into the wilder and more remote parts of Scotland. But we ought not to pass over the Grey Wolf, which occurred in England up to the end of the fifteenth century and for 150 years longer in Scotland and Ireland. It still occurs on the Continent, in Russia, Spain, and even in Germany and France.

It is interesting to note that of all the animals in this list—it is not a long one—those which are most numerous to-day are the smallest of them all. This is probably because man in his war of extermination has taken less notice



Fig. 46.—The Stoat in its winter coat.

of the small than of the large species. But at present he wages pretty constant warfare upon these small species and their numbers do not greatly diminish. Also the life of the Weasel is becoming better understood and intelligent man is staying his hand with regard to it.

Let us suggest points to be noted in the structure of these creatures.

The Stoat measures to the base of the tail about 10 inches in length and is about $2\frac{1}{2}$ inches high at the shoulder. Its tail is about $3\frac{1}{2}$ inches long. In summer its coat is reddish, with a black tip to the tail. The head is low and flattened, the ears are small. It is a keen and alert

creature, active on foot, progressing sometimes with side-long leaps.

The most interesting feature about the Stoat is its change of coat from the red in summer to white in winter. The tip of the tail remains black. The change is really a change of fur. Here are two problems. Why the change of coat? And why the persistent black tip to the tail? We know that the Stoat, were it red at this season, would be more readily seen upon the snow by its natural prey, which thus would be warned in time. The whitening is a winter adaptation in favour of the Stoat. In high altitudes, where the snow lies through a greater part of the year, the Stoat is always white (Fig. 46).

The black tip is not so easily "explained." But it may be a recognition mark amongst the members of the species. Stoats attack rabbits, young hares, water voles, and rats. Their depredations upon the poultry run and game preserve are notorious. They also climb trees, taking eggs and young birds. Stoats have 5 or 6 young in the spring.

The Weasel is generally about the same size as the Stoat, but the female is subject to considerable variation. It is reddish brown above and white below. It may always be distinguished from the Stoat by its short tail, which is less than half the length of that of the Stoat, and is of the same colour as the upper parts of the body. Its neck is longer and the body is arched. Sometimes the Weasel undergoes a winter change of coat, becoming white. But this is only an occasional occurrence. The Weasel has a litter of from 4 to 6 young each year.

The diet differs in important respects from that of the Stoat. The usual prey consists of voles, rats, mice, moles, and small birds. Weasels frequent farm buildings for the sake of these vermin usually. They occasionally kill chicks or ducklings, but it is generally admitted by those who have given attention to the subject that the good done by Weasels in killing young rats and other vermin more than balances the mischief sometimes wrought in the poultry yard (Fig. 47).

The slender body enables the Weasel to follow its prey into holes and crevices, through corn ricks as well as hedges. Its keen scent guides it even when its prey is out of sight. It kills more than it eats, biting its prey through the skull.

Sometimes the Stoat or Weasel is itself attacked, becoming the prey of hawks. But the remarkable agility and fierceness of these creatures renders them dangerous to meddle with. For if by any means they can reach their captors with their teeth they may bring them ignominiously to earth. Such an occurrence has been witnessed in which



Fig 47.—The Weasel.

Stoat or Weasel has brought down a bird of prey bleeding fatally.

In the study of the life of these creatures we witness in its most literal aspect the "struggle for existence." Here at all events we see "Nature . . . one with rapine."

The teacher should take every available opportunity of studying examples of various other common mammals of our country and preparing lesson notes upon these. He should aim at securing a certain amount of first-hand

acquaintance with, in addition to the foregoing, the structural features and general habits of the following:

Insectivora: Hedgehog and Shrew.

Rodentia: Squirrel, Rat, Mouse, Water Vole, Bank or Field Vole, Hare, Rabbit.

The list of British mammals is not a long one and the foregoing includes nearly all the smaller types. Teachers in the country at all events should not find it difficult to obtain specimens of most of these in course of time.

CHAPTER X.

THE STUDY OF SHELLS.

Introductory.—The attractions of the sea-shore are many and varied. There is the sea itself, heaving, restless; its ever-changing colours, its varying moods, its fresh salt-laden breezes; there is the far-off horizon; there is the sand or the rocks, the birds, the animals, and weeds of the pools, the shells flung up by the tide. The sea-shore is a place rich in physiological and intellectual quickening for the mature; a place full of ever new delights and interests to the child.

The shells are amongst the first objects which interest the child. Although shells are to be found on land, and in the fresh waters, it is generally on the sea-shore that they first attract particular notice. And here we note what has been already emphasised, that objects of definite form and colour have for the child mind an interest *sui generis*. On such material the child unconsciously exercises his or her undeveloped aesthetic faculty, hence we may regard shells as suitable objects for "nature study."

Another element of some significance here, which to the older children at any rate heightens the interest, is the mystery with which they are enwrapped. Shells are, except to the very young children, obviously incomplete things. Not always, of course, for sometimes the owner is present alive. But although this may remove in part the mystery, it does not decrease the interest. But the empty shells on the sea-shore do suggest mystery—if not, the teacher may profitably suggest it. The child knows that they are cast up by the sea, and may be guided to ask with interest some questions as to the life of the creatures of which they once formed a part.

HOW TO STUDY SHELLS.

A collection of different shells should be available. Teachers should take the opportunity of collecting shells when on a visit to the sea-shore, or supplies may be got in other ways.

The first thing to be done in the study of shells is to devote some time to a general appreciative examination of a collection. Drawings should be made, and in those cases where the circumstances admit of it, these should be coloured.

After the general preliminary study, some questions may be asked.

What are shells? An appeal may be made here to the pupils' experience as far as it goes. They will be familiar with terrestrial snails with spiral shells, perhaps with some fresh water forms, *e.g.* in school aquarium, or with the mussels, periwinkles, dogwhelks, limpet, and other common molluscs of the sea-shore. The class should be guided to arrive at the conclusion that shells are the hard outer parts of animals, which otherwise have soft bodies. The bodies of animals which possess shells such as these are generally so soft that the shell is required to keep the parts in position, *e.g.* oyster, mussel, snail, and also to protect the delicate animal from attacks which otherwise would certainly be made upon it.

Shells are supporting and protecting structures, and being such constitute true skeletons. It will interest pupils to learn that some creatures wear their skeletons on the outside of their bodies. Such a skeleton is termed an Exo-skeleton. (An internal one is usually described as an Endo-skeleton.)

Here we may ask what are the names of some enemies of these soft-bodied creatures. One of the greatest enemies of the terrestrial snails is the thrush, who breaks the shell upon a stone. Sea birds attack shore molluscs, either breaking the shell upon the rocks or swallowing it whole. And there is an interesting fish which may sometimes be seen in fishmongers' shops exhibited as a curiosity,

the wolf fish, the inside of whose mouth is paved with rounded blunt teeth as with cobblestones for crushing the strong shells of such creatures. But from most creatures living near them, the molluscs are very secure, the shell being truly protective.

There are several different kinds of shells, but only two kinds which are at all abundant. Pupils will be able to group an ordinary collection into these two natural divisions. In one group the shell consists of a single piece, which is usually, but not invariably, spiral in form, *e.g.*

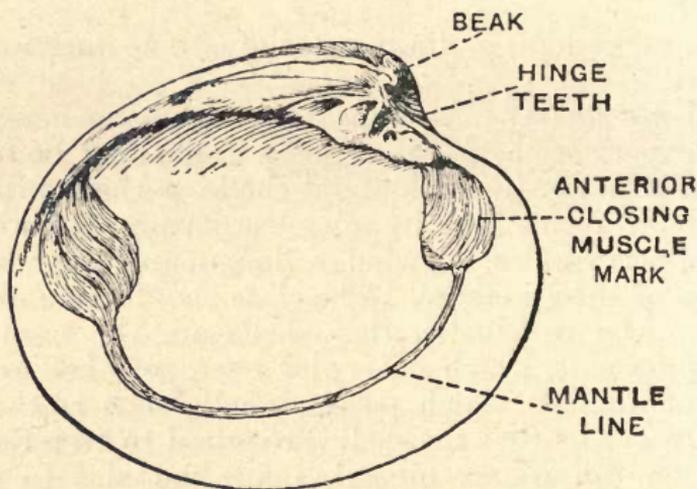


Fig. 48.—Left valve of Saucer Shell, showing markings on the inside.

periwinkle or whelk; in the other the complete shell consists of two separate valves which lie right and left of the animal, *e.g.* oyster, mussel, cockle, etc. These are appropriately termed bivalves.

Let us take to begin with a shell of this latter type and study it in detail. Any of the common bivalve shells of the sea-shore will do; a useful large example, known as the saucer shell (*Cyprina*), is very suitable for our purpose.

One of the characteristics of animals of the class which we are dealing with, is that from the back of the animal there grows out a fold of skin which is so large that it covers over and conceals all the rest of the body. Quite

appropriately this fold is known as a Mantle. It lines the inside of the shell, adhering to it some little distance back from the edge. Examine the inside of the shell and discover the mantle line (Fig. 48).

Two questions may be suggested here. How has the shell come to be as large as we see it now? It is a hard, insensitive, dead thing, yet it must have grown. It was not always as large as we now see it. How has it grown? Shells without living animals within them do not grow. And when we remember that the mantle is the part of the animal which lies against the shell, it is not difficult to realise that the mantle produces or makes the shell, adding to it along the outer edge.

Look now at the outside of the shell. Observe the succession of ridges which pass round it, marking successive additions to the shell. These may be termed lines of growth. By tracing them backward we arrive at the oldest part of the shell. Let the pupils find this part. It will be seen to be turned downward, and nearer to one end of the shell than the other. This part is termed the beak, and it is turned towards the front end of the animal. This is a quite general rule, so that by noting this fact we can tell from the shell where the head end of the animal lay.

Here is a simple exercise. Let each pupil hold a half-shell. How can we tell whether it is a right half, or a left half? First, let us name the regions we know. We have just determined the anterior or front end. The opposite end is of course posterior. The free open edge (growing edge) of shell is the under side (ventral side), hence the part where the valves join (hinge region) lies next the back (dorsal side). Now let pupils apply the following rule. Hold the half-shell in the hand with the front end directed upward and with the inside of the shell towards your own body. Next move the shell towards that side of your body which will cause the growing edge to be directed forward, and the hinge margin towards your back. You will occupy the same relative position to the shell which the animal did when living, and if the shell is a right half it will be held at your right side, and if a left half, at your left. Repeat the exercise with several different shells.

Note next the layers of the shell. On the outside we can recognise a dark coloured horny-like covering. Different kinds of shells examined will show that it is strong in

some and very thin in others, and in shells which have been dead a long time it may be all rubbed off. This substance, known scientifically as conchin, may also be called "shell stuff." Viewed from the inside the shell shows a third layer, limy but having distinctive properties. The surface of this layer shows a certain amount of glossiness, which in some shells produces a marked iridescence. This is known as the mother-of-pearl layer, and it is from this part that various useful and ornamental articles are manufactured, *e.g.* buttons, knife handles, etc. In the saucer

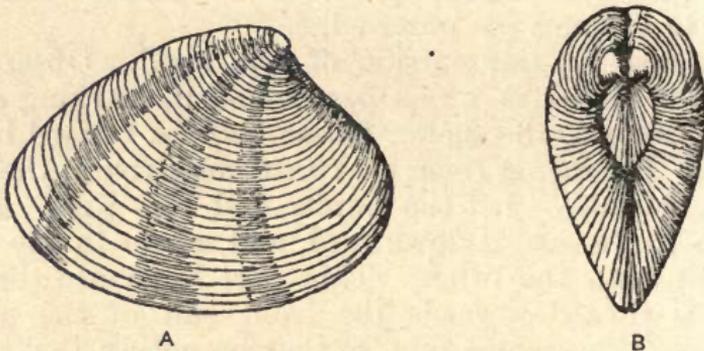


Fig. 49.—A common sea shell (*Venus gallina*).

A, the right valve; note the beak directed forward. In B both valves are seen as from the front. Under the beaks the two valves form a depressed heart-shaped area, very characteristic of this type of shell.

shell it is an opaque white. Between the two layers named there is a middle limy layer.

An examination of the shell shows that it is thicker in the older parts than in the newer. This is because the mantle not only adds to the shell along the edge but to its inner surface also, and it is to the innermost layer that the addition in thickness is made. It is owing to this property of the surface of the mantle that the occurrence of pearls inside shells is due.

When bivalves are found alive, their shells are tightly closed. We may appeal to the experience of the pupils, some of whom have probably seen live oysters, mussels, or clams. The shells are closed so tightly that it is found

impossible to open them without the aid of a sharp instrument. Bivalves are provided with powerful muscles passing across from shell to shell, by means of which they pull the two halves of the shell together. Oysters and clams have only one such muscle, but most others have two. Examine the inside of the saucer shell and find at each end of the mantle line an elliptical scar (Fig. 48). This marks the place of attachment of the shell-closing muscle.

In some shells it will be seen that the posterior end of the mantle line is indented into a kind of bay (Fig. 50). Common shells showing this are the "fool's mussel" (*Macra stultorum*), the Venus shell (*Venus gallina*), and the large well-known sand mussel (*Lutraria elliptica*). This bending of the mantle line is due to the presence of a respiratory tube in these animals. This tube projects from the hinder end

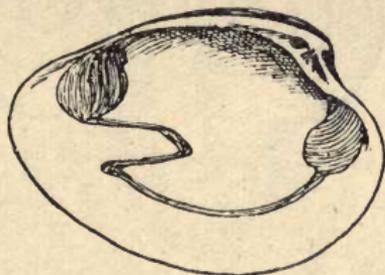


Fig. 50.—Inside of valve of *Macra stultorum*, showing adductor muscle marks and indented mantle line.

of the shell and can be more or less retracted within it. It is used as a means of conveying water into and out of the shell. The presence of a "bay" on the mantle line, therefore, is an indication that its owner possessed a respiratory tube.

Lastly, the interlocking teeth forming part of the hinge joint of the shell should be noted.

Pupils should learn the names of at least a dozen common shells. Examples which will well repay a close examination in detail are the clam or scallop (*Pecten*), which has only one adductor muscle mark; the oyster, whose left valve is deep and whose right is flat and which also has but one adductor mark (the posterior); the razor shell (*Solen*), on which all the usual markings may be found, but altered in shape; the common mussel; the wedge shell (*Donax*); etc.

SPIRAL SHELLS.

Take a common shell, *e.g.* the shell of a garden snail. Make a drawing of it so as to show the various parts—mouth, spire, apex. Note that the spiral is right-handed.

To determine this, look down upon the apex of the spire, and follow the coils downwards with the finger. The finger will move in the same direction as do the hands of a watch. Some shells have a contrary spiral, *i.e.* they are left-handed. Draw a left-handed and a right-

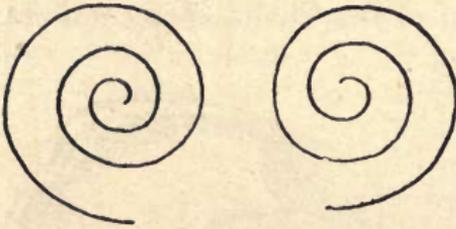


Fig. 51.—Spirals; that to the left is left-handed, to the right is right-handed. (In following the spiral, commence at the inner end.)

handed spiral side by side (Fig. 51).

When the outer wall of a shell is broken, we can see a pillar inside. To this pillar the snail is attached, so that it cannot be pulled out of the shell. The pillar is sometimes hollow—in part at any rate—and has an opening to the outside. Find the pillar opening on the shell of the garden snail. (It lies on the inner margin of the mouth opening.) This opening is sometimes covered over in part by the folded edge of the shell.

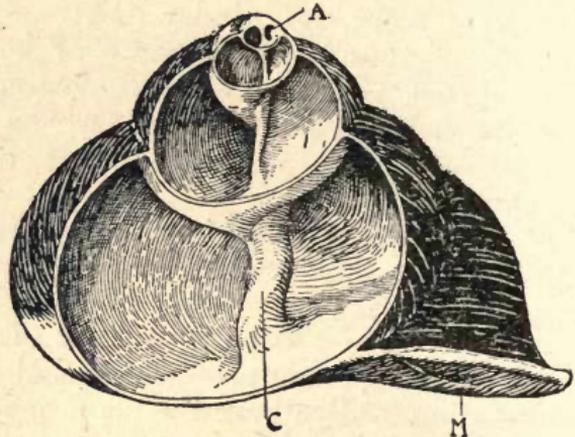


Fig. 52.—Shell cut to show pillar (C). M, mouth; A, apex.

The shell of the snail is a turreted spiral. Some shells have long turrets and others have very short ones. Compare such shells as the whelk, a common sea-shore form,

with a long turret, and such a shell as the cowrie, a short turret, both with a similar number of turns in the spiral (Fig. 53). How is the difference explained? If we break a cowrie shell, the greater part of the earlier turns of the spiral will be found overlapped by the later ones, and the last turn covers all except the tips of all the rest. In old shells the spiral may be obliterated on the outside, but of course it persists within.

As far as spiral shells are available, compare as to the number of turns and amount of overlapping. Draw a series of types.

Some special cases of interest are the ram's horn shell (*Planorbis*) found in fresh waters, whose spiral is flat, not turreted; the ear shell or "ormer" (*Haliotis*), whose spiral is so open that there is no pillar, and which is greatly drawn out to one side; the limpet (*Patella*) cap-like, whose spiral is present only in the youngest stages. The fresh-water limpet (*Ancylus*) is a small helmet-like form occurring in ditches, etc., which may be compared with this last.

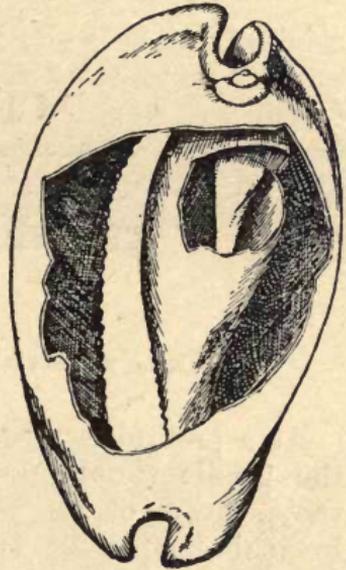


Fig. 53.—Cowrie shell broken to show the parts of the spiral concealed within.

CHAPTER XI.

THE SNAIL (*Helix Aspersa*).

AN EXPERIMENTAL STUDY FOR PUPILS.

As a preliminary to the experimental study of the snail, the pupils should note its general structure, discovering the position of the mouth, eyes (at tip of long horns), breathing opening (under the shell at the right side). The yellowish region surrounding the opening of the shell is the thickened margin of the "mantle" which is concealed beneath it. This region is usually termed the collar. The flat muscular region on which the snail creeps is known as the "foot." Snails and slugs which crawl on the under side of their bodies are known as Gasteropoda. (*Gaster* = belly; *pous* = foot). The Gasteropoda form a sub-division of the soft-bodied animals termed MOLLUSCA.

Place the living snail upon a slate or sheet of paper—or, best of all, a piece of glass.

Observe first its mode of locomotion—an *apparent gliding* motion upon a flat sole extending the whole length of the animal. Calculate its rate of motion in inches per minute. With the snail upon a piece of glass, when it commences to move observe the mechanism from the lower surface. Describe what you see. Compare this mode of movement with that of an earthworm. Remark on the presence or absence of variations in length of the body in motion. Cause the animal to retreat into its shell and leave it until it emerges. Repeat this experiment several

times without unduly annoying the animal. Meanwhile observe an orderly series of movements, and record what they are.

Make any other observations on its movements that occur to you.

Discover how the animal is breathing. Note the opening and closing of the pulmonary aperture (under the shell on the right side). Leave the snail to itself and observe whether this opening and closing occurs at regular intervals, whether frequently or seldom. Study next some snails feeding on lettuce leaves. Write down what you

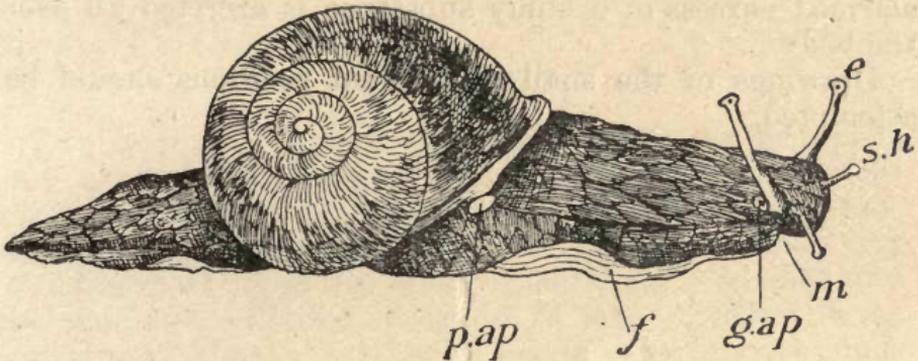


Fig. 54.—The edible Snail (*Helix pomatia*).

An unsymmetrical type. *p.ap*, pulmonary aperture; *f*, foot; *g.ap*, genital aperture; *m*, mouth; *s.h*, short horns; *e*, eye.

see and hear. (The teacher will explain the presence of a toothed ribbon in the mouth on which the food is rasped.)

Special senses: *Sight*.—Examine the organs of vision. Note their situation and how they are protected. What happens when the animal retracts its "horns"? Determine by experiment the range of vision. This may be done by carefully approaching the eyes with a pencil or fine brush. Note how near it is possible to come before the eyes are retracted. Test the response to moving and stationary objects.

Hearing.—Test some snails and determine whether their powers are good in this respect. Note if they respond to noises made close to them when they are expanded.

Touch.—Discover by the experiment of gently irritating the body in different places whether one part is more sensitive than another.

Smell.—There is some evidence that in the snail and in related forms it is a strong sense, *e.g.* marine gasteropods are usually attracted to crab-pots containing stale fish. Devise an experiment to test this sense.

Observe how the animal protects itself when unduly alarmed—excess of a slimy substance is excreted all over the body.

Drawings of the snail in different positions should be attempted.

CHAPTER XII.

SOME SUGGESTIONS FOR THE STUDY OF INSECTS.

CATERPILLARS.

THE rearing of caterpillars in school forms a profitable part of Nature Study work. Their feeding and other habits will become familiar to the pupils by direct observation, and with the senior pupils simple experiments may be devised to show the effect of differences in diet and surroundings. Drawings should be made freely, and the opportunity should be taken of making clear to the pupils all important noticeable features in the caterpillars themselves and in their behaviour.

A common hardy caterpillar available in the spring and summer is that of the Magpie Moth (*Abraxas grossulariata*). In a fruit garden harbouring these insects they will be found as soon as the foliage of the gooseberries or currants is unfolded. This caterpillar is hatched in the autumn and feeds on the gooseberry or currant leaves for a short time, but it soon ceases its activities and conceals itself in the soil or in crevices in the bark or cracks in walls, etc., for the winter. These small caterpillars may also be found amongst the dead leaves lying in the forks of the branches. When spring arrives they come out of their retirement, ascend the branches, and attack the leaves. This is the time to collect them. They should be placed in the insect cages and supplied with gooseberry

leaves. If practicable it will be found profitable also to study them along with pupils at the bushes in the garden.

A series of drawings to illustrate the general life habits of this insect should be made by the pupils. In order that this may be done satisfactorily, a lesson should be given on the structure, and of course it is not possible nor desirable that the whole series should be attempted in one lesson. Time must be given the pupils to assimilate the significance of what they see.

The caterpillars should be watched and their general appearance and behaviour noted. Pupils should begin by describing its colour. Some variation in this respect will be noted, and pupils should be encouraged to look for this. Black is abundant in large spots along the back and in smaller ones upon the sides; there is cream and orange red occurring between. Sometimes an example occurs which is almost or completely black. As the pupils watch the insects they will gradually become conscious of some of the values of the colours of this caterpillar, and of caterpillars in general.

This insect when fully grown is about $1\frac{1}{4}$ inches in length. Its body consists of a series of divisions or segments. Pupils will count these, and discover that thirteen can be made out. They can distinguish the head, which is black in colour and horny-like. With the help of a lens very short "feelers" can be distinguished and also two groups of minute black spots, the simple eyes. On the under side are the jaws, with which the leaves upon which they feed are cut.

The three segments following the head are very similar to those that succeed them except that they are provided each with a pair of black-clawed feet (Fig. 55¹). These three segments must be thought of collectively as a distinct region of the body termed the thorax. They retain this distinctiveness through the whole of the insect's life and constitute the thorax in the adult; their legs are the rudiments of the six legs of the adult.

The remaining segments constitute the abdomen or hind body, the tenth segment (counting from the head) carries a pair of stumpy sucker feet (Fig. 55¹), and so does the

last.* The last segment differs slightly in shape from the others. All these points will be seen clearly as the pupils make their drawing.

On the sides of the caterpillar's body may be seen minute oval areas, whitish in colour. In some species they appear quite conspicuous, although they are never very large. In the caterpillar we can see a pair of these on each segment behind the head except the last two of the thorax. These should be looked for. They are of interest, since they have slit-like openings through which the caterpillars breathe, air passing in and out with the movements of the body. The caterpillar should be drawn with body extended (Fig. 55¹).

Having become familiar with the leading external features, we may proceed to watch the caterpillar moving. Our next drawing must show how it progresses. Releasing its hold by its sucker feet it draws its body into a loop, placing segment ten close behind segment four (Fig. 55²). Next, releasing the hold of the thoracic feet, the body is raised (Fig. 55³), stretched forward, and laid down fully extended, a hold being taken again by the thoracic feet. Once secure, the hind part is released, the body arched as before, and so the process is repeated, the creature progressing by a series of looping movements. Caterpillars belonging to this family are popularly known as "loopers" on account of this habit. Pupils may be able also to see the appropriateness of the scientific name of the Family—*Geometridae* or "earth measurers."

A common experience, which doubtless will be shared by pupils when collecting, is to find that the caterpillar disappears as the hand is put out to remove it. They are usually more or less concealed amongst the foliage; frequently they rest against the leaf stalk. In the act of reaching towards the caterpillar we inevitably shake the bush and the caterpillar falls. Usually the actual fall is

* Caterpillars mostly have more sucker or stump feet. The maximum number is ten stump feet for a true caterpillar (see Fig. 164, p. 306).

not observed, and until we gain more experience of its ways the caterpillar has a good chance of escaping.

It has not fallen to the ground. In the momentary

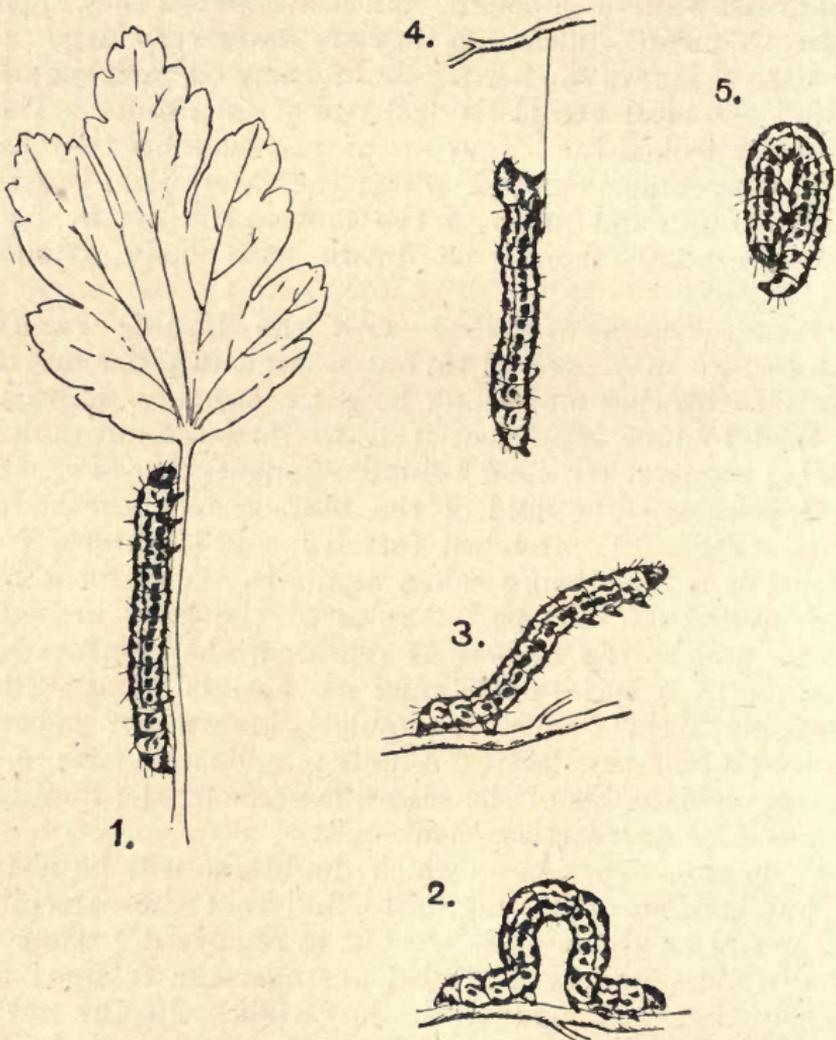


Fig. 55.—The Caterpillar of the Magpie Moth.

The series 1-5 illustrates its characteristic behaviour (see text).

period available it has fixed the end of a silken thread to the twig or leaf stalk, and in the act of falling has spun out the thread several inches in length. Here the insect

dangles in the air while we search the ground or amongst the leaves for the caterpillar we are sure we saw. The thread is extremely slender, and we may handle the bushes so roughly that it is broken; it will not stand all sorts of usage, but in the main it serves its end.

The caterpillar hanging by its thoracic feet and jaws upon its cord commences the return journey, and its progress upward is well worth watching (Fig. 55⁴). With hind body stiffened out behind, and head alternately thrown back and then forward to grip the silken cord by the jaws, the acrobat at length reaches the shelter of its leaf. Pupils should be made to observe the whole process. The caterpillars can be got to fall off the end of a pencil and climb up again.

There is no doubt that this habit is effectively protective, and that caterpillars which are able to do this, in a large number of cases will escape capture by their bird enemies. Our particular caterpillar is a well protected type in this and in other ways, as we shall note further on.

Sometimes the creature falls to the ground. What happens? Hold one in the hand and cause it to fall on the table. It doubles itself, head close to tail, but with the last segment projecting, and lies motionless (Fig. 55⁵). This is a quite definite piece of behaviour. Many other caterpillars do the same kind of thing. They have learned, somehow, the advantage of keeping still; that movement attracts attention, and that to be seen may mean death. Many animals through stress of life have discovered this. Our caterpillar in a short time if undisturbed will slowly turn over and proceed to crawl away, but there are some creatures which lie still so long that they are apt to be regarded as dead. The larva of the antlion, a predaceous insect feeding on ants, is an adept at this kind of "death-feigning." The fox is credited with the same kind of behaviour.

The pupils should add another to their series of drawings, that of the caterpillar as it lies folded motionless upon the ground.

Our caterpillars are remarkable for the variety of ways in which they are protected from attack. Besides the ways

noted above, we observe further that they are not easily seen. In the confused light and shade of a currant bush the black and creamy pattern of their skins renders them difficult of observation. One has to look upward to find them, as they occur generally on the under side of the leaves. Keen-eyed birds may see them more readily than the eyes of men do, just as young children will find them quicker than men will. But keen-eyed small birds will not touch them on account of their nauseous taste. The only bird which appears to take them in numbers is the cuckoo (Sparrows attack the adult insects).



Fig. 56.—Leg of a Caterpillar, magnified.

When the caterpillars are fully grown, *i.e.* about the month of June, they pass into the pupa or chrysalis stage. This transformation should be watched in the rearing cages and a description of it written out by pupils. They will note the soft yellowish appearance at first, becoming transformed into the glossy black and gold banded colour in a short time. The pupae should also be figured, and it is important that the pupils should distinguish the chief parts of the body upon it, recognising in particular the wing rudiments, head, thorax, and hind body.

What is the significance of these two stages?

Caterpillar Stage.—It will have become obvious to the pupils that the life of a caterpillar is devoted entirely to feeding, with growth as a result. Attention should also be called to the moulting consequent upon growth. Why do caterpillars moult? What is thrown off when they moult? The outer layer of their skins. A tough cuticle (composed of the substance chitin), which, being simply a non-living product of the skin, cannot grow. Hence it must from time to time be thrown off from the body growing beneath it. This is the answer to our question why they moult.



Fig. 57.—Pro-leg of a Caterpillar.

Pupa or Chrysalis Stage.—In this stage our insect does not feed or move about, but lies quite passively (Fig. 58). This is the almost universal rule (but we may note in passing the pupae of gnats and some other insects which retain their powers of locomotion, but do not feed). Yet we know that under the stiff outer shell important changes are going on. There is a breaking down of the caterpillar organs and a building up of new ones. And when this is completed there emerges from the cuticle of the pupa, which is cast aside, the winged adult insect—in the present instance, a beautiful moth.

At this point it is well to summarise the outstanding facts.

We have seen that caterpillars are only a stage in a life history. When young animals which feed themselves are unlike their parents in general habits and structure, they are usually termed larvae. Caterpillars are larvae.

Their life consists in feeding and growing.

The pupa is a stage in which preparation is made for the adult condition. *It exhibits neither feeding nor growth.* The teacher should inquire the meaning of the terms pupa and chrysalis. If possible the pupae of the small tortoise-shell butterfly (*Vanessa urticae*) should be obtained—(its caterpillar feeds upon the nettle)—in order to show the appropriateness of the latter term (*Chryseos* = golden). Many of the pupae of this common insect exhibit a remarkably fine metallic lustre.

It is desirable that some comparisons be made of different common caterpillars, *e.g.* as regards the number of pro-legs; the colour in relation to that of the food plant, whether resembling it, or conspicuous upon it; and some observational work might be attempted out of doors with a view to discovering what common types are taken or rejected by birds.

The winged insect is considered in the following lesson.



Fig. 58.—
Pupa of
Magpie
Moth.

THE MAGPIE MOTH.

We have here an insect, the magpie or currant moth, common in gardens in the months of July and August. Let us begin our study by gratifying for a little our aesthetic sense. As our lesson proceeds we shall become familiar with the details of its external bodily structure; meantime let us note the short somewhat blunt body, the large wings outspread as the creature rests, the slender



Fig. 59.—The Magpie Moth (*Abraxas grossulariata*).

feelers, poised with slightly incurved tip in front of the head. Let us draw the moth in outline (Fig. 59).

In colour the moth is extremely pretty, exhibiting creamy white, black, and orange colours. As we look over a number of examples we discover these colours are constant, charac-

teristic of this creature. We also find a general arrangement of colour giving a definite pattern, variable in detail, yet conforming to a type. Let each pupil guided by the teacher now write out a description of the colour arrangement of the wings and body.

Commencing with the fore wings, we note a ground colour of creamy white. Around the posterior margin there is a row of black semi-lunar or oval spots; a little way in front of this a double row of closely set larger spots, also black, sometimes confluent, undulating in a double curve; the space between the two halves of the row is orange in colour. In front of this the markings are less regularly arranged, but about the middle of the anterior border of the wing a triangular black patch occurs followed across the wing by three or more black spots. At the

anterior border there is a short set of black markings in a double row with orange between.

The under wing, which is but slightly exposed when the moth is at rest, has also a cream white colour with a border of black semi-lunar markings. In front of this there is an irregular line of small black spots, while in the anterior region of the wing there are a few scattered spots of the same colour. There are no orange markings.

The body itself is of a rich orange colour, having a single row of black spots on the upper side and a double one of smaller spots below. There is a larger black mark upon the thoracic region, *i.e.* between the place of attachment of wings to body. The wings are symmetrically marked and the body markings form a median set fitting in well with their pattern.

There is no doubt that here we have an arrangement and combination of colour which is pleasing to the eye, and a few minutes devoted to a close examination and comparison of different specimens are well spent. We may be struck with the fact that these insects are so conspicuously marked, or at any rate they appear to be so. But it is one thing to see them as we perhaps are doing, *i.e.* indoors or in the hand at close quarters away from their natural surroundings, and another as they rest upon a wall or against the trunk of a currant bush. Here they are much less readily observed. Further reference to the significance of colour is made below.

The pupils should here make a coloured drawing of the moth.

It cannot but be noted that the moth at rest spreads its wings flat so that the upper surfaces are exposed, the front wings overlapping all but a small portion of the inner and posterior borders of the hind pair. These and similar details will be verified in the making of the sketch, which should not be omitted.

We become very familiar in handling the moth with the delicate nature of the surface of its body. It rubs off all too readily, and if we shake on to a glass slip a little of the fine dust of the wings, we discover it is made up of a great variety of exquisitely formed and delicately ridged and

fluted scales. A lens is required to see this. Certainly the scientific study of the wing of the moth or butterfly does not destroy our appreciation of its beauty (Fig. 60).

Let us now watch the moth in active movement. It can run well, although it is not much given to this mode of locomotion except shortly after emerging from its pupal case. If at this particular time it is disturbed or interfered with, it will run very quickly. Its wings are small and incapable of flight (Fig. 61). If these moths are reared in school this feature should not be missed, nor should the



Fig. 60.—Scales from the wing of the Cabbage Butterfly, magnified.

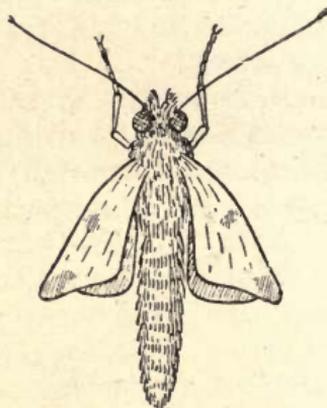


Fig. 61.—The Cabbage Butterfly as it emerges from the Chrysalis case.

rapid way in which they expand to the full size be overlooked.

On the wing the moth is active. Watch its rapid flight. How do we describe its course? Straight or uneven? Can we suggest a meaning in the seemingly erratic and more or less aimless course it follows? Does this make it easier for moths and butterflies to “dodge” their natural enemies, the bats and the birds? It is probable that this is so.

It may be noted in passing that this fluttering irregularity of flight exhibited by butterflies and moths has suggested to certain writers the idea of aimlessness in life.

Hence the term "frivolous butterfly." No doubt it is daintily put:

"O pretty painted butterfly, what do you do all day?
I roam about the sunny fields and nothing do but play.
Nothing do but play! O, silly painted butterfly to waste
your time away."

But this is not quite fair to the butterfly, as we shall see.

In the course of examination of the moth, pupils will be able to identify the regions noted in the caterpillar—head, thorax, and hind body. It will be most profitable if in this study we make a comparison between the larva and the adult in detail.

We note on the head in the winged insect—

- (1) Longer and finer antennae. They should be examined at close quarters.
- (2) Quite new eyes, large and compound in character.
- (3) The mouth parts are transformed. The biting jaws of the caterpillar have become long sucking jaws in the adult. These jaws will be seen on the under side of the head coiled up like a watch spring (Figs. 62, 63). The moth has complete control over this slender coiled tube, straightening it at will and inserting it into flowers when feeding.

On the thorax we observe—

- (1) The legs are longer and adapted for supporting the insect whilst it rests or is feeding or is depositing its eggs upon the food plant.
- (2) The adult insect has two pairs of wings; the caterpillar has none.

On the abdomen we note—

The stump legs have disappeared.

Lastly the whole body is smaller and lighter and the arrangement of colour is different.

These changes can best be understood by a consideration of the distribution of the functions of the insect over the whole period of the life-history. In many insects, *e.g.* in the moth we are at present studying, the prime functions of life are set in apposition in different life stages with marked definiteness. In the larva, feeding is the dominating function. It is accompanied by growth. We see in it a period given over to the **Individual Interest**. In the adult, feeding is quite a subsidiary function, being subservient to that of egg-laying, *i.e.* the continuance of the

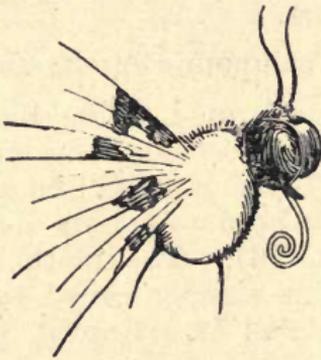


Fig. 62.—Head of Magpie Moth, showing coiled sucking jaws.

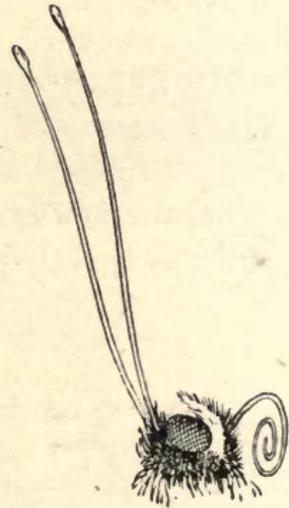


Fig. 63.—Head of Cabbage Butterfly showing clubbed antennae and coiled mouth parts. (Cf. Fig. 62.)

species. Adult insects do not grow. This period is given over to the **Race Interest**.

A detailed examination of the various parts of the insect in the light of these facts is not possible here, but some points should be touched on, and some of them may profitably be suggested to senior pupils.

Antennae or feelers are, as experiment has shown, also important as organs of smell. The caterpillar hatches from the egg upon its food plant and commences to eat right away, and on the whole abundant supplies are

generally well within its reach. It may spend its whole larval existence on the same spot. The parent butterfly on the other hand is equipped so as to disseminate the species. It must go on depositing eggs upon food plants in widely distributed areas and must find these plants mainly by its sense of smell. This function is therefore more acute in the adult.*

The food of a caterpillar is solid, and biting jaws are required to deal with it. A great deal must be eaten to extract a small amount of nourishment. Since as already

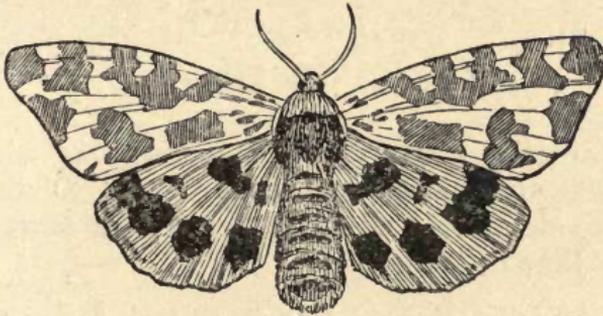


Fig. 64.—The Tiger Moth.

indicated the adult insect must travel some distance in the performance of its prime function, it is important that its body should be light and also that time should not be lost. Lightness is gained and time saved in the change of diet from solid to concentrated liquid food. Some insects indeed do not feed at all in the winged state.

The presence of wings and the disappearance of hind body legs are to be explained with reference to the same needs. The wings of the moth (as well as other parts of the body) are covered with minute scales of different colours, and it is the grouping of these scales that yields the colour pattern already described. Moths and butter-

* The significance of the antennae in enabling the two sexes to meet need not be raised with children, although it is a very important illustration of our point.

flies are classed in an Order of Insects termed Lepidoptera, which means "scaly winged."

Very frequently the colours and patterns produced by these scales have protective significance. We may note here just one general point. In those Lepidoptera which rest with the upper sides of the wings exposed (moths) the brightest colours are concealed and the exposed parts frequently harmonise with the normal background (*e.g.* a tree trunk). In those Lepidoptera which rest with the wings erect over the back so that their under sides are exposed, the showy pattern is on the upper (*i.e.* the hidden) side (butterflies).

ORDERS OF INSECTS.

In our previous study we became familiar with certain general facts of insect structure. As a contribution towards the definition of an insect let us enumerate the more important of these.

- (1) The body is divided transversely into segments.
- (2) Three divisions (constituting groups of segments) are recognisable in the adult, viz. Head, Thorax, and Hind Body or Abdomen.
- (3) The head carries one pair of feelers or antennae.
- (4) There are three pairs of legs upon the thorax (one pair to each of its segments).
- (5) Wings are usually present, but not invariably (Fig. 65).

In a revision lesson all these points should be verified on a new type, *e.g.* a Bee, Crane-fly, or Butterfly, or Grasshopper. In some types, *e.g.* Flies, the antennae are small, but the other characters are readily made out.

The variety of form amongst insects is very great. Hence the group is subdivided into Orders, and of these

a few embrace a large number of the commonest types. We shall classify the most familiar examples. For our purpose we shall confine our notes to outstanding features

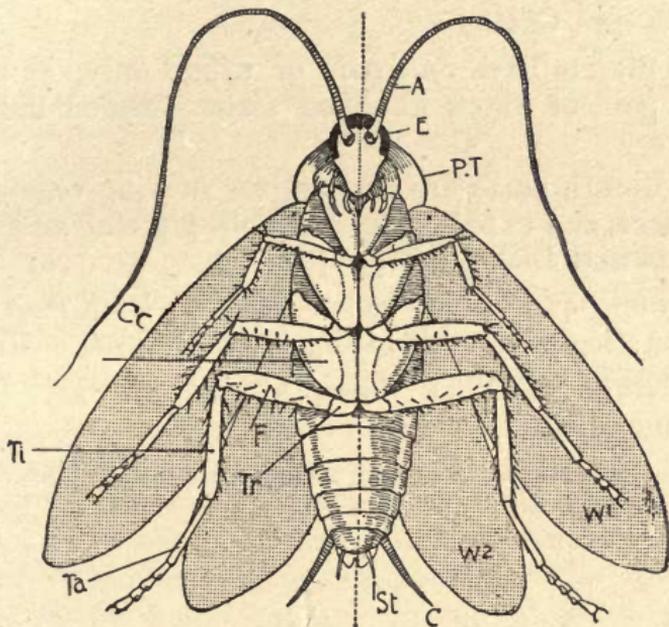


Fig. 65.—Cockroach, diagrammatically displayed to illustrate the external features of Insects.

only, indicating the nature of the wings, the character of the jaws as throwing light upon the nature of the food, and the type of life-history as shown in the form and habits of the young insect.

Butterflies and Moths.

We have already studied an example, but their characters may be summarised here.

They have two pairs of scaly wings.

Their mouth parts are adapted for sucking juices of plants.

Their young are *Caterpillars*.

They belong to the order *Lepidoptera* (scaly winged).

Flies.

E.g. House-fly, Blue Bottle-fly, Crane-fly (Daddy Long Legs), Gnats, Midges, Warble-flies, Bot-flies, Biting-flies of Horses and Cattle.

These insects have one pair of wings only, and behind them a pair of short knobbed stalks termed halteres or balancers.

Their mouth parts are adapted for sucking vegetable and other juices, and in some cases for both piercing and sucking, *e.g.* Gnats and Biting-flies.

The young of Flies are worm-shaped ; head rudimentary or absent ; legless ; with biting jaws—termed a *Maggot*.

The larvae of Flies which are aquatic are, however, greatly modified.

Flies are classed in an Order termed *Diptera* (two-winged). Fig. 66².

Bees, Wasps, Ants, Sawflies, Gallflies, Ichneumon Flies.

These insects have two pairs of wings, which are membranous in texture (they are absent in worker Ants). The wings resemble those of Flies, but in these latter, as noted above, there is one pair only.

The mouth parts are adapted for biting and sucking, or for biting alone.

The young is in most cases a soft *Grub*. For our purposes we may describe a grub as the young of an insect, which is caterpillar-like in form, but has no hind body legs, or at most a clasping or rudimentary pair at the tip. The larvae of Sawflies are caterpillar-like in form and are known as "false caterpillars." The number of the stump feet varies, but is never so few as ten.

These insects are classed in the Order *Hymenoptera* (membrane winged).

Beetles.

E.g. Ladybirds, Weevils, Chafers, Ground Beetles, Black Beetles, Turnip Beetles, Water Beetles. Some are best known in their larval stage, *e.g.* Wireworms, Mealworms. Beetles have two pairs of wings, but the anterior pair is not used in flight. This pair is greatly hardened and thickened and serves as a sheath, covering the hind pair, which are used in flight.

The jaws are biting organs.

The larvae are grubs, sometimes soft, in other cases hard. In some the legs are very weak and rudimentary. Aquatic larvae are modified. Fig. 66³.

This Order is known as *Coleoptera* (sheath winged).

The insects of the foregoing Orders all undergo a transformation or complete metamorphosis in the course of their life-history. There are larval, pupal, and adult stages. But this is not always the case. In some insects there is only a gradual change from the young to the adult condition, so that it is customary to speak of direct development as opposed to metamorphosis. As examples of these we may quote

Grasshoppers, Crickets, Cockroaches.

There are two pairs of wings, the fore pair the stronger. The veins upon the fore wings run in straight lines.

The jaws are biting organs.

The chief observable difference between young and adult is in size, and in *absence of wings* in the former. It is customary to term such a young form a *Nymph*. It arrives at the adult condition by a series of moultings; there is no passive pupal period.

These insects belong to the Order *Orthoptera* (straight veins on wings).

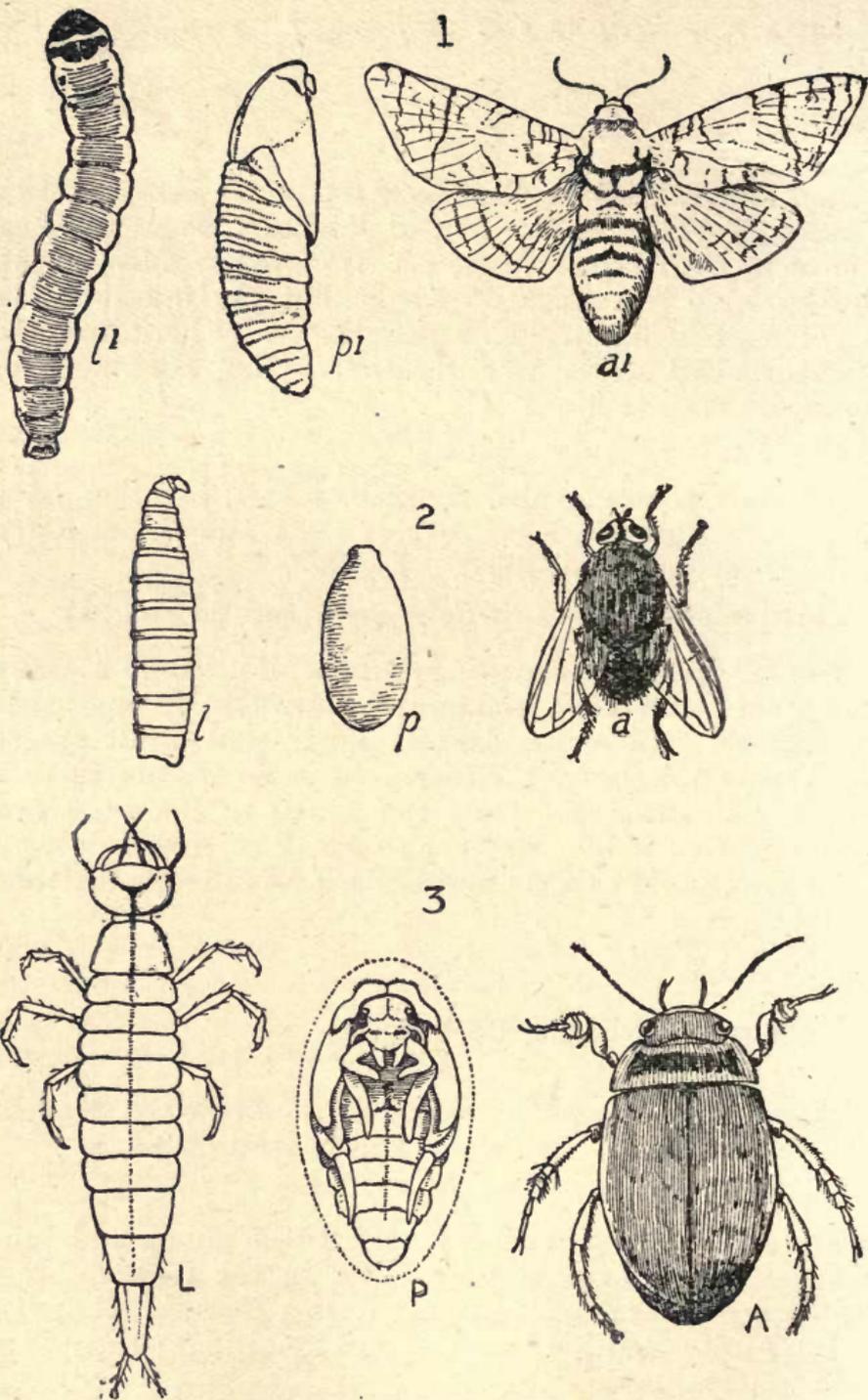


Fig. 66.—Types of Insect Life History.

1. Larva, pupa, and adult of Goat Moth (*Cossus ligniperda*). 2. Larva, pupa, and adult of Blue Bottle Fly (*Musca vomitoria*). 3. Larva, pupa, and imago of Water Beetle (*Dyticus marginalis*). These last show "adaptations" to life in water.

Greenfly or Plant Lice.

Wings delicate and transparent, with few veins, but winged forms occur only periodically.

Needle-like piercing and sucking jaws.

Young similar to parents.

These insects are classed as *Hemiptera* (half winged).

Simple exercises in identification of insect types might be given as far as classifying those belonging to the common Orders. This should be done in particular with all insects seen visiting flowers. Drawings should be made of all the types. It will be found that a very large proportion belong to the Orders just enumerated. The teacher who wishes to carry identification further should consult works on Entomology.

THE HIVE BEE.

The general life of Hive Bees forms an appropriate subject of study. This can be done ideally in an observational hive such as dealers supply. This, however, is available only to the few, hence we suggest other methods. A suitable starting point is the Worker Bee, seen in the open visiting flowers. With a little skill a Bee may be captured by inverting over it a plain glass tumbler whilst it is busy in a flower, at the same time closing the mouth of the tumbler with a piece of cardboard. The risk of being stung is slight, and the experiment, resulting in no harm to the Bee, is worth the trouble.

The Worker Bee.

What can be learned from such a capture? Slip beneath the cardboard a small piece of moistened sugar, and while waiting for the Bee to discover it, examine the Bee itself. Its general aspect does not call for much comment, but one or two special features may be noted. There is the "hairiness" of the back and legs. Look for adhering pollen on these places. In particular examine the hindmost

pair of legs. The joints towards the extremity will be seen to have the appearance as figured (Fig. 67). Two of the joints are greatly flattened.

On the inner side of the lower of these (fifth from the tip) the stiff hairs are arranged in close set rows which act effectively as a comb for gathering the pollen from the various parts of the body (*b* in figure). It is quite possible that

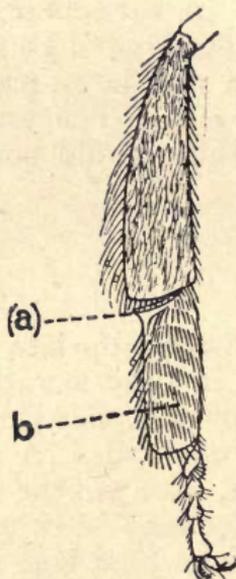


Fig. 67.—Portion of Hind Leg of Bee.

a indicates the pincers used in removing the wax from the abdomen; *b*, the division (tarsus) with comb-like hairs for brushing out pollen. The division above *a* is the shin and constitutes the pollen basket.

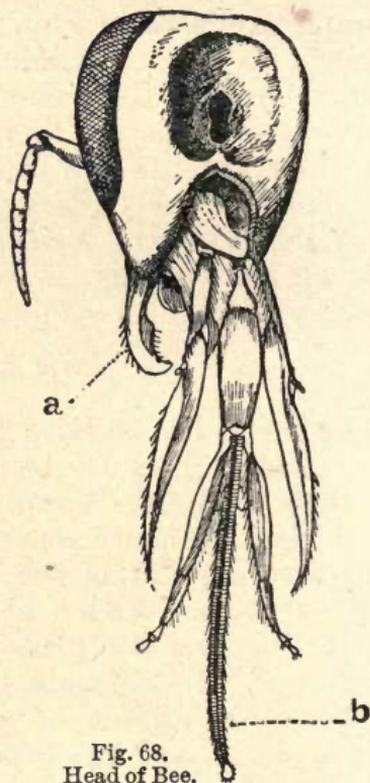


Fig. 68.
Head of Bee.

a, mandibles which mould the wax in comb-making; *b*, the tongue which gathers the nectar.

this grooming process will be seen whilst the Bee is under observation. The pollen is next combed out by the bristles on the hinder margin of the anterior broad joint (shin, sixth from tip) and collected into a "basket" formed by the hollow outer face of this shin-joint, together with the bristles along its border. Bees may be seen returning to the hive with their pollen baskets filled.

On the under side of the hind body grooves between the segments will be seen. In these grooves wax is formed in thin plates. From these grooves the wax is removed and cut by means of the pincer-like gap between the two broad segments already referred to (Fig. 67 (a)).

When the Bee finds the sugar it will commence to suck. If the sugar is slightly moist, it will be attacked with vigour, and then the whole action of sucking will be seen with great clearness. Pupils will also see the remarkable length to which the central portion of the complex mouth apparatus may be extended, also its hairy character, which greatly assists in the gathering of honey (Fig. 68).

The sting of the bee is situated at the posterior tip of the body. Its point may be seen protruded. A figure of the sting with poison gland attached is given (Fig. 69). Worker Bees are modified females, and their sting consists of the egg-depositing apparatus modified for the purposes of defence. When the Bee has been examined it should be liberated. Although the Bee may have been carried some distance from the spot at which it was captured it will be able to find its way back to the hive. Recent experiments on the "homing" faculty of Bees seem to prove that they possess a "sense of direction" more or less comparable to that of Carrier Pigeons.

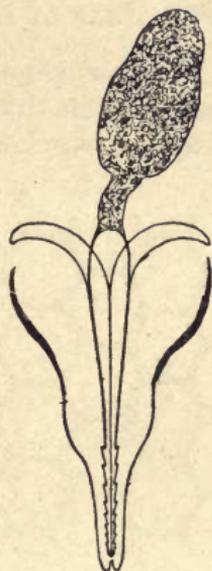


Fig. 69. — Sting of Bee, with poison gland (dark body in figure) attached.

The Queen and Drones.

We may now proceed to consider the queen, who is the mother of the colony. She is larger than the workers and has a more slender body. The duration of life of a queen is from two to three years. Her sole function in the hive is that of egg-laying, which office she fulfils at the rate of between two and three thousand in 24 hours. Her wants

are attended to by the workers. The drones, which are the male members of the colony, are produced at will by the queen. They hatch out in 25 days, and in about a fortnight afterwards they engage in the nuptial flight with the young queens. They are subsequently killed off by the workers before the end of the season.

Functions of the Workers.

The workers make the cells from the wax which is secreted in thin plates in the joints of the abdomen. Cells for the worker grubs and honey are smaller than those

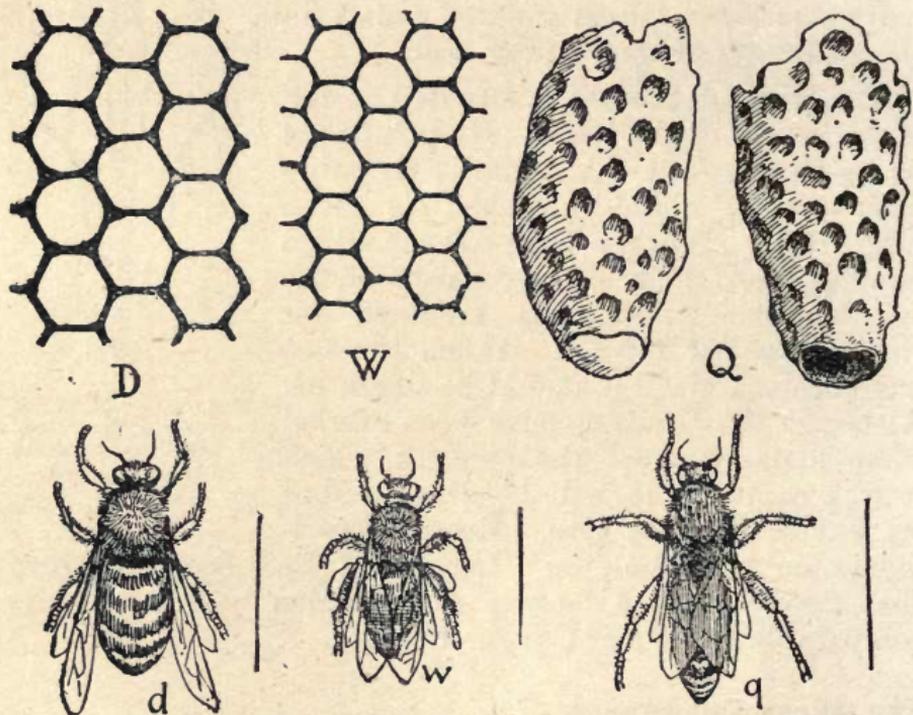


Fig. 70.—Bees and Comb.

D, Drone comb ; W, Worker comb ; Q, Queen cells.
d, Drone ; w, Worker ; q, Queen.

intended for the grubs of the drones. The cells are of the usual hexagonal type. The queen cell is irregularly oval in shape, and about one inch long by $\frac{1}{3}$ broad. It is made of

a mixture of wax and pollen. The workers remove the wax from their bodies by means of the nipping joint between the shin and the first tarsal joint, and knead it into flat plates about $\frac{7}{8}$ inch in thickness, in which the hexagonal "cells" are moulded upon both sides (Fig. 70).

The workers, besides making cells, collect nectar and pollen, with which they feed their queen and grubs. When newly hatched they serve as nurses to the grubs for a time before going outside the hive. A worker grub takes about three weeks in which to hatch out.

Eventually the hive becomes overcrowded and "swarming" becomes necessary. This may take place about the end of May or the beginning of June. The first swarm is headed by the old queen. The new queen then kills off the other queens remaining within the hive. Should she be prevented by the workers from so doing there may be a second swarm.

The colony persists through the winter.

In the Hive Bee we see the highest stage of sociality exhibited by Bees. The two most important features of this society are the division of the labours of the colony amongst queen, workers, and drones, and the provision whereby the colony is continued from year to year. In this latter feature especially the Hive Bees show an advance upon the Humble Bees.

CHAPTER XIII.

THE EARTHWORM.

A TALK WITH YOUNG PUPILS.

NOTE.—*For the purposes of this lesson, there should be provided a box or glass vessel, with glass cover, containing earth and some worms; also a pocket lens.*

THE Earthworm is a small and delicate creature. When we look at its wriggling body as it is turned up amongst the soft earth by the spade, we may not at first think it a very interesting animal. If we are willing, however, to study it for a little, we shall learn some things about it which show that it is a wonderful and important creature.

Let us put a little earth in which we have found some worms into a pot or glass vessel, pressing it down gently and placing the worms on the top. Now we shall watch their behaviour. Observe how freely and easily they move. We see them wriggle, and twist, and turn, and crawl. Watch one as it crawls along. You see that the end which is moving in front is stretched out very long and thin. It is next shortened and thickened. This takes place all along the body, but is best seen at the front end. The result is that the worm moves forward; the *parts* which produce the motion are long muscles which reach from end to end, and lie very closely all round its body. They are very powerful, and it is by their help that the worm pushes its way into and through the soil.

If we cover our vessel with a piece of glass, so that we can still see them, and also prevent them from climbing over, we shall not have long to wait before we view them at work. Observe how they insert the finely stretched-out tip of the body between the particles of soil. Note that this part is then made thicker by the drawing up of the portions within and behind, so that the creature, using its body as a wedge, bores its way through the ground. In a short time, if we have not packed the earth on the top too firmly, the worms will all disappear below.

Perhaps you wonder why they go underground so quickly. Of course their home is below, and they are usually ill at ease in the light. They do not like the light. At night or in the dark they will remain much longer above ground. They have no eyes to tell them; they do not *see* the difference—they *feel* it.

Now take one of the worms in your hand, and, without hurting it, draw it gently through the tips of your fingers. Do you feel that there are two rows along the body near its lower side which are rougher than any other part? This roughness is caused by very fine stiff bristles, which stick out along these rows. We cannot see them well without a magnifying glass, but there are really four rows, two on each side, set closely together. The worm uses these bristles to grip the ground as it crawls along, and to hold by the sides of its burrow. So that when we know this, and also remember that it can thicken its body and make it quite tight in the burrow, we are not surprised that the Blackbird has to pull very hard to drag it out of the earth. Indeed, the worm often grips so firmly that it is broken in two in the struggle.

The bird, of course, eats its share. But the wonderful thing is that the part left in the earth does not always die. There grows upon it a piece exactly like the bit which the bird ate. A tail-end grows a head-part, and a head-part a tail-end. What happens, then, when the gardener accidentally cuts one with his spade? If the worm was well and strong at the time, it is likely that two worms will result. Remember that this should never be done wilfully, *since the worm feels*.

Sometimes a more wonderful thing happens. I once saw a worm injured by a spade; its body was torn at the side, but not cut in two. At the broken part a new tail grew, so that it had three ends. It lived a long time, though it could not move very feely. It dragged its tails behind it.

What do the worms do below the ground? We have seen that they can make burrows for themselves by pushing the earth aside. Wherever they go, air and rain

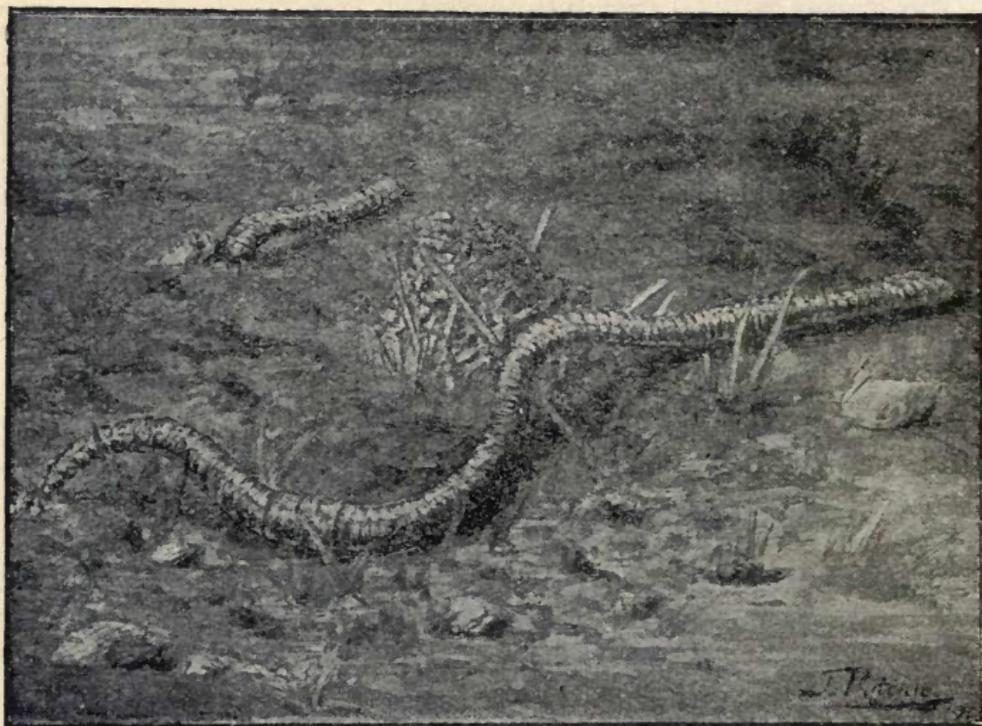


Fig. 71.—Earthworms at the surface of the ground in the night.

follow. The air and the rain change the soil in such a way that plants can feed more richly upon it. This is why the farmer turns over or ploughs the soil. Where there are many worms, therefore, the soil is made better for plant-life.

While they are burrowing they swallow large quantities of earth. Their bodies are long slender tubes surrounding

an inner narrower tube, which is open at both ends. The outer one does the moving and feeling, and the inner is used for feeding. The earth taken into the body is passed along the inner tube, being first grasped by a lip which hangs down at the very tip in front, and acts like a finger. You should look for this small "finger" on a good-sized worm.

Amongst the earth swallowed there are little bits of decaying plants, and this is the food of the worm. The rest is passed on, and leaves the body as "castings." You may see these on a lawn or garden-path in the early morning. Or you may have noticed those of the Sand-worm, whose habits are similar, on the sea-shore. They are left on the surface by the Earthworm, so that you see this creature not only lets the air down into the soil, but also brings the soil up to it. But this is not all. In the same manner as the soil is altered by the air and rain, it is changed by juices in the worm's body. Many of the little bits of soil, too, are ground down in a gizzard which forms part of the inner tube, and made so much smaller and finer that they become very useful to plants.

There are many other interesting things to learn about Earthworms. Perhaps when you are older you will read some of the books which have been written about them, or, what is better, study them yourselves.

CHAPTER XIV.

THE STUDY OF FRESH-WATER ANIMALS.

It will be best in dealing with this subject here to confine our attention to the animals likely to find a place in a small fresh-water aquarium or school collection.

And first it seems desirable that in the teacher's mind at all events the mixed company of the aquarium inmates should be reduced to order. To facilitate this the following facts of classification are submitted.

CLASSIFICATION.

AMPHIBIA.—Newts, Frogs, Tadpoles belong to Class *Amphibia*. Cold-blooded Vertebrate animals, naked skinned, breathing by gills in young state (*i.e.* aquatic), possessing lungs as adults (*i.e.* with power of terrestrial respiration). Limbs have clawless fingers and toes.

PISCES.—Sticklebacks, Minnows, Carp, etc. Class *Pisces* (Fishes). Cold-blooded Vertebrate animals, scaly, breathing by gills; limbs are fins.

MOLLUSCA.—Pond Snails, *e.g.* *Lymnaea*, *Planorbis*, *Ancylus* (lung breathing); *Paludina* (gill breathing), Univalves of Class *Mollusca*. Soft-bodied Invertebrates, without appendages, with mantle and foot; limy shells.

INSECTA.—The following belong to the Class *Insecta*: Water beetles, Whirligig beetles. Order: Coleoptera. Though aquatic these beetles breathe air directly from the atmosphere; they are carnivorous.

Pond skaters belong to Order Hemiptera or Bugs. They have a long needle-like boring and sucking appendage below the head; it is pushed into dead insects, etc., and juice extracted therefrom. Water Boatmen belong to this order of Bugs.

Guats. These are true flies. Order: Diptera. These spend their larval and pupal stages in the water; their adult life is aerial. All stages have aerial respiration. (For characters of the foregoing Insect Orders see p. 166.)

Caddis-fly larvae. Order: Trichoptera. These larvae usually inhabit cases made of twigs, leaves, sand grains, etc. They have aquatic respiration. The adults have four hairy wings; the fore wings are usually longer and narrower than hind wings.

Stone-fly larvae. Order: Platyptera. These larvae have usually paired tufted gills upon the hind body. Found on stones in running water.

Mayfly larvae. Order: Plecoptera. Older larvae with paired gills upon hind body. Younger stages breathe by skin. In muddy bottom of streams, etc. Adults do not feed.

CRUSTACEA.—Water-fleas, Fresh-water Shrimps. These are members of the Class Crustacea. In fresh-water pools there are three common types of water-flea, all of which are likely to occur in school aquaria, viz. *Cypris*, *Cyclops*, *Daphnia*. The popular name "flea" is probably due to the jerky movement by which they progress in the water as well as to their small size; they are, as already indicated, not insects. They have two pairs of feelers, one pair of which is used in swimming. The fresh-water shrimp (*Gammarus*) is a higher type of Crustacean. It has a laterally compressed body and breathing appendages on its legs.

ANNELIDA.—In the mud at the bottom of aquarium jars may be found a slender reddish worm, known as *Tubifex*. It belongs to the same group as the earthworm, viz. Annelida, or ringed worms.

These are only a few of the commonest inmates of ponds.

Besides these, many minute or microscopic forms of life will undoubtedly be present in aquarium jars. But as these require, for satisfactory observation, the use of a compound microscope, they are not further referred to here.

AQUARIUM STUDIES.

The following lines of study of aquarium animals are suggested. They do not exhaust the possibilities, and teachers should be able to plan others. The distribution of the lessons over the different school grades will be found to be indicated in the several courses which are given in another part of this work. Here they are summarised.

1. The study of *young animals*. A simple study for the youngest pupils, which may consist simply in watching the behaviour of larvae, e.g. gnats, caddises, water beetle larvae, tadpoles, embryo trout, etc. Hints may be given as to what young animals chiefly do—i.e. feed, grow, move about a great deal (the restlessness of growth; excess of energy resulting in play in higher animals; play as training for life. But this last scarcely applies to larvae in pools).

2. The study of *life-histories*. For older pupils. Attention should be called at the outset to the large number of creatures whose appearance and life are quite different from those of the adult, and also to those which resemble their parents. The main facts in each life-history should

be followed as far as possible on the aquarium inhabitants. Points of importance which should be emphasised are :

Is there a metamorphosis in the life-history ?

Are all stages aquatic in habit ?

Compare breathing organs in young and adult.

Compare locomotor organs in young and adult.

Compare feeding habits of young and adult.

If a terrestrial type, what adaptations to aquatic life are apparent ?

3. Study of *activities* of the inmates, *e.g.* of their methods of locomotion, respiration, feeding, etc. (This is in part dealt with under 2.)

4. Relation of inmates of the pond to each other, *e.g.* as hunters and hunted. This may be studied incidentally in connection with the consideration of their feeding habits, *e.g.* in noting the carnivorous forms. In general there are three types, viz. Carnivorous, Vegetarian, and those feeding on dead or decaying stuff, viz. the scavengers.

5. Relation to, or effect of diverse *physical conditions*, *e.g.* light, or temperature; show how alterations disturb the balance of life, or rate of growth. Illustrations of simple experiments under this head are the keeping of jars of small animals, *e.g.* water-fleas or tadpoles in light and warm places, and dark and colder places respectively. Care must be taken that all other conditions, food, water, etc., are the same. After a time compare growth in the case of the tadpoles, numbers in the case of the water-fleas. Similar experiments may be performed with the feeding of tadpoles or other young animals. Different lots of tadpoles may be fed on vegetable matter, particles of fish, bread, or flesh, and the results noted in the growth and in the time taken for the complete metamorphosis.

6. Lastly, pupils also should *classify* the inmates of the aquarium.

STUDY OF A LIFE-HISTORY.

The Common Gnat

(Culex pipiens).

We commence at the stage at which this insect is likely to be observed first, viz. the larval stage. In early spring when the aquarium jars are being stocked, these larvae should be obtained. Most boys in the country know them under the name of "wrigglers," because of their jerky movements in the water. They double themselves into a loop, suddenly straightening themselves again, and in this

way they rise to the surface. They may be seen falling passively (Fig. 72).

If the jar in which these wrigglers are put is kept under observation the wrigglers will be observed to be growing in size rapidly, especially if food is plentiful and the room is not too cold. In the vessel may be noticed, after a time, floating near the top, whitish ghost-like shadows of the

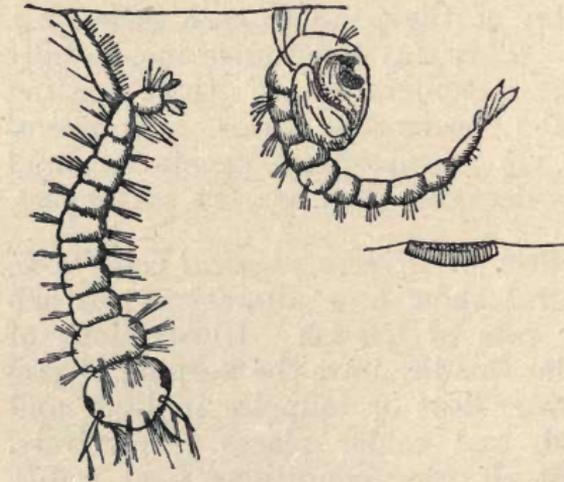


Fig. 72.—Larva, pupa, and egg raft of Common Gnat (*Culex pipiens*). (The eggs are drawn upon a larger scale.)

gnats. These are their moulted skins (cuticles) which they shed from time to time as they grow. The larva when fully grown may be half an inch long.

After some weeks the form changes to that of a little but bulkily-shaped creature like a comma. This is the pupa, which although it does not feed is active when

disturbed, swimming off quickly by the lashing of its flipper-like tail (Fig. 72). On this pupa may be seen with a lens the outline of several of the organs of the adult insect. In about a fortnight or less the pupal stage is completed. Soon after the gnats are seen to be entering the pupal stage, a piece of muslin should be tied over the mouth of the jar, and each morning the jar should be examined for the adult insects, or for their emergence from the pupa.

This latter sight is interesting and should be watched. The skin of the pupa splits at the back, and through the opening the back of the winged insect is pushed up into the air. Next the head, wings, legs, and tail are withdrawn until the insect stands at the surface of the water upon its former pupal husk. Here it rests for some time until its wings are stiffened and it has gathered strength. Then it flies away. About the time the gnats are hatching, if a cover has been placed over the vessel to prevent their escape, numbers will be found every morning resting upon the glass.

The winged insect is equipped with a boring and sucking apparatus for feeding purposes (Fig. 73). Male insects suck the juices of plants, but the females attack animals or men, sucking their blood. After a time these females return to the water. They do not enter it, but resting on grass or leaves at the edge of the pool they deposit their minute eggs upon the surface where they float in a cluster. The eggs in due time open on the under side, and from them there pass out the larvae with which we started our observations. The eggs, owing to their minute size, are

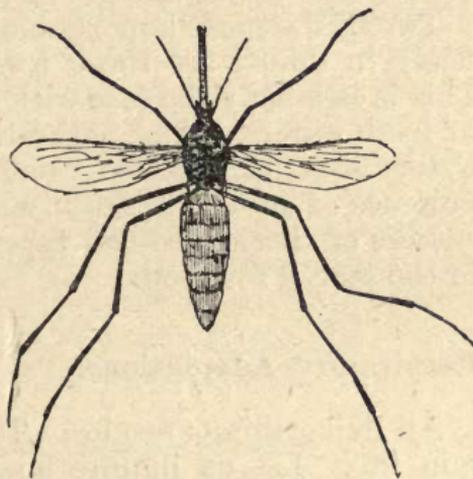


Fig. 73.—Adult female Gnat. Note the blood-sucking proboscis in front.

rather difficult to find, but all the other stages can be readily followed in the school aquarium.

Pupils, having followed the life-history, should make a set of drawings representing all the stages.

Some of the structural adaptations of the gnat will be found described below (pp. 186, 187).

For another life-history study see p. 86, "The Life History of the Frog."

ADAPTATIONS IN FRESH-WATER ANIMALS.

Two of the most important adaptations worthy of a little study in school are those for breathing and locomotion. This is especially the case with insects, which are abundant in fresh waters. And naturally so, since insects living in water are in a sense "out of their element." The presence of insects in fresh waters is probably due to the success of those ancestral types which invaded this region in the search for food.

Respiratory Adaptations.

All living things respire. They require oxygen to maintain life. Let us inquire how some of the inmates of a pool obtain it.

Gnats.—Gnats are air-breathers throughout the whole of their existence. Although the larval and pupal stages are spent entirely in the water, the insect has never acquired the power to use dissolved oxygen. Note how the larvae hang in large numbers at the surface of the pool. Near the tail they have a long tube with five folding plates at the tip. These plates converge to a point, which the larva pushes through the surface film of the water. The plates are then spread outward so as to lie upon the film and support the larval gnat. Whilst the creature hangs here its respiratory system is opened through the medium of this tube to the atmosphere above, enabling breathing to go on.

The position of the breathing tube close to the tail is noteworthy. A close examination of the larvae as they hang suspended on the surface film will show that meantime they are not otherwise idle. Under the head a pair of brush-like structures may be seen in constant action, sweeping the water and sucking towards the mouth the smaller organisms falling within the currents they create. While the larvae, by taking advantage of the supporting properties of the surface film, hang without effort breathing there, they are still able to feed in the pool.

When the larva enters the pupal stage it ceases to feed, but must continue to breathe. It is therefore interesting to find that it is now supplied with a pair of respiratory funnels and that these are placed just behind the head, so that the pupa rests with its thorax at the surface of the water (Fig. 72). It should be possible for pupils to tell correctly the real significance of this change of position. When the adult insect emerges it must pass directly into the air without getting wet. In the new position taken up by the pupa this is quite easy. The thorax splits just behind the respiratory tubes upon the back, and through the opening the gnat rises into the air above. Of course the process should be watched in the aquarium.

Water Beetles.—The larva of the water beetle (Fig. 66^{3L}) is equipped with a pair of finely fringed appendages at the tip of the tail. These are pushed through the surface film, and by their means the insect is suspended. It has a pair of breathing openings at the tip of its body, which are thus brought into communication with the atmosphere. There are spiracles too upon the sides of the body, but these are closed until during pupation. When the adult beetles are watched they will be seen to rise passively to the surface from time to time, the tail end slightly tilted upward. When doing this they are renewing their air supply. They are lighter than water (as are the larvae also), and the tail end more so than the rest.

The tips of the wing covers on being pushed up into the air are slightly diverged, and it will be seen that the beetle carries a supply of air beneath them. The dorsal surface

of the abdomen by means of its hairs entangles air at the surface of the water, which is shut into an air-tight chamber on the insect's back by the closing of the wing covers. The spiracles are situated on the back of the abdomen, and thus the insect whilst in the water continues to breathe from this supply. The beetle may be seen from time to time rising to renew its supply. Small beetles may often be seen carrying down a bubble of air at the tips of their tails for the same purpose.

Water Bugs.—*Nepa*, the water scorpion, has a long tube made up of two halves uniting longitudinally, which is pushed to the surface so as to take in an air supply (Fig. 74).

The breathing of the water boatman, *Notonecta*, is interesting. It may be seen to float upward, pushing the tip of the abdomen above the water, thus bringing the hind spiracles into direct communication with the air. But further it may be noticed that the under side of the body which is nearest to the surface is keeled and fringed with hairs arranged in parallel rows, so that air is entangled here. The oar-like legs may be seen sometimes brushing the entangled air forward towards the spiracles upon the thorax.



Fig. 74.—The Water Scorpion (*Nepa*).

It will be noted that all of the foregoing use oxygen obtained directly from the atmosphere. Other creatures use the oxygen dissolved in the water. The adaptations of such creatures as caddis flies, which cause the water to

flow through their tubes over the tuft or hair-like filaments upon their bodies; of the alder flies (abdominal filaments); may flies or stone flies (gill tufts or flattened gill plates), should all be looked for, and their action as far as possible understood.

Crustacea.—Water fleas and fresh-water shrimps breathe dissolved air by means of appendages upon certain of their swimming feet.

Newts.—The larvae breathe by tufts of external gills (compare tadpoles); the adults by lungs obtaining the air from the atmosphere.

Locomotor Adaptations.

The limbs of all aquatic insects should be examined. Note in particular the following:—

Water Beetles (Dyticus). Larvae creep on the bottom;

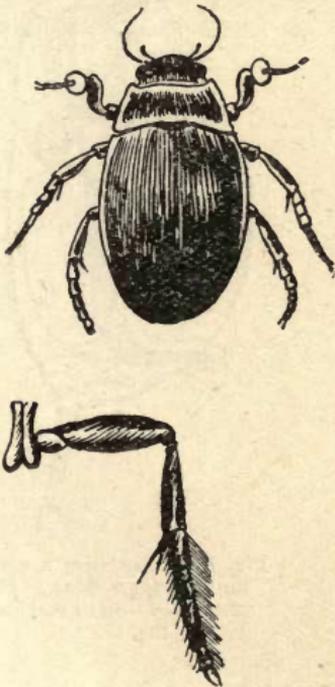


Fig. 75.—Water Beetle (*Dyticus*). In the lower figure the hind limb with its swimming bristles is drawn on a larger scale.



Fig. 76.—Water Bug (*Corixa*).

thoracic legs clawed, fringed with hairs for swimming; rise to surface passively. Adults, hind pair of legs longer

than others, flattened and fringed with hairs, acting as paddles (Fig. 75).

The water bugs, *Corixa* and *Notonecta*, have the hind pair of legs greatly enlarged, flattened, and fringed with hairs, forming very effective swimming organs. These are the chief locomotor organs in each. In *Notonecta* the middle pair is not used in swimming, but in mooring the insect or in clambering amongst weed. In *Corixa* all the legs are

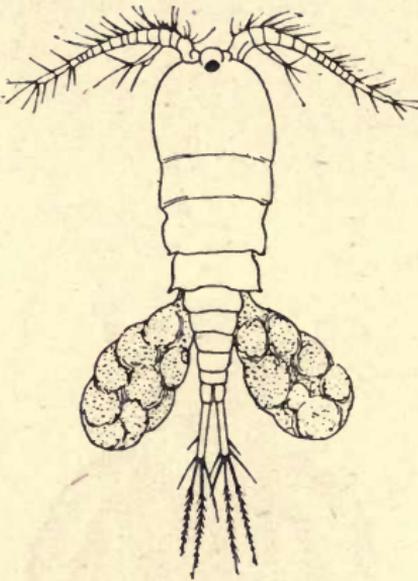


Fig. 77.—*Cyclops*, a common water flea. The example is a female, carrying egg sacs. The antennae are used in swimming.

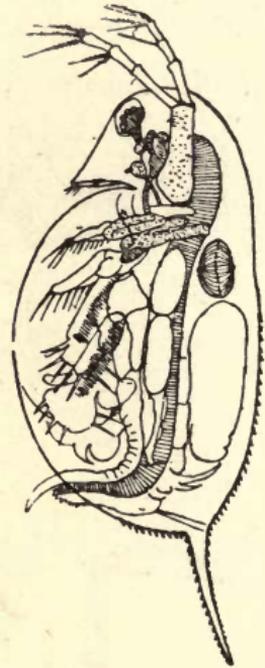


Fig. 78.—*Daphnia*, a common water flea. The antennae on head are locomotor.

furnished with swimming hairs, although the last pair is undoubtedly the chief rowing organ. The legs of *Nepa* are used for walking, not for swimming. Note the active "doubling" movements of the legless larval gnats. Note also the swimming feet of *Gammarus* and swimming antennae of water fleas (Figs. 76, 77, 78).

The creatures walking or running upon the surface film should be noted, and the peculiarities enabling them to do so should be carefully studied. Whirligig beetles have the two hind pairs of legs very broad and fringed, by which means they paddle themselves both upon the surface and below it. The fore legs are used more particularly for prehension and holding prey, etc. Pond snails and flat worms creep upon the under side of the surface film. Pond skaters skate or jump upon it.

The properties of the film, enabling these animals to use it as they do, should be explained to the pupils.

Other adaptations which might be investigated are those connected with feeding, *e.g.* note the perforated sucking jaws of the water-beetle larva, the knife blade-like fore limbs of the water scorpion, the water-sweeping "brush" of the gnat, etc.

CHAPTER XV.

ANIMAL LIFE AND WINTER.

THIS lesson should be taught as much as possible along the lines of an appeal to the knowledge already possessed by the pupils, and supplemented by the teacher only for the sake of giving the necessary completeness to the survey. It is a lesson in fact-grouping or classifying in illustration of a general principle.

The key-note to the understanding of the facts summarised is the question :

What are the conditions under which terrestrial animals live in winter ?

We elicit from the pupils :—

It is cold.

Snow covers the ground, frost hardens it.

The day is short, *i.e.* there is less light in which to find food.

Both vegetable and animal foods are scarcer.

By writing this out we shall make clear that the conditions are the hardest of all the year, for terrestrial animals as for mankind. In the sea, we note in passing, the seasons do not affect life in the same way.

How do these conditions affect animals more particularly ?

(1) There is a general slowing up of activity. The cold checks the vital functions, and we note all grades of this from the dormant-like, inactive state to which small animals

in the soil are reduced, *e.g.* that of many insects, both in the larval and the adult state; of worms, snails, and slugs; of some fishes, *e.g.* chub, roach, mudfish; to the well-defined hibernation of frogs, toads, newts, snakes, lizards, tortoises, hedgehogs, bats, dormouse, etc.

While there is in general a correspondence between the severe conditions of winter and hibernation, it will be well to notice that the habit of hibernation is instinctive; that is, it is part of the inherited qualities in the animal practising it, and has meaning with reference to the past history of the type in the first instance. This will help to explain how it is that bats, for example, may hibernate quite early when food is plentiful and the weather is mild. But in general it is probable that the actual cold is the immediate inducing cause. In any case it is clearly of value as a life-prolonging arrangement.

(2) Some provide for winter by laying up stores in autumn. Squirrels are our best illustration of this habit. Pupils may sometimes have found their "hoards" at the foot of trees. Hive bees also will be thought of. Arctic foxes lay by stores, and some others, but on the whole remarkably few creatures are endowed with the faculty of providing for more than present needs.

(3) Then there is the interesting case of those which flee from winter, our migratory birds. Note in particular the case of those birds which visit us in winter, *e.g.* fieldfare, redwing, hooded crows, wood pigeons, etc. Also the resident birds which go from one region to another. Their quest is the same as that of those who leave us at this time, *viz.* easier conditions of climate and more abundant food.

(4) Notice next those who by structural adaptations are fitted to meet the more rigorous conditions, those animals which change colour, becoming white. There are three such animals in Great Britain, the stoat or ermine, the mountain hare, and the ptarmigan. The stoat is enabled to stalk its prey upon the snow with more likelihood

of success, the hare and ptarmigan are more likely to escape observation than they possibly could in their summer dress when snow is on the ground.

But we must remember that this also is a hereditary quality which appears at a particular time, and sometimes is present when snow is absent. The ptarmigan, for example, may sometimes be seen in late autumn as conspicuously white objects upon their native hills, which as yet are bare of snow.

“The ptarmigan that whitens ere his hour
Woos his own end.” (Tennyson.)

But although this adaptation may thus fail in some years, there is no doubt whatever but that for the saving of the race at large it also is effective.

(5) To a great many creatures, particularly invertebrate types, winter brings death to the individual, but the race survives in the eggs, which pass the winter in a dormant state. Such are rotifers, fresh-water sponges, various insects. Many insects are creatures only of a year or less.

(6) Lastly, there are a great many who face the winter and make the best of it. Some of them do not survive, for winter is a great eliminator. Others live through it—an illustration of the survival of the fit. Our resident birds are the best example of this group.

CHAPTER XVI.

PLANT IDENTIFICATION.

As will be seen by reference to the courses already outlined, the recognition of plants already receives a prominent place. There is no doubt as to the value of exercises of this kind. The power to name plants at sight is an achievement upon which even skilled botanists pride themselves, and there is no doubt that it gives to pupils a sense of satisfaction. A feeling of "ownership" is acquired with reference to the plants named, which is the best guarantee of continued interest. It is also the case that pupils are stimulated to recognise out of doors the plants they know, and thus their observational powers are cultivated. Doubtless the gain is not great if pupils are allowed to rest content with mere naming of specimens, but we aim at more than this.

The question for us at present is: How is the teacher who is unfamiliar with plants himself to qualify for this kind of work?

No doubt most teachers are familiar with the appearance and know the names of a few of the common wild flowers, but unless they are prepared to extend their knowledge in this direction, difficulties will early arise. Pupils soon evince a keenness for asking names and will be found eager to bring fresh subjects for recognition.

It is no immediate solution of the present difficulty to ask the teacher to master the details of systematic botany. This is the sound course to recommend, if time is no object. In due course such knowledge will be built up, but we

must assume that a comparatively rapid means of gaining a certain amount of information is desired. As a beginning the teacher should master the names of the chief parts of a flowering plant and their functions (see p. 207). When these are understood the teacher should next examine any common wild flowers which are available, the names of which he knows. The natural Order to which the plant belongs should be ascertained from a text-book, the specific characters of the plant should also be looked for, and as far as possible verified upon the specimen in hand. The parts of the plant (flowers especially) should then be drawn. (See also p. 197.)

Some little time spent in this way upon even a few plants will be of more value than many hours of reading. The teacher should possess a good pocket lens and a couple of needles mounted on handles with which to dissect the flowers, etc. It will also be desirable to have some good work on botany for consultation.*

For a beginner's needs Professor Cavers' *Life Histories of Common Plants* (University Tutorial Press) will be found very useful. Another work which can be recommended for practical service in identification is Fox's *How to Find and Name Wild Flowers* (Cassell). If a commencement is made with this work in the spring when the wild flowers are not too numerous, and identification practised by its means, an encouraging start will be made. Although the arrangement in Part I. of this work is artificial, this book meets the beginner's needs better than any other we have seen. The teacher should keep a list, with dates and localities where found, of the plants identified by himself. Special attention should be paid to trees as well as flowers. In rural schools the common weeds also should all be identified and classified.

* It may as well be clearly pointed out here that the study of plants and plant life as far as "Nature Study" is concerned should be confined to observational work such as is possible to the private student with ordinary equipment. The teacher may of course read botanical works and accept statements as to microscopic structure, functions, etc., although they cannot be verified.

There is no reason why teachers should not help each other in a matter of this kind. It is suggested that county or district associations of "Nature Study" teachers might be formed, and one of the members, skilled in plant identification, appointed to deal with matters of this nature. An arrangement might be made whereby members may send specimens to him for naming and receive replies by post-card. There should be no difficulty in such matters, and the work need not of course be confined to plants, but should include identification of natural history specimens generally.

Once the trouble of identification is over the teacher should pursue the course suggested above. Teachers should understand that knowledge can be gathered only by degrees and be content to learn slowly. There is, further, no reason why teachers who are beginners should not learn along with the pupils. Many excellent teachers are continually doing this.

IDENTIFICATION EXERCISES.

It is possible for a beginner of intelligence to acquire in a comparatively short time by a little persistent application some mastery of the leading parts of a good many flowering plants. With a view to leading teachers on towards a commencement, the following list of spring flowers is submitted for study. Spring is undoubtedly the best time in which to commence, since the flowers are not too numerous; the plants named are nearly all common and widely distributed, and a good many at least are likely to be known at sight. As each flower is obtained the teacher should definitely perform the exercises suggested below.

LIST.

Ranunculaceae.

Wood Anemone (*Anemone nemorosa*), woods.

Marsh Marigold (*Caltha palustris*), marshy or wet places.

Lesser Celandine (*Ranunculus ficaria*), damp places.

Cruciferae.

Shepherd's Purse (*Capsella bursa-pastoris*), waste places, etc.

Wall-flower (*Cheiranthus cheiri*), garden walls, rocky places.

Fumariaceae.

Common fumitory (*Fumaria officinalis*), cornfields, etc.

Violaceae.

Sweet Violet (*Viola odorata*), banks, roadsides, woods.

Dog Violet (*Viola canina*), woods, banks, etc.

Caryophyllaceae.

Common Chickweed (*Stellaria media*), waste ground, etc.

Greater Stitchwort (*Stellaria holostea*), woods, shady places.

Red Campion (*Lychnis diurna*), damp copses, banks.

Geraniaceae.

Herb Robert (*Geranium Robertianum*), waste places, banks.

Wood Sorrel (*Oxalis acetosella*), damp woods and shady places.

Leguminosae.

Gorse (*Ulex europaeus*), heaths, etc.

Rosaceae.

Barren Strawberry (*Potentilla fragariastrum*), banks and shady places.

Water Avens (*Geum rivale*), by streams, damp places.

Saxifragaceae.

Golden Saxifrage (*Chrysoplenium oppositifolium*), damp places.

Red Currant (*Ribes rubrum*), fruit gardens.

Black Currant (*Ribes nigrum*), ditto.

Compositae.

Groundsel (*Senecio vulgaris*), waste places.

Daisy (*Bellis perennis*), fields, etc.

Butterbur (*Petasites vulgaris*), wet places, river banks.

Coltsfoot (*Tussilago farfara*), fields, roadsides, etc.

Dandelion (*Taraxacum officinale*), roadsides, etc.

Primulaceae.

Primrose (*Primula vulgaris*), woods and banks

Scrophularineae.

Ivy-leaved Speedwell (*Veronica hederifolia*), banks, etc.

Labiatae.

Ground Ivy (*Nepeta glechoma*), waysides, etc.

Red Dead-nettle (*Lamium purpureum*), ditto.

White Dead-nettle (*Lamium album*), ditto.

Orchidaceae.

Early Purple Orchis (*Orchis mascula*), fields, heaths.

Irideae.

Purple crocus (*Crocus vernus*), cultivated; naturalised in meadows: Notts., Suffolk, Middlesex.

Amaryllideae.

Daffodil (*Narcissus pseudo-narcissus*), Cultivated ; locally, moist woods.

Poet's Narcissus (*Narcissus poeticus*), cultivated.

Snowdrop (*Galanthus nivalis*), cultivated ; locally, woods.

Aroideae.

Cuckoo Pint, Lords and Ladies (*Arum maculatum*), woods, shady places.

The plants having been identified, the teacher should write out descriptions. There is absolutely no doubt as to the value of this exercise in ensuring close and definite examination. The first difficulty will undoubtedly be with regard to the nomenclature of parts. Recourse will be necessary for a time to botanical works, but if the plants under examination are studied in the light of the descriptions given in any of the standard botanical works of recent date, familiarity with the terms and the structures to which they apply will rapidly increase. These descriptions are intended to develop knowledge along two different lines.

1. The structural features noted are to be read in the light of **Classification** so that the teacher may become acquainted with the parts and their arrangements which determine the Natural Order to which a plant belongs. This being so, as suggested above, the teacher should compare the plant under examination with the Ordinal description. It has to be borne in mind that a given plant in an Order may not show *all* the characters of that Order ; it may even show exceptions in some particulars. But the beginner must rest content if he is able to verify the main facts and to gradually familiarise himself with the distinguishing features of the commoner Orders, so that he may eventually be able to judge without reference to a book from the general aspect of a plant the Order or even genus to which it belongs.

In his descriptions, then, whilst writing out a detailed account of the naked eye appearance (with the assistance of a pocket lens where necessary), the observer should in particular pay attention to the following:—

The venation of the leaves, whether netted or parallel veined, and along with this whether the showy parts of the flower are recognisable as sepals and petals distinct, or not distinguishable but all of one colour. Parallel veins in leaves along with a perianth (outer part of flower) not separable into two groups (sepals and petals), and not 5-partite, indicate the large "Class" **MONOCOTYLEDONS**. On the other hand netted venation indicates the "Class" **DICOTYLEDONS**.

Amongst netted veined flowering plants note whether flowers are complete or incomplete. That is whether all the parts, calyx (sepals), corolla (petals), stamens, ovary (carpel or carpels), are present. (In the foregoing list there are no incomplete flowers; in the list of trees, p. 258, there are several.)

Note also whether the petals of the corolla are all separate from each other (free):

Examples—the Orders Ranunculaceae, Cruciferae, Violaceae, Caryophyllaceae, Geraniaceae;

or whether the petals are more or less united (connate) into a two or more lobed corolla:

Examples—the Orders Compositae, Primulaceae, Scrophulariaceae, Labiatae.

Other points of importance in classification to be noted in a description are whether the stamens are inserted on the top of the flower stalk and free from the calyx and corolla (hypogynous) or whether on the calyx or disc (perigynous or epigynous). Also whether the ovary is below the insertion of the outer floral parts (inferior), or above these (superior). The form and arrangement of the leaves, *e.g.* whether placed opposite or alternate; whether radical (*i.e.* in a rosette-like arrangement close to ground; whether leaves have stipules (blade-like outgrowths at

the base of the leafstalk) or not; whether leaves, simple or compound; entire; edged or toothed; lobed; stalked; or sessile (without stalk); etc. Form of stem—cylindrical or quadrangular; existence of bulbs, tubers, corms, etc., smooth or hairy; whether subterranean, etc. Root of tap variety; or branching (adventitious), etc.

2. The descriptions should also have in view **functional or adaptive characteristics**. For example, it should be borne in mind that all the foregoing plants flower early in the year. Consequently students should try to understand the various reasons for this. Some of them may be viewed as plants of hardy constitution growing with a limited supply of heat. Shepherd's Purse, Chickweed, Daisy, Groundsel are hardy in this sense.

It ought to be noted also how many of the foregoing plants grow in shady situations, *e.g.* Wood Anemone, Butterbur, Greater Stitchwort, Dog Violet, Wood Sorrel, Primrose. These may be said to be hardy as regards small amount of light. But it must be borne in mind that the shade is less in spring than later in the year. Others again flower early in wet situations, *e.g.* Marsh Marigold, Lesser Celandine, Water Avens, Golden Saxifrage.

It must also be borne in mind that some of the foregoing as well as others in the list are supplied with reserve stores of food from the previous year, *e.g.* Coltsfoot and Butterbur, whose leaves grow big and develop great activity, making reserves after the flowering period is over. Wood Anemone has reserves in an underground stem, Lesser Celandine in root tubers, Water Avens in underground stem, Crocus in corm, Snowdrop in bulb, etc.

Not many in our list arise from seeds; most are perennials arising from rhizome, corm, tuber (underground stems), or bulb. These notes have reference simply to the spring flowering habit, but in plant studies generally other functions to be borne in mind are relations of nectaries, colour and odour to insect visits; structural adaptations for insect visit or for seed dispersal; protective arrangements in vegetative organs—spines, prickles; adaptations

to particular situations for room and for light, to dry situations, to the sea-shore, etc.

While many adaptations are in general clear enough, the beginner will be wise to interpret cautiously and to seek as much external aid as possible. Pure description faithfully carried out is the first step; the rest will suggest itself in due time to the thoughtful teacher.

A student's description of two plants is given below.

DESCRIPTIONS.

A.—THE BARREN STRAWBERRY.

(*Potentilla fragariastrum*.)

I examined specimens on the 4th May.

There is a perennial underground branching stem, woody in texture, and of an irregular "knotty" appearance. From it arise the adventitious rootlets the main branches of which are woody. Leaves arise in a tuft around the tip of stem. These are stipulate; the stipules are large and membranous, adnate, but the tips are free. The leaf stalk (petiole) is comparatively long, $1\frac{1}{2}$ inch or so, and hairy, the blade is 3-lobed, roundly ovate and toothed. Both surfaces have silky hairs. The venation is "penninerved." Branches bearing flowers arise in the axil of the foregoing leaves. They are cylindrical, solid, reddish brown, and covered with soft hairs. Leaves here generally resemble those on underground stem but are distinctly smaller. Buds are developed in their axils, bearing flowers. These have short pedicels.

The Calyx is 5-lobed, lobes free and have bracteoles alternating. The sepals are acute. Petals, 5 in number, are free, alternating with sepals; white, broadly ovate, 1-notched, with short claw. Stamens are indefinite in number, the pistil consists of many carpels, free, with filamentous styles and glandular stigma. The carpels are mature before the stamens (proterogynous).

Runners originate at the end of the root stock, and on these buds arise which give off adventitious rootlets.

Habitat, etc.—Dry sandy banks in shady places. The only special point regarding nutrition I have observed is that the leaves arising on the underground stem mostly have long stalks, a common arrangement for bringing the foliage into a favourable position for carrying on the work of the plant. I found the plant growing under crowded conditions. Further, as the burden of “elaboration” falls upon these leaves, the blades are much larger than are those found upon the flowering branches. Besides propagation by means of seeds, there are runners which give rise to fresh buds in a vegetative manner.

B.—THE TORMENTIL.

(*Potentilla tormentilla.*)

This is a perennial herb. It has slender fibrous rootlets arising from a thickened branching underground stem. From the axils of brown scales on the underground stem arise slender branches 6 inches to 10 inches, bearing simple leaves and terminating in flowers. From the axils of the leaves other branches may be developed, and these also terminate in single flowers. Branches are reddish below, green above, cylindric, firm, and solid. Leaves divided, three segments, wedge-shaped, three or five toothed, petiole is very short, and there is a pair of large green leaf-like stipules. These are lobed, and are shorter and broader than the leaf segments.

Flowers are solitary, $\frac{3}{8}$ inch or so in diameter, may be even $\frac{3}{4}$ inch, upon slender hairy pedicels 1 to 2 inches long. Receptacle is somewhat expanded, and on its margin are the sepals. These are normally 4 in number, free with epicalyx of 4 simple pointed, ovate, lanceolate segments as long as sepals. I find the number of parts in the several whorls may vary. In the epicalyx the parts grade off from having one or two teeth to deeper lobing, ultimately forming separate segments giving five or six parts. This increase in parts here is sometimes continued uniformly through the different whorls. The floral formula is apparently 4, 4, 16, 8, but 5, 5, 20, 16 I have found frequently.

There is greatest tendency to variation in the number of stamens, this ranging from 13 to 20.

Petals are yellow, free, 4 in number normally. Carpels generally 8, free, superior with stigma curved, achenes in fruit. There are nectaries on top of receptacle at base of stamens.

Habitat.—Grows abundantly on moor-lands, roadsides, and on banks of streams. *Pollination.*—Cross pollination is effected by the aid of small beetles and flies. There is a double provision for the perpetuation of the species in the production of seeds and by the perennial underground stem.

Such exercises are desirable for the training of the teacher, if he is successfully to guide pupils towards seeing the significance of the structure of some of the commonest flowers and trees of the waysides, fields, or woods. As already indicated they are of fundamental importance to the pupils (see p. 266).

CHAPTER XVII.

A LESSON ON BUTTERCUPS.

WHILE we may find it necessary for the understanding of plant life to direct our attention temporarily to an individual specimen, let us not distract our attention or that of our pupils from the wider outlook. As we examine the individual in detail, let us not forget the buttercups in the fields and by the waysides. When out of doors we should endeavour to see them with the precise vision of our early childhood, when we gathered them because in those days we saw the buttercups and not the fields; but we should seek to see them now with understanding, and to help our pupils to do so also.

Our first point is: For ourselves and for our pupils we wish to make real the facts that *plants are alive*, and to learn a little at least of what this means, and of how the vital process goes on.

THE COMMON MEADOW BUTTERCUP.

(*Ranunculus acris.*)

Let us draw it, learning the names of the chief parts as we proceed, and at the same time noting their uses. The functions of these chief parts should be educed as far as possible from pupils (see Courses, Chapter III.), and at quite an early stage they should have a clear grasp of these.

GENERAL FACTS REGARDING FUNCTION.

The Root.

We omit all details of structure at present. What are its functions ?

(a) It holds the plant in the soil. Obviously *fixation* is an important function of the root. Notwithstanding the fact that there are plants endowed with powers of locomotion, and animals that are fixed and sedentary, we come at the outset to one of the biggest contrasts in mode of life, in method of reacting to environment, between animals and plants. Plants are in general habits stationary organisms.

(b) Secondly, the root is *absorptive*. It absorbs mineral ingredients dissolved in water from the soil. This is also an important fact distinctive of plant life.

These are the chief uses of roots, but we may mention one other which although a subsidiary one is of common occurrence in some other plants, but is not noticeably so here.

(c) Some roots are utilised for the *storage* of reserve food products.

The Stem.

(a) Plants have direct relations with the sun, and the first function of a stem undoubtedly is to hold up the parts of it which deal in sunlight, viz. the leaves. They also need air (carbon dioxide), and here again the stem, by means of its length and its branching, spreads out to the atmosphere the leaves which are more especially reacting to it. And the flowers must not be forgotten, which in most cases must for fulfilment of their functions be exposed to insects, to wind, or to other fertilising agents.

But here also some secondary functions may be noted.

(b) Along the stem of necessity there passes the crude sap absorbed by the roots from the soil. This passes to the leaves, returning along the stem again as elaborated sap (food) to the whole plant.

(c) Sometimes the stem of a plant is used in a more or less specialised form to store reserves of food stuff, *e.g.* as tubers and corms.

(d) Also in some cases for the multiplication of the plants as runners, either above or below the ground, *e.g.* the creeping buttercup (*R. repens*).

The Leaf.

As already mentioned the leaf

(a) decomposes carbon dioxide in sunlight;

(b) elaborates food, building up organic substances—starch, sugar, etc.;

(c) transpires excess of moisture from the plant.

The Flower.

The production of seed is the primary function of the flower.

The Seed.

The function of the seed is the continuation of the species.

Summarising at this point we may say that the life of a plant such as our buttercup is manifested in its reacting (in a characteristic manner) to

Moisture,
Minerals,
Oxygen,
Carbon dioxide,
Sunlight.

It is a remarkable fact that the numbers of plants are so great and their distribution often so crowded that there is competition for these universally disseminated elements ("struggle for existence"). It seems strange that air and sunshine, for example, in which the world is bathed should be denied or restricted in amount to any living thing. Yet nothing is easier to understand than how plants may put each other in the shade and in this way impair their power of using the air in food-making. In the struggle for the best places multiplicity of "adaptations" will be found to exist, and some of these we seek to understand.

DETAILS OF STRUCTURE.

Let us now examine the buttercup in more detail.

The root consists of spreading fibrils, being of what is known as the adventitious type. There are delicate hairs on the parts nearest to the growing points, and to these the soil adheres. These should be looked for with a good lens. The stronger fibrils moor the plant in the soil, the root hairs do the work of absorption.

The stem is long and slender and of firm consistence. It is nearly smooth, hollow, but solid at the nodes, reddish at the base. There are several nodes at the base undeveloped, but the others up the stem are fully so. Branches similar in appearance to the stem arise in the axils of the leaves at the nodes. The stem terminates in a single flower, as do also the branches.

At the base of the stem leaves consist of sheath, leaf-stalk (petiole), and blade. The sheath is more or less membranous, but, except at the edges, fairly firm. The leaf stalk has a furrow on the upper surface and is hairy. The blade is three or five-lobed, the lobes are deeply segmented, and the plan of venation is palmate. The surface is hairy. Further up the stem the leaf stalk becomes progressively shorter, ultimately disappearing, whilst the lobes become almost lanceolate with short lateral segments. The arrangement of the leaves upon the stem is alternate (Fig. 79).

The flower stalk (peduncle) is mostly longer in those flowers arising from the lower portion of the stem than in those arising higher up. Its surface is brownish green and slightly hairy. In section it is solid. The flower is valvate

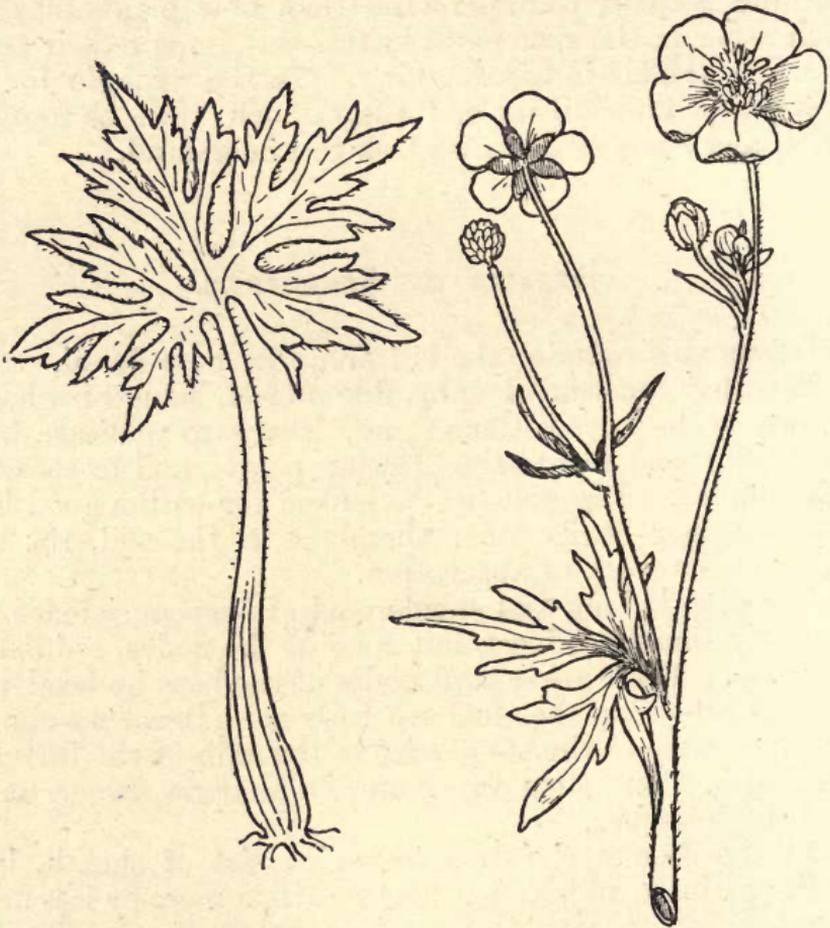


Fig. 79.—Meadow Buttercup. Sheathing leaf from base of stem to the left. Upper part of stem to the right.

in the bud. There are five free, whitish green sepals, membranous at their edges. The five petals are free, yellow, and sometimes notched at the margin. They have a nectary with overlapping scale at their base. There is an

indefinite number of stamens and of seed vessels (carpels). The seed vessels have a short curved style (Fig. 80).

Some notes may now be made of an interpretative character. It need scarcely be said here that care must be taken not to force explanations. Our conclusions must be limited to those of a general character until the field of our observations has been widened. It is wiser to be content with detailed observation alone than to misinterpret. This must be borne in mind.

What is the significance of a root of the adventitious type such as we have here? It is advantageous both for fixation and in giving a large surface for absorption.

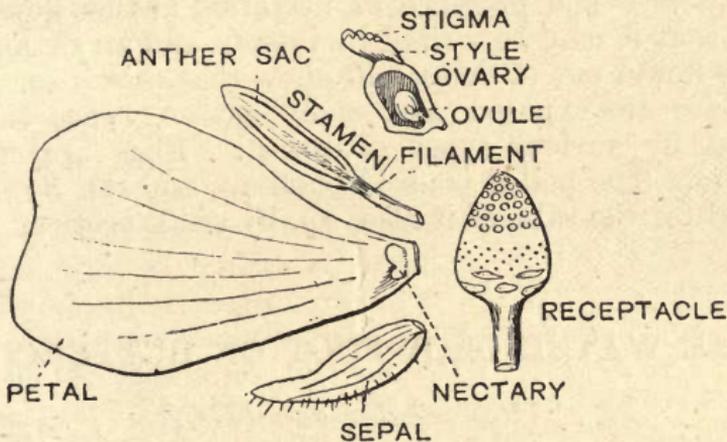


Fig. 80.—Diagram of parts of the flower of Buttercup.

A hollow stem is both strong and pliant, so that it sways in the wind without breaking. The stem is long, since in the situation where this buttercup grows there is an upward competition for light amongst all the plants. In a section through the stem, demonstrate the conducting channels (fibro-vascular bundles). With a good lens the two regions of these bundles may be made out, viz. the woody vessels towards the centre of the stem (upward conducting channels, containing crude materials) and the bast towards the circumference (downward conducting channels, containing elaborated materials).

Leaves.—Note the length of the stalk at different levels and interpret this with general reference to the normal situation of the plant; so also the alternate arrangement, general dissected character of lower leaves, sessile and linear type of upper leaves. All these may be regarded as adaptations to a situation in which room is scarce and many shadows are cast. Microscopical examination shows that the stomata (openings for transpiration of moisture) occur mostly on the under side. This is a quite general arrangement which tends to check too rapid evaporation of moisture. The hairs on the surfaces of the plant may also be interpreted in this case as having the same significance.

Flowers.—The presence of nectaries in this flower suggests that it may be visited by insects, and an examination of the flower out of doors will show that this is so. These nectaries are exposed and easily got at, hence they are visited by various types of insect. Flies are common visitors. The pollen is also abundant, and the flowers are visited for the sake of it also, *e.g.* by small beetles.

THE WATER CROWFOOT OR BUTTERCUP.

(*Ranunculus aquatilis.*)

In contrast to the meadow buttercup, taken as an average illustration of a terrestrial flowering plant, we now examine another member of the same genus, in this case of aquatic habit. Here we need refer only to the special features which may reasonably be interpreted as adaptations to the habitat in question. And first let us note that even within the species we shall find specialised features according to whether the plant grows in a rapidly running stream or in sluggish or stagnant water.

Let us contrast the conditions. We have just described the terrestrial type, noting its needs as regards support in soil, strength above ground for parts bearing flowers and leaves, etc. Now let us look at the water buttercup.

The root will be found to be in general only moderately developed. Its function is chiefly that of fixation, and root hairs are scarce because the other submerged parts share in absorption. The stem is smooth, almost cylindrical, hollow, solid at the nodes. Short rootlets are given off at the nodes. Leaves arise here and in their axils occur branches which repeat the structure of the stem. Portions broken off are capable of rooting and growing fresh plants.

If the stem is sectioned it will be found that the inside tissue (parenchyma) is loosely arranged, having large intercellular spaces. A ring of vascular bundles is present, but the woody vessels are few. No stomata are present. The whole stem lacks the robust character of the terrestrial type, and out of water it cannot stand erect. In the water it is of course buoyed up. From the water all the necessary mineral salts, carbon dioxide and oxygen are obtained direct, hence the reduced nature of the wood vessels and the absence of stomata.

In plants growing in swiftly running streams the leaves are all more or less submerged. The leaf sheath is large and membranous, enveloping the young buds; in most cases the leaf stalk is undeveloped or only slightly so. The blade is very much divided up—dissected type—being reduced to a bundle of filaments. These filaments have an abundance of green corpuscles (chloroplasts) in the epidermis, as may be seen in section. Also the conducting vessels are quite rudimentary. There are no stomata. Gases and mineral salts pass into the plant by absorption.

It is quite apparent that the clearly defined differentiation of functions of the organs—root, stem, and leaves—is largely obliterated in the water buttercup. The form of these persists but the functions are generalised, stem and

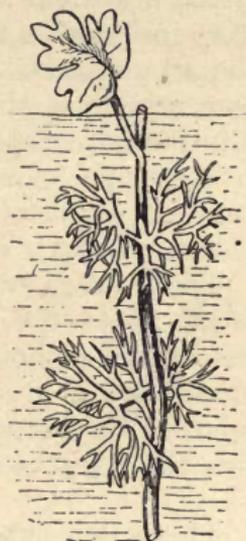


Fig. 81.—The Water Crowfoot, showing floating and submerged types of leaf.

leaves acting more or less similarly in doing the work of roots and leaves both.

In the type growing in sluggish or stagnant water, a second type of leaf occurs, viz. the floating leaves. Here the leaf stalk is long and slender, the blade orbicular and lobed, the under side is covered with short hairs, the upper side is smooth. There are no stomata on the under side, but on the upper they are very numerous.

The most noteworthy adaptation here is, of course, the situation of the stomata. These leaves function as ordinary foliage leaves and transpiration is possible only into the atmosphere, hence the stomata occur only on the surface which is above water. It is an interesting fact that intermediate types of plant exist showing more or fewer of either type of leaf depending on situation as regards amount of water. The plant sometimes grows in marshy places when all the leaves are of the aerial type.

The flowers, which have smooth cylindrical stalks, are borne above the water. The petals are whitish, but otherwise there is nothing distinctive. Whilst we note much modification of all of the vegetative parts of the plant in relation to changing environment, we must contrast with this the relative constancy of the floral parts.

These two types have been considered in some detail, not only that these lessons may be repeated along with the pupils, but also that the beginner may be helped to grasp the principle of adaptation to environment (science of Ecology). If he cares to follow up the subject as a matter of training which will help in interpretation, he should take the opportunity to *describe in detail* other species of buttercup, of which there are several, noting carefully the general situation in which the species occurs and its time of appearing.

If he makes use of a compound microscope and cuts thin sections of the various parts with an ordinary razor, and takes the trouble to draw them, the work will be correspondingly more valuable. For it will have been noted already how much a study of internal structure reveals important adaptive peculiarities.

This work, however, must also be pursued along other lines out of doors. In all collecting of wild plants the teacher should understand the importance of noting the situation where found, the kind of substratum generally, as well as the mere identification of the species. It is desirable that he should recognise well defined "regions" such as "wayside," "field," "moor," "wood," etc., and also the kind of soil, sandy, clayey, etc., for plants, and that he should record the plant under these headings.

Pupils should be taught never to hand in a plant without stating the kind of situation where found. From the lists built up in this way, in course of time, "plant associations" or groups of plants of the same type of habitat may be drawn up. For detailed guidance with regard to studies of this kind teachers should consult *Plant Biology* by Cavers (University Tutorial Press).

CHAPTER XVIII.

THE STUDY OF LEAVES.

FOR this study specimen leaves of different types should be provided.

It may be assumed that in general the functions of the leaf are understood (see p. 208). To aid in interpretation of the structure of the leaf the facts should be revised.

Pupils should be supplied with a few typical leaves for drawing, *e.g.* a blade of grass, plantain, daisy, clover, laurel, sycamore, lime, horse chestnut, etc. At this stage the names of the parts should be learned. The most general character observable in them all will be readily noted, viz. the flat blade (lamina). Other features common to all are the veins, and of course the colour.

Differences may now be looked for. The following may readily be deduced:—

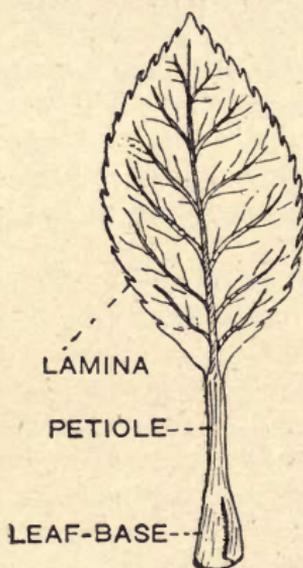


Fig. 82.—A Typical Simple Leaf.

1. Outline of blade. Differences here are very noticeable, and a lesson or lessons may well be given on the shapes of leaf blade alone. Special cases to note are blades with pointed tips and those of leaves from the same plant—this difference to be interpreted with reference to position on stem.

2. Presence or absence of a leaf stalk. The shapes of those leaves without stalk to be noted.

3. Differences in length of leaf stalk in leaves from the same plant—to be interpreted with reference to position on stalk.

4. Differences in degree of greenness. Particular case is those leaves equally green on both sides as compared with those which are lighter on the under side.



Fig. 83.—Leaf of the Privet.

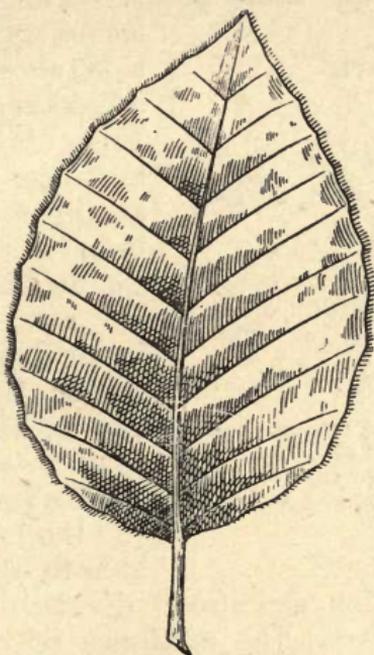


Fig. 84.—Leaf of the Beech.



Fig. 85.—Whorled Leaves.

5. Presence or absence of hairs, etc.

6. Differences in texture, glossiness, etc.

7. Differences in venation—parallel veins and netted veins.

8. Simple and compound leaves,

Having examined a collection of leaves and noted the foregoing points, we may now ask some questions. Why are leaves flattened in form? Bearing in mind the fact that the leaf is the part of the plant whose special function it is to react to sunlight and air, we may readily suggest the answer: that the expanded leaf is a means of obtaining a large amount of these.

The limits to success with such an arrangement will be clear when it is noted that a large leaf intercepting light casts a large shadow which may cut off the light from another part of the same plant. The arrangements of

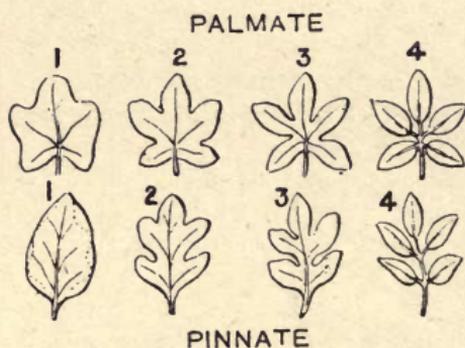


Fig. 86.—Formation of Palmate and Pinnate Compound Leaves by the gradually increasing incision of Laminas with Palmate and Pinnate Venation respectively.

leaves upon plants to avoid this should therefore be considered, clear cases only being taken in the first instance. Some of these arrangements have already been incidentally noticed, e.g. on the same buttercup we saw that the leaves lower down the stem have longer stalks than those above; where vegetation is thicker, as in a meadow, the leaves are divided up so that they are better able to spread themselves

out in spaces which are much divided. The lobing of leaves in general and the existence of compound leaves may be explained with reference to the same point (Fig. 86).

On plants where the leaves are opposite the successive pairs on the stem stand at right angles to each other so as not to intercept the light, e.g. stitchwort, nettle, etc. (*Decussate*). A common arrangement of the leaves upon the stem is a spiral one, so that there is ensured some distance between leaves which stand directly over each other (*Alternate*). Verify this, and note different types of spiral, relatively close and open.

An examination of trees and shrubs as well as herbaceous plants from this point of view will reveal many instances

of mosaics; that is, of dispositions of the leaves upon branches so that they do not intercept the light from each other, and an arrangement of the branches so that there are "gaps" as it were permitting light to reach the leaves on a lower level. The general shape of a tree also fits in with this plan. The teacher should give some attention

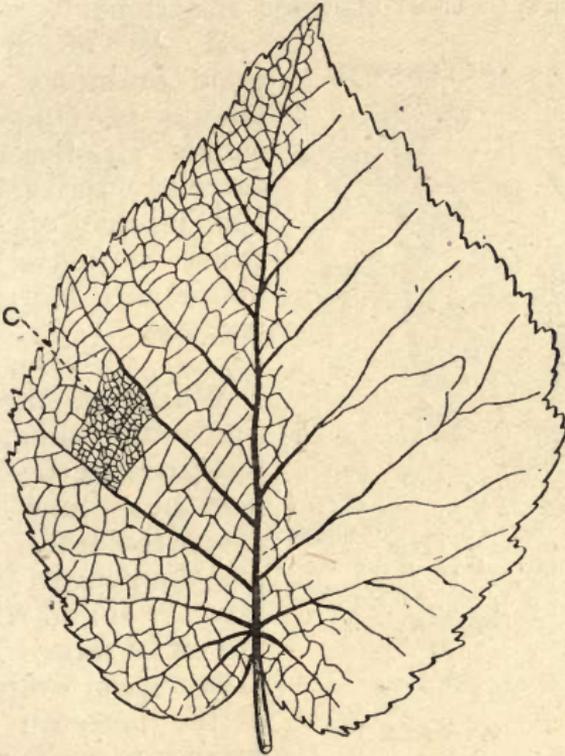


Fig. 87.—Arrangement of Veins in the Leaf of the Pear.
The Principal Veins only are shown on the right side, and the smallest Veinlets at C.

to this point out of doors, cultivating an eye for seeing mosaics which are apt to pass unnoticed otherwise. In general it may be pointed out that, while the arrangement of leaves of a particular tree is such that they must not interfere with each other, they actually do so with those of other individuals. This is a phase of the struggle for light.

A demonstration of mosaics out of doors upon trees is desirable. Branches should be studied in detail; in this way we may explain, *e.g.* the unequal lobing of the leaf of the lime or elm. Spread out a branch of a lime tree and the effect of the unequal lobing as a factor in the mosaic arrangement will be clearly seen.

The case of linear leaves of grasses should be interpreted with reference to their crowded situations.

A set of drawings of good examples of mosaics should be framed by the pupils, *e.g.* the rosette mosaics of daisy and plantain, the mosaic of the nettle (view the nettle plant from above), sycamore, lime, elm, ivy, etc.



Fig. 88.—Types of leaf arrangement on stem.

Whilst in the main the shape is “adapted” with reference to the light, other influences may of course affect the leaf. For example, the pointed tip of many leaves is suited to the carrying off of rain. The surface gloss upon evergreens due to the presence of a thick cuticle is well adapted to causing the snow to slide off the leaves, avoiding break-

age of branches; a specially thick cuticle is also of service in checking too rapid transpiration of moisture.

How are leaves in general lighter on the under side than on the upper? Are there any leaves which are light green above as well as below? Without the aid of a microscope we cannot in any very direct way demonstrate the cause of most leaves being darker on the upper than on the under side. If the teacher possesses one he may do this very easily. Take a portion of a fairly strong leaf, *e.g.* ivy,

box, or laurel, place it in a slit made in a piece of pith and cut thin sections by means of a sharp razor, keeping the razor wet with alcohol. Place the sections on a glass slip in water and examine, selecting the thinnest parts for study. Similar sections may be obtained by rolling up a large leaf, *e.g.* rhododendron, and cutting without pith.

A study of such sections shows that the tissue of the leaf is much more closely packed towards the upper

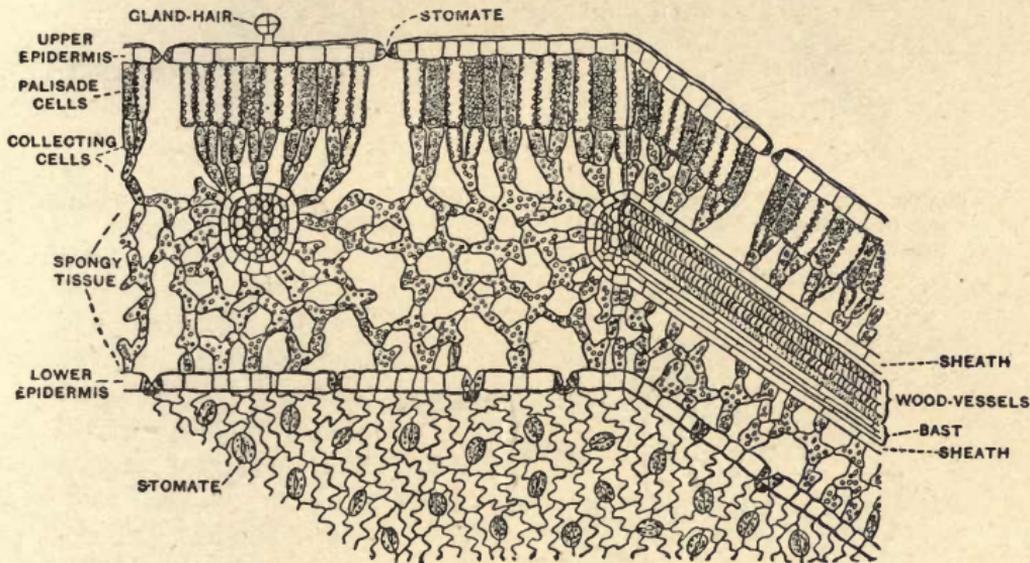


Fig. 89.—Portion of a leaflet of Broad Bean, magnified so as to show the arrangement of its parts.

than the lower side. The arrangement is as shown in Fig. 89.

Immediately beneath the upper "skin" (epidermis) there is a layer of cells which lie close together and which are arranged with their long axis across the thickness of the leaf (*palisade cells*), while beneath these the cells are arranged loosely in columns so that there are numerous interspaces (*spongy tissue*). By stripping off the lower epidermis—a small fragment is sufficient—and examining with the microscope a very large number of openings (stomata) leading into these spaces will be seen. Similar



Fig. 90.—Branch of Barberry, showing transition of Foliage Leaves into Spines.

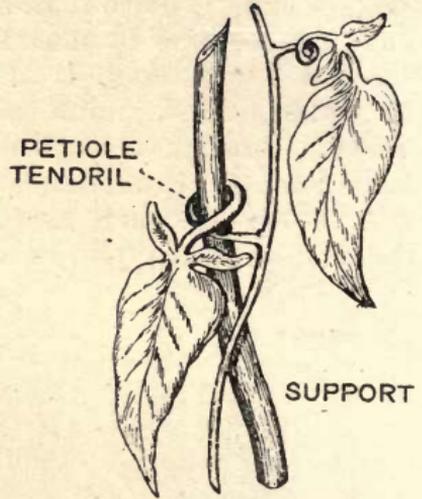


Fig. 91.—Leaf stalk of Woody Nightshade modified for support.

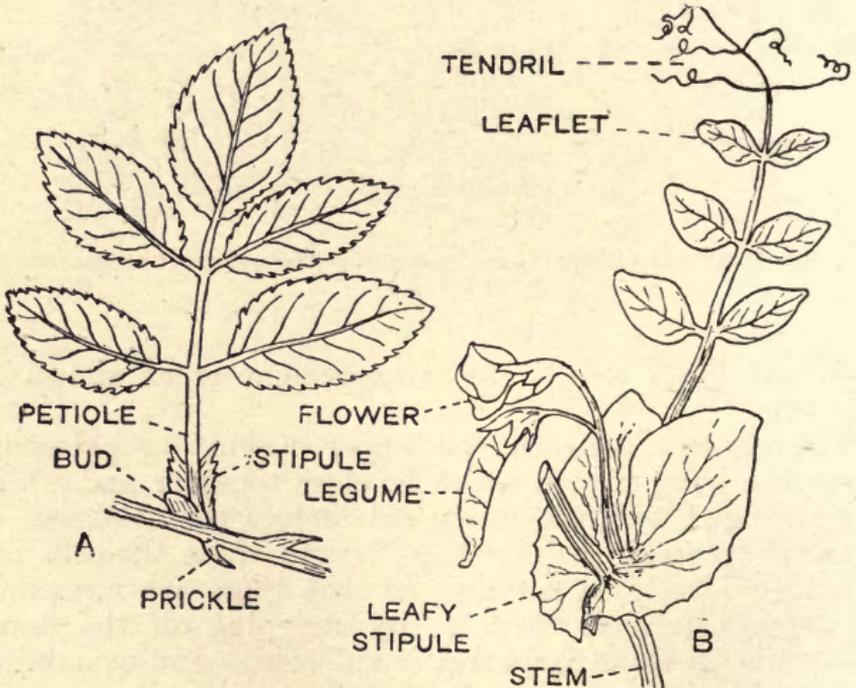


Fig. 92.—A, Compound Leaf of Rose, with five Leaflets and Stipules ; B, Compound Leaf of Pea, with terminal Leaflets modified into Tendrils.

openings may be found in the upper epidermis, but ordinarily in much smaller numbers.

The difference in the arrangement of the cells of the upper and lower regions of the leaf is the cause of the difference in the colour. It is owing to the presence of air spaces below that the leaf is lighter here. In the clover leaf light patches occur in the upper side which are due to the presence of air. On placing the clover leaf in boiling water the light colour disappears by the expulsion of the air.

As the green colouring matter of the leaf is thus massed for the most part towards the upper side, we may describe the upper as the assimilating surface and the lower as the transpiring surface.

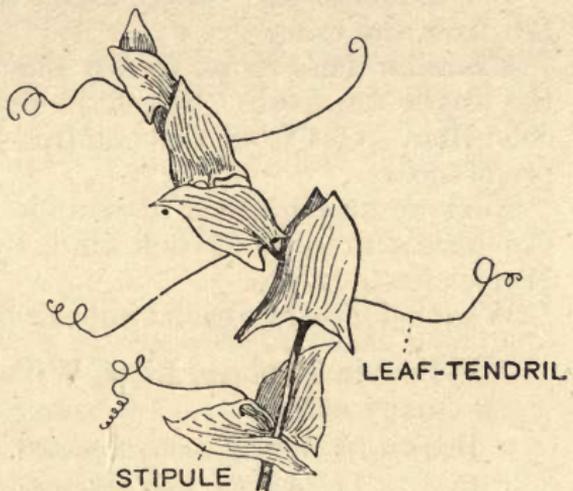


Fig. 93.—Leaves of Yellow Vetch (*Lathyrus aphaca*) modified as tendrils. Stipules function here as leaves.

It is important too to notice the structural relations between buds and leaves. Buds arise in the axils of leaves. Pupils should examine a number of plants to verify this point. They will then appreciate leaf modification, *e.g.* spines, and will distinguish, by reference to relative positions on the plants, spines which are modified leaves and spines which are modified branches (Fig. 90).

Other modifications, such as tendrils, should also be pointed out (Figs. 91, 92). Note may also be made of the presence or absence of stipules—blade-like expansions at the base of the leaf stalk, and their degree of development. Note *e.g.* the small adnate stipules in rose, the large leafy ones in pea tribe, including those of the Yellow Vetch which take the place of the aborted leaf blade (Figs. 92, 93).

AUTUMN LEAVES.

In this study we must not omit to call the attention of our pupils to the leaves while they are upon the trees to delight our eyes with the autumn tints, to encourage pupils to watch the changes upon individual trees, and generally to cultivate appreciation of this aspect of nature.

For indoor study, collect leaves newly fallen or about to fall from the trees.

Examine these so as to see the various colours whilst the leaves are fresh. Select the prettiest for drawing and colouring. Get from the children an expression of their preferences.

Next we may proceed to arrange according to the trees. Compare a number of each kind, Sycamore, Poplar, Lime, Horse-chestnut, etc.

What colours does each kind exhibit? Note, for example :

Yellow in Poplars, Lime, Willow, Horse-chestnut, and many others.

Brown in Oak, Beech, Service.

Red in Mountain Ash (Rowan), Rhododendron.

What parts of the leaf retain the green colour longest? Parts close to the veins frequently.

What is the nature of the change taking place? In the simplest cases the change consists in a dissolution of the chloroplasts, exposing a yellow pigment (xanthophyll). But there are usually complications owing to the formation and unequal distribution of other pigments.

According to Miss Newbigin there are three main factors: " (1) the disappearance of the chlorophyll green, (2) the increasing prominence of the lipochromes, and (3) the development of anthocyan. Other changes of minor importance also occur. Thus the general effect is often heightened by the dull brown colours assumed by the leaves of such trees as the oak and the beech. These colours are produced by the oxidation of the tannins of which these trees contain such an abundant supply. These

substances are probably useless and are got rid of in the falling leaves and the bark."

What is the cause of the change? Two facts may be noted. There is in general the regularity of its occurrence at each returning autumn, and there is the great diversity as to the particular time for the same kind of tree in different parts of the country or in different situations. There is in fact much individual variation as to the time and rate of progress of the changes involved in the production of the autumn tints.

The period over which autumn leaf changes extend may reach from August to November. Teachers might collect evidence on this point. There is no doubt that the inducing cause is seasonal—failing light and temperature perhaps, or frost, and that the immediate cause is chemical change with the transference of some of the products to other parts.

Can we attribute any significance to the colours in the life of the tree? Are they of any direct service to the tree in its external relations? We know of nothing. They are the outward manifestations of an inward process. They delight the eye of man, but do not seem—as colour—to serve the tree any more than the brilliant pigments of a deep-sea starfish serve that animal in the darkness of its natural environment.

The Fall of the Leaf.

The mechanism of the fall may be described. At the base of the leaf there grows a layer of cork tissue which cuts off supplies between leaf and stem. Behind this part towards the leaf there usually grows a layer of soft tissue which liquefying enables the leaf with a slight breath of wind to detach and fall to the ground.

CHAPTER XIX.

THE STUDY OF FLOWERS.

WITH the youngest pupils in school, flowers are dealt with from the point of view of their colours, scent, and other attractive features. Observational work may be encouraged also at this stage with reference to the visits of insects to them, and also to the fact that they give place in due time to the fruit and seeds.

In the next stage, whilst continuing to cultivate general appreciation by means of drawing and colouring, our suggestions with regard to the meaning of flowers must now direct attention more definitely to details. There comes a stage when it is profitable to dissect a flower—a practice which need not often occur in our Nature Studies. We may take a common wild or garden flower of simple structure, *e.g.* Wallflower. Pupils should learn the uses and names of the different parts.

Sepals—protective, especially in the flower bud.

Pupils will see also that they hold the petals in position.

Petals—attractive by colour and scent.

Stamens—pollen producing for making seeds fertile.

Carpels—producing ovules which give rise to seed.

The nectaries which in the Wallflower occur at the base of the outer stamens occupy different positions in different flowers. Attention should be called to these as of

importance, since they constitute the chief attractions of the flower to insects (Fig. 94).

It should not be difficult to get from pupils the seed producing as the primary function of the flower, to which the functions of colour, scent, and nectar producing are subsidiary. It might be well also to emphasise this in another way, viz. by representing the parts of the flower in two divisions—

Stamens and Carpels—principal parts.

Sepals and Petals—subordinate parts

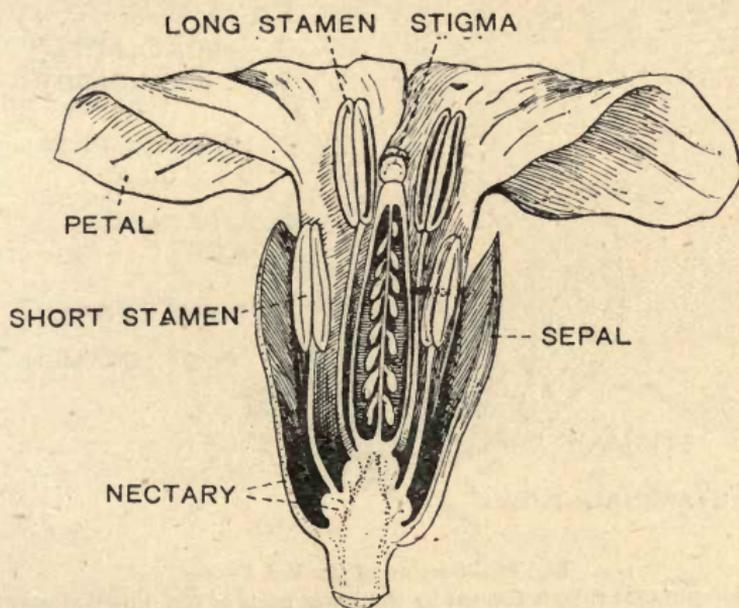


Fig. 94.—Vertical section of Wallflower, showing the parts and their relations.

A survey of the fact that very large numbers of plants have flowers which may be regarded as designed to attract insects (other animals also, *e.g.* birds and bats in tropical lands) will serve to emphasise the fact that cross pollination conveys an advantage to the plant, *e.g.* more vigorous seed. It also probably tends to produce variations. It would be well here to appeal for examples, *e.g.* of large brightly coloured flowers (Poppy); medium sized flowers, sweetly scented (Wallflower); small flowers but

conspicuous, because in close set inflorescences (Umbelliferae); flowers clustered in "heads" (Clover and Compositae); with conspicuous sterile flowers surrounding "head" (Cornflower); and so on. By this means pupils may be encouraged to observe more closely the intimate relations between insects and flowers.

The secretion of nectar and in some cases excess of pollen, together with the production of scent and the display of coloured petals, etc., are facts which may be grouped together as *arrangements inviting insects to the flowers.*

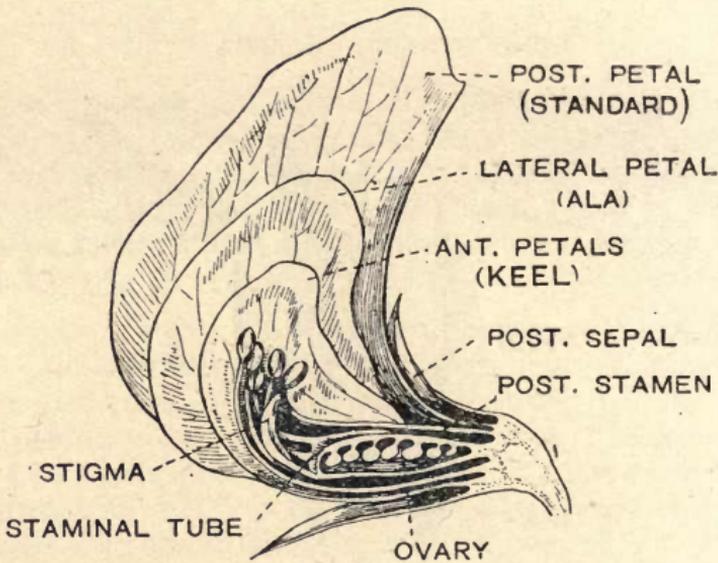


Fig. 95.—Section of the Pea Flower.

The staminal tube is formed by the lower parts of the united stamens.

In many cases these arrangements are backed up by further devices ensuring that the visiting insects shall render some unconscious service in return. The simpler instances of this kind should be examined as opportunity offers. Examples are here indicated.

The most familiar is undoubtedly that of the Pea family (Leguminosae), all the British examples of which have papilionaceous flowers. Examples are Broom, Garden Pea, Rest Harrow, Vetches, etc. Flowers of this type should be

examined. They are brightly coloured, scented more or less, and many possess nectar. On dissecting the flower, it will be seen that the stamens are united together at the base, either ten together or nine together and one free. At the base of the ovary enclosed by this sheath of stamens will be found the nectar which the bee seeks. Pupils should taste the liquid.

The general shape of the flower and arrangement of its parts should next be noted. It will be seen readily

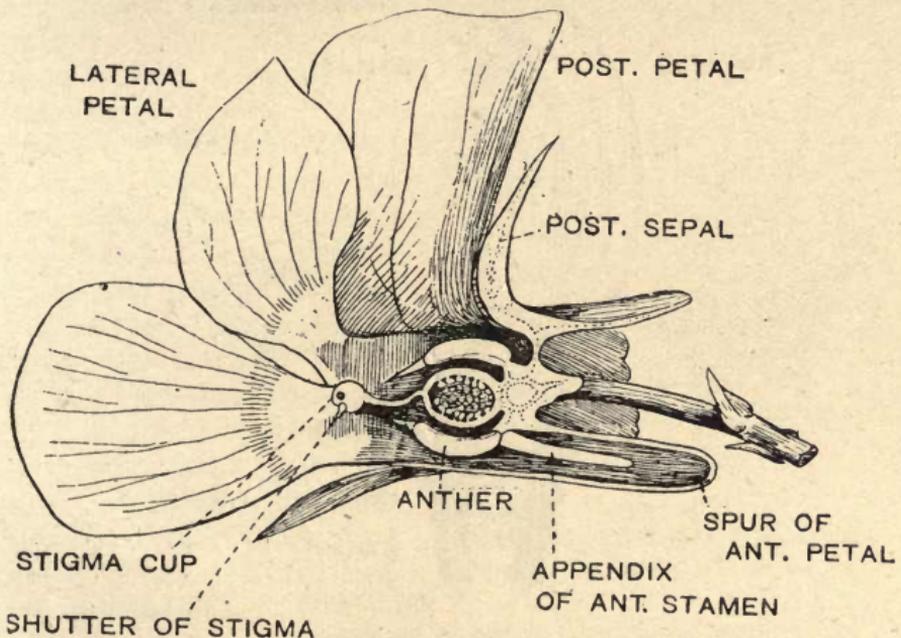


Fig. 96.—Section of Heart's-ease flower.

that when a comparatively heavy insect, such as a bee, alights on the flower, it must rest upon the lateral petals. These are thus depressed, the keel (anterior petals) which encloses the stamens and style being dragged down also. Stamens and stigma are released and strike the under side of the bee's body, which in this way is dusted with pollen. Meantime the bee is licking up the nectar. If the bee has already visited a similar flower it will be already dusted with pollen, so that when the stigma strikes its body it will

receive some of this and thus cross pollination is effected. See Fig. 95.

Another well-known example is that of the violets or pansies. Take, for example, a flower of the Heart's-ease (*Viola tricolor*). Let pupils suggest the significance of the "spur" upon the anterior petal. This should be opened and the nectar-producing appendages of the two anterior stamens observed.

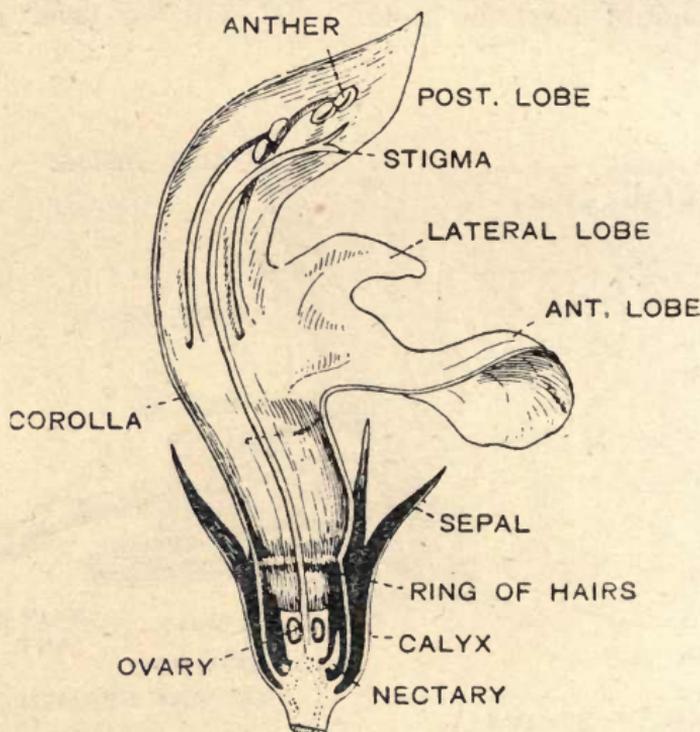


Fig. 97.—Flower of White Dead-nettle (*Lamium album*) in section. Stamens are mature before stigma. Nectary is protected by ring of hairs from small insects. Humble-bees pollinate.

The position and form of the stigma should next be noted. The end of the style is globular and has the stigma in a depression on the anterior face, whilst it bears a projecting "shutter" beneath. The stamens are lower down within the flower. As the insect pushes its head inward it rubs on to the stigma any pollen it may be carrying, whilst as it withdraws its proboscis the "shutter" protects the stigma from receiving pollen from the same flower.

There is thus here an arrangement preventing self- as well as one ensuring cross-pollination (Fig. 96).

Other examples which will reward study are Columbine, Monkshood, Larkspur, and White Dead-nettle (Fig. 97).

Arrangements preventing self-pollination are frequent. Some of these are here enumerated, and it is suggested that pupils be given opportunities for examining illustrative types.

The most familiar illustration is that in which stamens and stigma mature at different times. The commonest case is that in which stamens ripen earliest (protandry), *e.g.* Harebell, Crane's Bill, Compositae, Umbelliferae, etc. If a series of buttercups be examined some will be found whose outer stamens have shed their pollen, whilst the inner ones are still curved inwards towards the carpels which are not yet mature. In this case the carpels generally ripen as soon as the inner stamens, so that there is an overlapping period when self-fertilisation is possible.

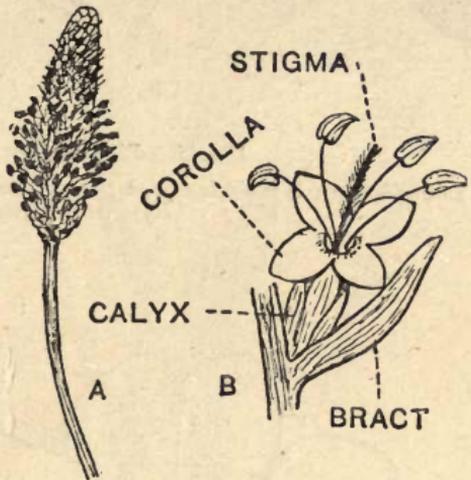


Fig. 98.

A, Spike. B, Flower of Plantain.

There are some interesting cases in which the stigmas of a flower ripen before the stamens (protogyny). Plantains (*Plantago*) are a good example of this (although, except in some special cases, this is not an insect-pollinated flower). If the spikes are examined when their lower parts show the protruding stamens with their pendulous anthers, it will be seen that the stigmas in this region are already withered, whilst in the upper parts the stigmas are mature and the stamens are not yet extruded (Fig. 98).

The Figwort (*Scrophularia nodosa*) is another interesting case. In the young flowers the stigma may be seen

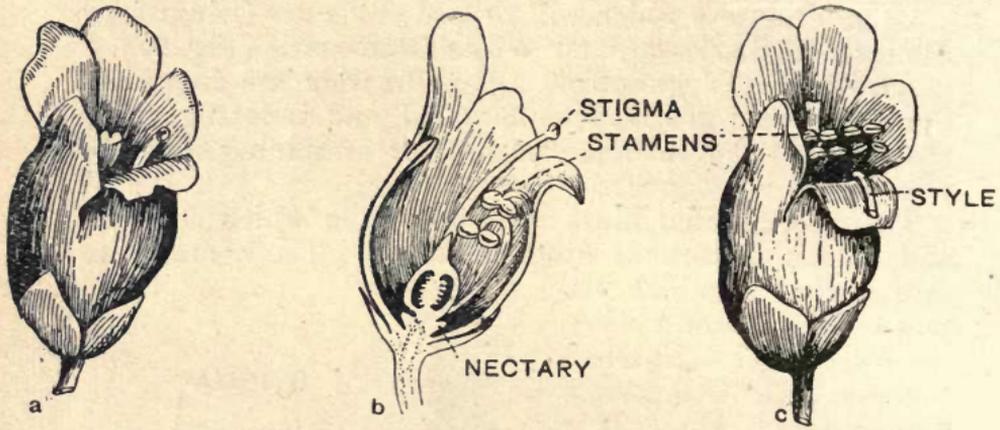


Fig. 99.—Figwort (*Scrophularia nodosa*).

a, young flower ; b, the same in section ; c, older flower with stamens ripe and exposed ; style with withered stigma.

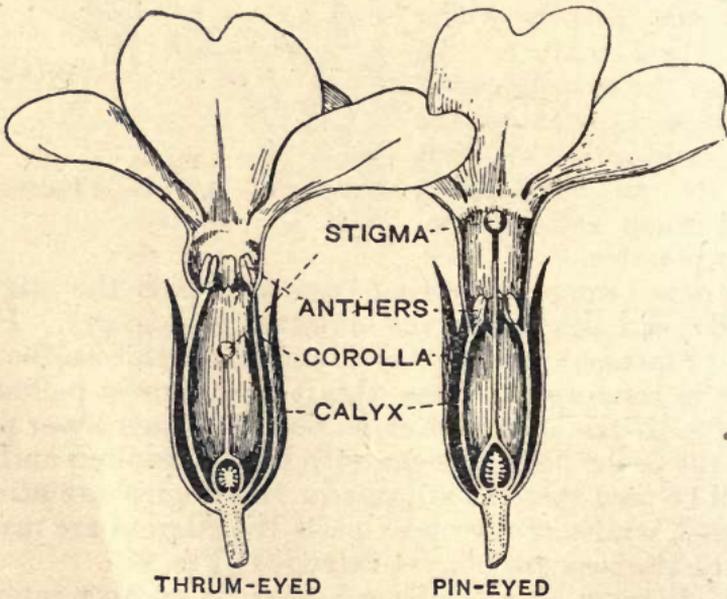


Fig. 100.—Sections of "thrum-eyed" and "pin-eyed" flowers of Primrose.

protruding from the flower, whilst the unripe stamens are curled up below with the anthers directed inward. By the time these have ripened and have been turned outward in the mouth of the corolla the style has withered (Fig. 99).

Heterostyly.—The case of the Primrose should be understood. If a collection of primroses be examined two types of flower will be found, viz. those in which the pin-like stigma is seen just in the throat of the corolla (pin-eyed), and others where no stigma is visible but instead the stamens (“thrum-eyed”). Further examination of the flowers shows that the former type has a long style and short stamens, and the latter a short style whose stigma stands at the same level as the stamens of the other type, and stamens at the top of the tube on a level with the stigma of the pin-eyed type (Fig. 100).

In this case cross-fertilisation “is rendered more certain by the fact that insects in visiting the flowers touch

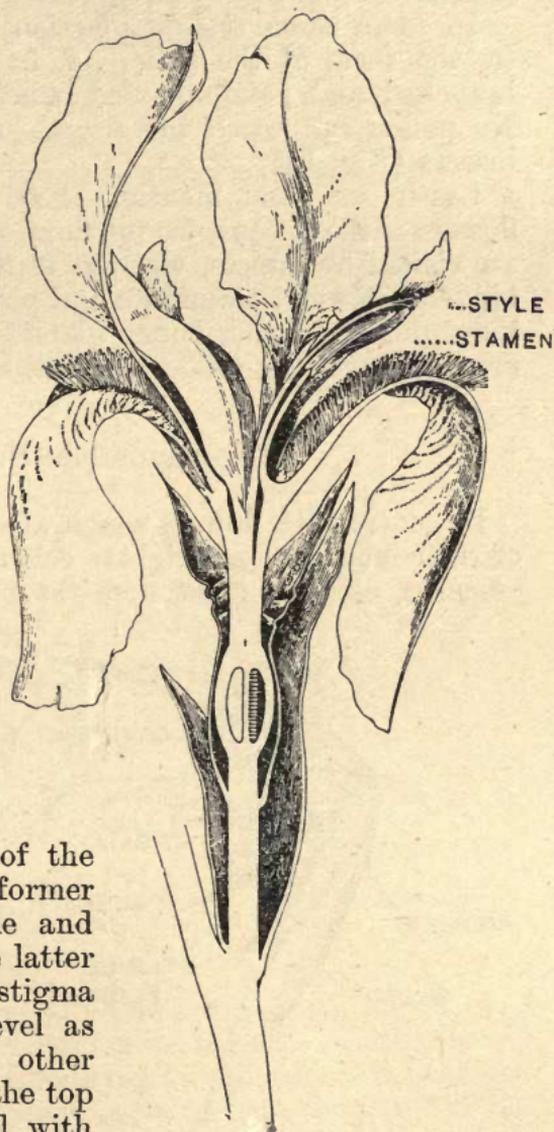


Fig. 101.—Section of Iris. On the right a style is cut in half lengthwise, showing its relation to the stamen which may be seen below. The style on the left is shown entire.

correspondingly placed sexual organs with the same portions of their body" (Strasburger).

In some cases self-fertilisation is rendered impossible by the form of the style, *e.g.* in *Iris*, where it is large branched and petaloid—and conceals the anthers below. No pollen can reach the stigma unless by the agency of insects (Fig. 101).

Lastly we must mention those cases of insect-visited flowers without conspicuous floral parts which nevertheless are visited by insects, *viz.* the *Willows*. These have two kinds of flowers, staminate and pistillate, arranged in catkins, and each has a honey gland. The staminate catkins are bright yellow, whilst the pistillate catkins are green.

INCONSPICUOUS FLOWERS.

In contrast to flowers which are conspicuous by reason of their more or less brightly coloured petals, large inflorescences, etc., we must note the many flowers which are

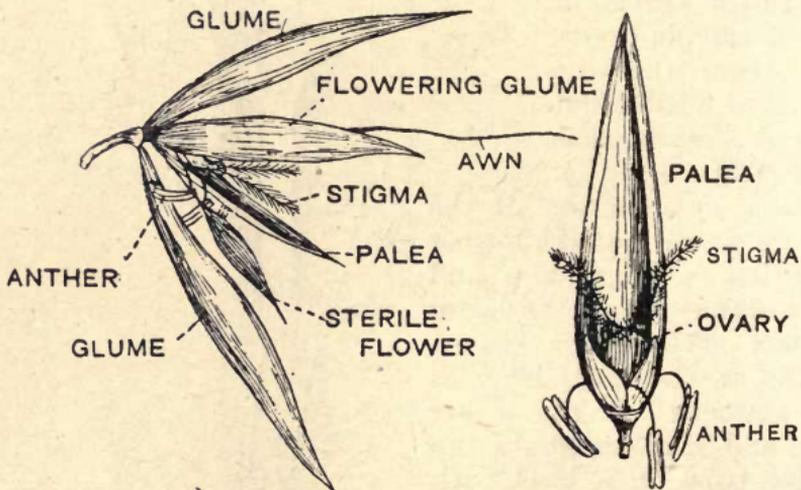


Fig. 102.—Spikelet and flower of the Oat. Note the extruded anthers and feathery style.

inconspicuous. These are, for example, the flowers of grasses, of cone-bearing trees, and most of our common

forest trees, Poplar, Alder, Birch, Hazel, Beech, etc. A study of these will reveal the fact that they do not produce nectar and have none of the usual attractions for insects. Pollination in such cases is effected by the wind. Examination of particular cases will repay study. Here the more general facts regarding wind-pollinated plants may be set down. Verification is expected as opportunity arises.

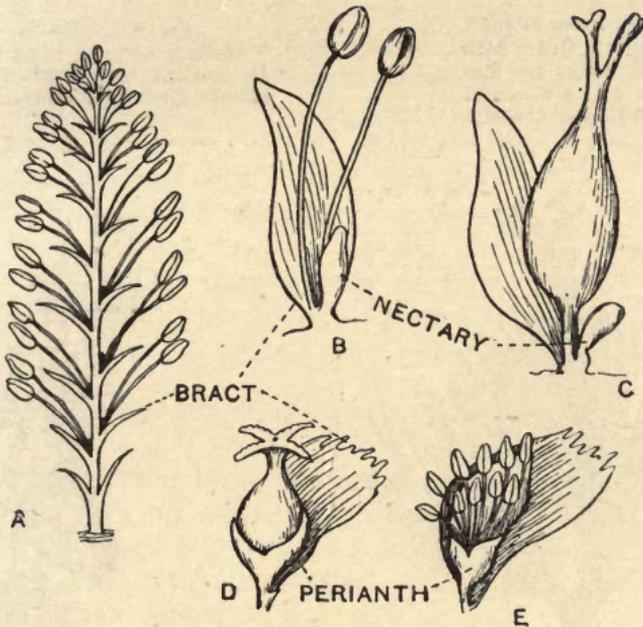


Fig. 103.

A, male catkin of Willows; B, male flower; C, female flower of ditto;
D and E, female and male flower of Poplar.

Abundance of Pollen.—In Coniferae (Pine, Larch, etc.) pollen is produced in enormous quantities. The pollen is dry and powdery, and in many cases each grain is provided with a pair of air sacs which serve to float the grain in the air. Abundance of pollen is a necessity with all wind-pollinated flowers.

Extrusion of Anthers.—This also is general, and is well seen in Grasses, whose anthers are pendent (versatile) from long swaying filaments (Fig. 102).

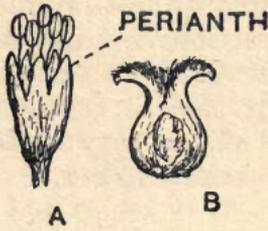


Fig. 104.—Flower of Elm.
A, Flower. B, Ovary with two stigmas; these are mature before the stamens and are wind-pollinated usually.

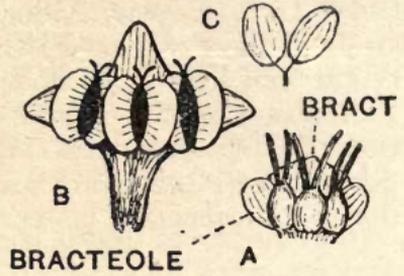


Fig. 105.—Birch.
A, Female flower in axil of bract; B, fruiting scale with 3 fruits; C, stamen from male flower.



Fig. 106.—The Pine, showing cone and male flowers.



Fig. 107.—The Larch, with cones.



Fig. 108.—Male and female flowers of Dog's Mercury.

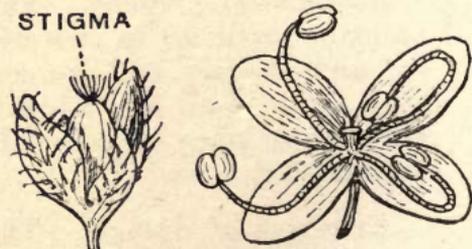


Fig. 109.—Female and male flowers of Nettle.

Feathery or hairy styles to which pollen readily adheres, e.g. Grasses, many forest trees, e.g. Birch, Hornbeam, Hazel, etc.

Unisexual Flowers.—Conifers, Poplars, Birch, Alder, Hornbeam, Beech, Oak, Ash, etc. (Figs. 103 to 109). These flowers are grouped in staminate (male) catkins and carpellary (female) catkins, or in the case of many of the conifers male and female cones. In connection with observations made by pupils regarding times of flowering of trees, notes should be made regarding the order of ripening of the female and male flowers and of those cases where flowers mature before the leaves unfold. The significance of this in relation to pollination by wind is of course obvious.



Fig. 110. — Flower of Ash, with two stamens and one pistil with two stigmas. The Ash may also have unisexual flowers on the same tree.

AESTHETIC VALUE OF FLOWERS.

The flower having been studied from the point of view of a race-preserving organ, we would once more seek to emphasise its aesthetic value. Man delights in flowers all through life, and this aspect must find a place in nature studies in school.

An excellent way of giving prominence to this is to emphasise their decorative value by having flowers in pots and also cut flowers in the schoolrooms as much as possible. Flower-growing indoors by the pupils, as well as flower-growing in the school garden, should form a definite part of the work as an end in itself, as distinct from experimental growing for instruction. It is also appropriate that some of the references to flowers either in general or to particular cases occurring in literature form part of the memory work of the pupils. Teachers should take some pains to find suitable subjects appropriate to some of the flower studies engaged in in school. See *The Greenwood Tree* (Arnold).

CHAPTER XX.

STUDY OF FRUITS AND SEEDS.

WE pass from the flower to the consideration of the fruit. Indoors this subject should be dealt with observationally. In the first instance, *i.e.* in the youngest classes, as indicated in the courses outlined, nothing particular should be attempted in the way of "explaining" the parts of the fruit. The fundamentally important point, *viz.* that fruits enclose seeds, should be educed from an examination of a number of different kinds, and this will incidentally exclude some edible products which are not fruits. Facts regarding shape and colour, numbers of parts, and corresponding parts in different fruits will all yield subject-matter of profitable comment.

The fruits can be drawn and persistent parts of the flower may be noted in simple cases, *e.g.* the calyx in a gooseberry or strawberry may form the subject of suggestive comment, the one occurring above the fruit and the other below. The chief thing for the teacher is to raise points of real significance which will be developed in later studies. Even here some of the commoner wild fruits may form the subject of study, being admitted because they answer to our elementary test, *viz.* the presence of seeds.

The next step may suitably be a study of fruits with reference to their dissemination and the dispersal of the seeds. Pupils will readily see the necessity for scattering when the numbers of seeds produced by a single plant are noted. A profitable preliminary exercise is one in which each pupil is asked to count the seeds in all the fruits

from any single plant. The particular plant to be chosen is a matter of convenience ; it should not be one with very small seeds. A stem of wheat or corn does very well, and it can be examined in this way before the seed is actually formed. The teacher, after tabulating the results obtained by the class, should write upon the board the conclusion :

Scattering of seeds is a necessity.

Fruits should now be examined with a view to determining modes of dispersal, and in order that pupils may receive some guidance as to how to examine the fruits and as to what to look for, lessons on a collection of fruits exhibiting typical modes should be given. Subsequently all fruits found or brought to the notice of the pupils should be examined from this point of view, as well as of course others.

DISPERSAL OF FRUITS AND SEEDS.

There are four chief ways in which seeds are scattered. We may begin our consideration of the subject with the action of the *wind*.

Seed-scattering by the agency of the wind is the one

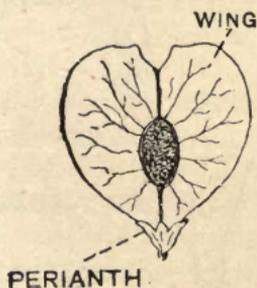


Fig. 111.—Fruit of the Elm.

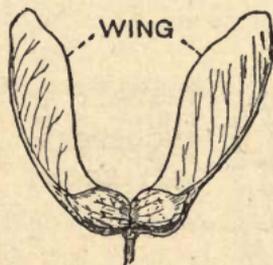


Fig. 112.—Fruit of Sycamore.

most likely to be noticed first by the children. Have they not all at one time or another blown from the globe of Dandelion fruit the "fairy arrow," or chased the thistle-down as it floated on the lightest air? A beginning should be made with these, and pupils should draw the

fruit with its parachute-like pappus. With these might be classed the *seeds* of Willow or of the Willow herb, which are also floated by means of a tuft of hair. Cotton seeds, it may be noted, are covered with hair, which grows to a considerable length and which constitutes the cotton of commerce.

Wing-like expansion of Seeds or Fruits.

Pine-tree seeds are borne on the wind by a lateral membranous wing. Pupils should extract these winged seeds from ripe pine cones (Fig. 113).

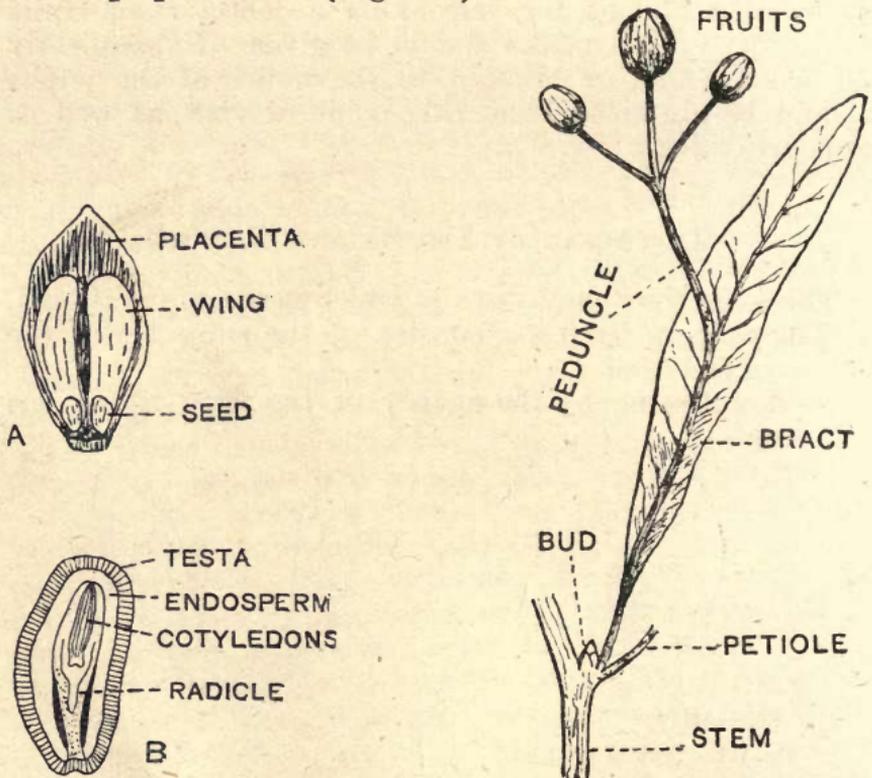


Fig. 113.—A, Seeds of Pine upon scale (Placenta). B, Section of seed showing young plant.

Fig. 114.—Fruit of Lime with adherent bract.

Winged fruits occur upon the Ash, Sycamore, Elm, Birch (Figs. 105 B, 111, 112). All of these should be

examined. In the Ash the spiral twist upon the "wing" should be noted. Some observations ought also to be made in the neighbourhood of these trees, when it will be found that large numbers of the fruit fall quite close to the parent tree. But it is to be observed how the fruits after they have fallen are liable to be stirred by the wind from time to time and eventually carried some distance.



Fig. 115.—Fruit of Hornbeam.

If Ash and Sycamore fruits are looked for in the early spring many will be found caught in loose soil by the wing sticking in the ground, so that it sometimes acts as a holdfast until the seed has germinated. These wings are outgrowths of the wall of the fruit itself.

In the Lime there is a large lanceolate bract attached to the flower stalk on which the fruits (nuts) are borne (Fig. 114). In the Hornbeam fruit also a broad wing-like bract is attached (Fig. 115).

Another familiar example is the fruit of the Dock, which has three keel-like expansions which are of service in the scattering of the fruit.

Before leaving the subject of wind dispersal a note should be made that here also as in many other of Nature's processes relative success is sufficient to maintain the various species. Many seeds fall in unsuitable places, yet the species continue. This point should be verified by the pupils.

Animal Agency—Passive.

Some fruits are prickly, so that they adhere to the bodies of passing animals. Pupils will mostly be familiar with the Goosegrass or Cleavers (*Galium aparine*), in which not only the fruit but the whole plant is covered with small hooks. In the Wood Avens (*Geum urbanum*) the style is hard and hooked, and in the Corn Crowfoot (*Ranunculus arvensis*) the individual carpels are rough and prickly. These are interesting cases which should be examined, and there are many others of this kind. Sometimes fruits or seeds of aquatic plants adhere to the feet of water birds in mud, and are distributed in this way.

Animal Agency—Active.

Another familiar example is that of the Mistletoe berries, which are very sticky. They are eaten by birds which in wiping their bills on the branches of trees leave the seeds adhering, and there they subsequently germinate.

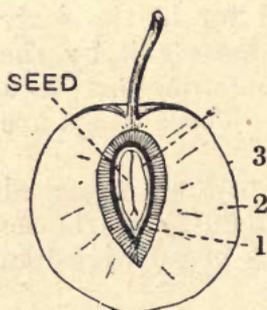


Fig. 116.—Section of the Cherry; 1, 2, 3, layers of the seed vessel (pericarp).

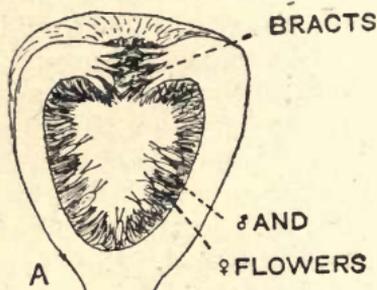


Fig. 117.—Fruit of Fig cut lengthwise. Here the succulent portion consists of the expanded head of the flower stalk which encloses the entire inflorescence. The "seeds" in this case are really the fruits.

The seeds of many succulent fruits are scattered by birds and other animals which feed upon the fruit. Hence the attractions of juiciness, sweetness, and such like have a

direct bearing on the seed distribution. Very frequently the seeds pass unharmed through the bodies of the animals. Most cases of succulent fruits will repay individual study from this point of view.

Berries: *e.g.* Gooseberry, Grape, Tomato. Here the enveloping parts of the fruit (pericarp) are all, except the "skin," soft and juicy.

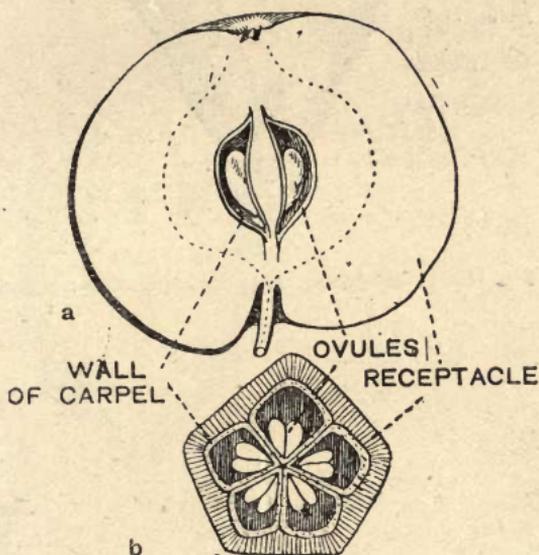


Fig. 118.—(a) Fruit of Apple cut vertically;
(b) Young Ovary cut transversely.

Drupe: *e.g.* Cherries, Raspberries, Plums. In this case the innermost layer of the fruit next the seed is hard and stony (Fig. 116).

Other fruits to be classed here are, Strawberry, Fig, Apple, etc. (Figs. 117, 118).

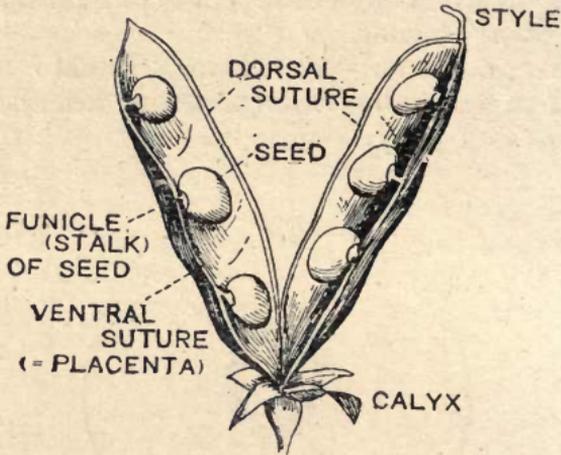


Fig. 119.—Pod of Pea. It splits along both margins.

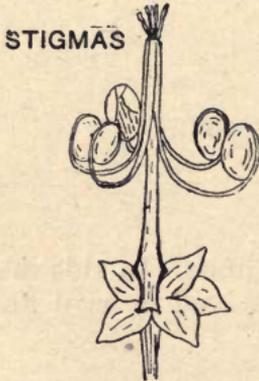


Fig. 120.—Fruit of the Geranium.

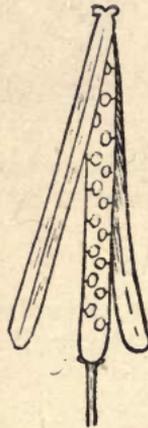


Fig. 121.—Fruit of Wallflower.



Fig. 122.—Fruit of Monkshood (Follicles). The follicle splits along the edge to which the seeds are attached.

Dispersal by Plants themselves.

The commonest case is by the sudden splitting of the dry carpel (explosive fruits), by which means the seeds are thrown some distance away. This is quite audible in some cases, *e.g.* Broom. Violet seeds are also scattered in this

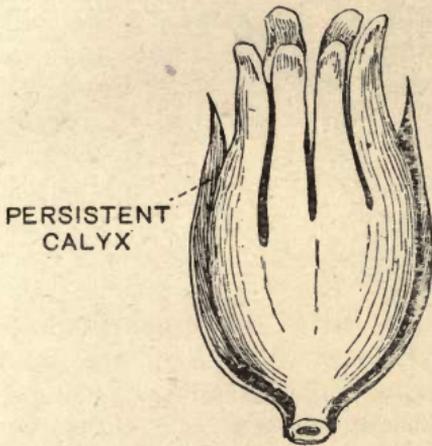


Fig. 123.—Capsular fruit of Stitchwort, which splits lengthwise into a number of teeth at top, permitting the seed to escape when the plant is shaken by the wind.

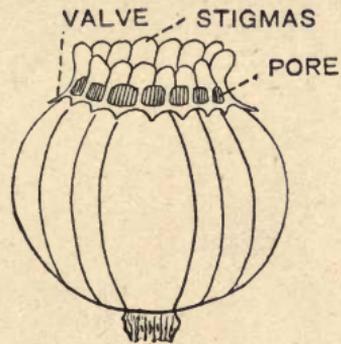


Fig. 124.—Fruit of Poppy (Capsule).
The seeds are shaken out through the pores.

way. In Geraniums the style splits into a number of one-seeded pieces (Fig. 120), curling up and throwing out the seeds. In other cases the seed vessels split open and the seeds are shaken out by the wind. Pods, Follicles, Capsules (Figs. 119, 121 to 124).

Dispersal by Water.

This occurs chiefly in connection with water plants, in which case there is sometimes a special adaptation, *e.g.* in the Water Lily (*Nymphaea*) there is a growth (arillus) outside the seed coat, and between these an air chamber

which thus serves to float the seed. The fruit of the Alder, which grows by the banks of streams, is frequently borne on the water.

The lessons given on fruits generally are intended to

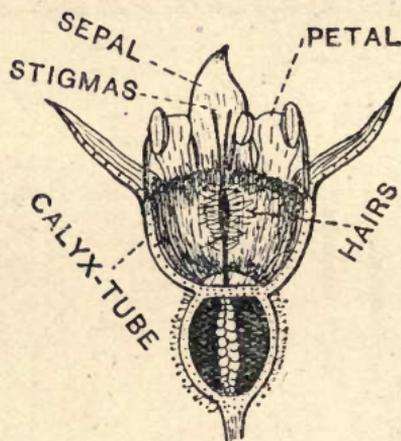


Fig. 125.—Section of Flower of Gooseberry.
The berry develops below the calyx-tube.

stimulate observation out of doors and to lead to questionings. Whilst the foregoing represent a few of the more noticeable adaptations for dispersal, it will be found that there are cases which do not admit of any special interpretation, and the dispersal of the seeds in such cases appears to be left largely to chance.

A series of studies on fruits should be drawn up to show the relation of the fruit to the parts of the flower. This can readily be done by the botanical student, but care should be exercised in the selection of examples. In some cases it will be found profitable to trace the development experimentally by examining the fruit at different stages. In this connection the study of edible fruits will probably be found most interesting, *e.g.* Gooseberry, Apple, Strawberry, Pea (Fig. 125). (See also Figs. 116 to 118.)

STUDY OF SEEDS AND SEEDLINGS.

The study of seeds is most appropriately carried out in spring.

This study must of necessity be almost entirely experimental. The chief points to be aimed at are a clear demonstration of the functions of the seed, of the conditions necessary for their fulfilment in the production of a plant, and the different arrangements within the seed for the carrying out of these functions.

It will on the whole probably be better that at the outset the teacher do not confine attention to a single type. Seeds of various plants, big and small, might be germinated first of all on clean soil under normal conditions of moisture, heat, and light. The essential can be differentiated later on from the non-essential, and while the advanced botanical student may commence the study of seedlings by arranging artificial conditions right away, it is probably more desirable for elementary pupils that they should commence with a study of the conditions under which seeds actually germinate in nature.

Seeds of various weeds, cereals, garden flowers, fruit trees, etc., should be mixed and sown in boxes such as may be obtained at the grocer's shop. Make a list of the seeds sown. In other boxes (controls) the seeds of the various types should also be sown apart in rows and labelled, so that the seedlings, if unfamiliar to the teacher at first, may be readily identified in the mixed sowing.

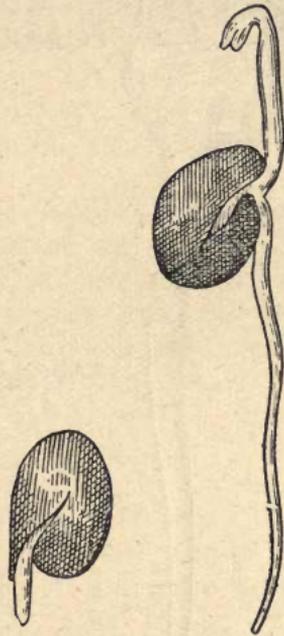


Fig. 126.—The Germinating Bean—two stages.

Keep a record (1) of the aspect of each type as it appears above ground, the number of cotyledons, size, etc.; (2) of the order of appearance above ground of the different seedling types; (3) of the average time taken to germinate by each type under the heat, etc., conditions of the experiment. Repeat the experiment, varying the conditions as regards heat, depth below surface, etc. In one mixed sowing a fixed number of each kind might be used and the whole thing left to flower, or seed. The numbers of each kind successful in producing seed should be counted and tabulated. In such experiments as these the teacher will be able to demonstrate the effect on various types of the struggle for light and room, of the advantages of particular habits of growth, and so on.

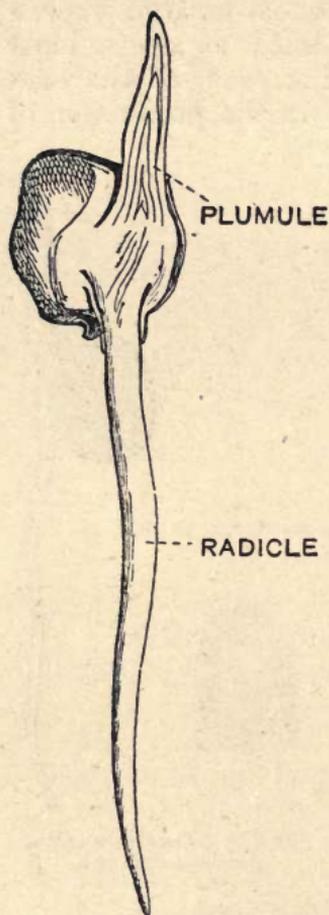


Fig. 127.—Young Seedling of Maize in longitudinal section.

Particular note should be made of what comes above ground as distinct from what is seen to grow afterwards. Examples of the different kind of seedlings should be carefully removed from the soil and drawings made. It will not be difficult to indicate that in general there emerge from seeds under normal conditions a root (radicle), a shoot (plumule), seed-leaf or leaves (cotyledons).

Individual seeds may now be appropriately examined with a view to discovering how much of this is already formed in the seed. Beans, being of conveniently large size, are generally used for this purpose. They may be opened after soaking for some time, when the radicle and plumule may be demonstrated, and also

Individual seeds may now be appropriately examined with a view to discovering how much of this is already formed in the seed. Beans, being of conveniently large size, are generally used for this purpose. They may be opened after soaking for some time, when the radicle and plumule may be demonstrated, and also

the thick modified storing cotyledons. Or, what is better, the teacher might dissect after soaking in water for some time a seedling of the Sycamore, exhibiting the long coiled cotyledons, the radicle, and plumule. Examination in this way of other seeds, *e.g.* the Ash, or Maize, will show that the parts seen in the young seedling are present in some form in the seed, and that in most cases a food store can be demonstrated in addition.

The same points should also be demonstrated by growing the soaked seedlings in glass cylinders (lamp chimneys) or in glass jars. Place the seeds between the glass and blotting-paper kept in position against the glass by filling the chimney with damp sawdust or moss. In this experiment a series of stages should be drawn showing the order in which the parts appear, the downward direction of growth of radicle, upward of plumule, bent form of plumule, etc.

By modifying the conditions of this simple experiment in various ways the teacher should prove the conditions required for successful germination, *viz.* living seed, moisture, air, heat. By growing in light and darkness the relation to light may also be shown. The teacher might prepare the pupils for the result of such an experiment by reminding them of the conditions under which seeds germinate in nature, *i.e.* in the soil (in darkness). The relation to the soil should also be made out, by showing how after a time (usually) growth stops when seeds are germinated out of the soil. A further suitable experiment is that of growing a plant from the seed in a culture solution containing the mineral salts usually found in the soil.

The teacher desiring to develop experimental work with seedlings will find a large number of experiments detailed in Professor Cavers' *Plant Biology* (Clive).

CHAPTER XXI.

THE STUDY OF TREES.

VARIOUS suggestions for the study of trees will be found in the Courses already outlined ; and incidentally in other studies (*e.g.* of leaves). Here the main points desirable for a unified scheme of study of trees are submitted.

The work must of course be practical in the sense that individual trees in the neighbourhood of the school should form, in the first instance, the subjects of observation. These should be studied throughout the year with reference to the following points:—

In spring examine shoots of the trees before the buds are unfolded, during and after opening. This examination is to be accompanied by careful drawings in the case of the unopened and fully opened buds. Drawing of the opening buds may prove too difficult in some cases. Attention should be drawn to the delicacy of the texture and colouring of the spring leaf, mode of folding in bud, special features of bud leaf, *e.g.* silkiness, etc. Shoots should be developed in water indoors.

Note the time of flowering in each case. Examine and draw the flowers. Determine the order of ripening—if female flowers before male flowers. Distinguish wind and insect pollinated trees, and trees with conspicuous and inconspicuous flowers. Keep a record with dates of the order of flowering of different trees in successive years.

Identification of trees in their summer foliage.

Identification by trunk in distinctive cases. Drawings of these.

Identification of fruits and their mode of dispersal.

The foliage in autumn. (See lesson on autumn leaves, p. 224.)

The appearance of the tree in winter. Examination, with drawings, of the winter twigs. Special notes on Evergreens.

Study of the structure of a twig in relation to its functions.

The parts of the work outlined here, which are of a detailed character (*e.g.* examination of twigs), are suited only to the higher grades in school. In general it may be suggested that the emphasis be laid upon recognition studies, accompanied by drawings in the lower classes, and interpretation work in the higher.

Care should be taken not to develop the work along too intensive lines. The study of twigs, for example, may be overdone, so that interest is killed rather than heightened. Of course the quite distinctive appearance of the twigs of trees should be illustrated by reference to good examples, and the lesson may be capped with apt quotation, *e.g.*

“ Kate, like the Hazel-twig,
Is straight and slender, and as brown in hue
As Hazel-nuts, and sweeter than the kernels.”

(*Taming of the Shrew.* Act II., Sc. i.)

Alice's hair is—

“ More black than Ash buds in the front of March.”

(Tennyson, *The Gardener's Daughter.*)

There is the “ruby-budded lime,” a quite distinctive feature of the twig in spring. Some of the best examples

for detailed study are Ash, Birch, Beech, Horse-chestnut, Alder, Elm, Lime.

There should be an attempt made to form general impressions of the various trees, especially of those of more distinctive habit. The teacher, at all events, can appreciate such descriptions as Lowell's of the Birch tree, with

"Foliage, like the tresses of a Dryad,
Dripping about thy slim white stem."

And again,

"Thy shadow scarce seems shade, thy pattering leaflets
Sprinkle their gathered sunshine o'er my senses."

Or Wordsworth's of the Mountain Ash, which

"No eye can overlook, when mid a grove
Of yet unfaded trees she lifts her head,
Decked with autumnal berries that outshine
Spring's richest blossoms."

And he should phrase for himself his impressions, *e.g.* in contrast to the Birch we think of the spreading splendour of a Horse-chestnut in full glory, or of the dark and gloomy interior of the Holly, the blood-red glory of the Copper Beech in spring, and so on.

Then, also, as pointed out elsewhere, the tendency to form "mosaics" should be noticed; the effect of trees as elements in landscape; their climatic and economic importance are also features a skilled teacher can bring before his pupils with good results.

THE STUDY OF A TWIG.

It may be pointed out at the commencement that twigs may be regarded as small stems, since their functions are in general the same. The most satisfactory times at which to study them more particularly are probably spring and winter.

We hold in our hand a winter twig of a Sycamore tree. What can we do with it? What can we learn from it?

First let the pupils draw the twig natural size, colouring it, and filling in markings, etc. Pupils should be encouraged to perform this exercise reflectively, mentally framing questions to be raised later.

Next let us frame a verbal description. What is the general habit of our twig? The twig is straight, cylindrical, robust, about a quarter of an inch in diameter in its internal section. What is its colour? My twig is ten inches long, and I recognise a terminal portion about $4\frac{1}{2}$ inches lighter than the rest. This terminal portion is brownish in colour, with a distinct suggestion of greenness. I peel off a little of the bark here, and find that it is light brown with no green. Beneath it, however, the tissue of the twig is green. The other portion of the twig is darker brown, with no perceptible greenness, and here we see the bark is thicker, so that the green underlying tissue does not show through.

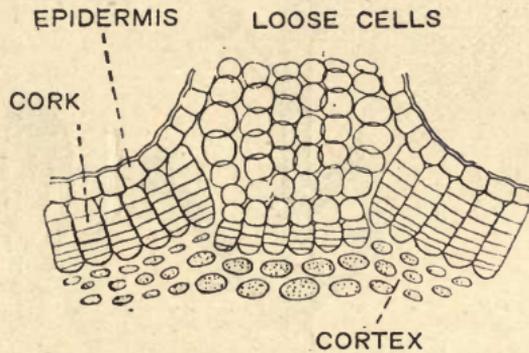


Fig. 128.—Section through a lenticel, magnified.

There is a little gloss upon the bark, but this is not uniform; it is thickly dotted with lightish spots, which form little elevations in shape longer than broad. I examine these with a pocket lens. On the older parts of

the twig these have a distinct slit in the middle, in the younger parts the slits are not so noticeable. Are these accidental scars? What reason can we give for thinking that they are not? They are too constant in shape, and their appearance suggests some relation to the interior of the twig. That is, we are quite sure they are not impressions made on the twig from the outside.

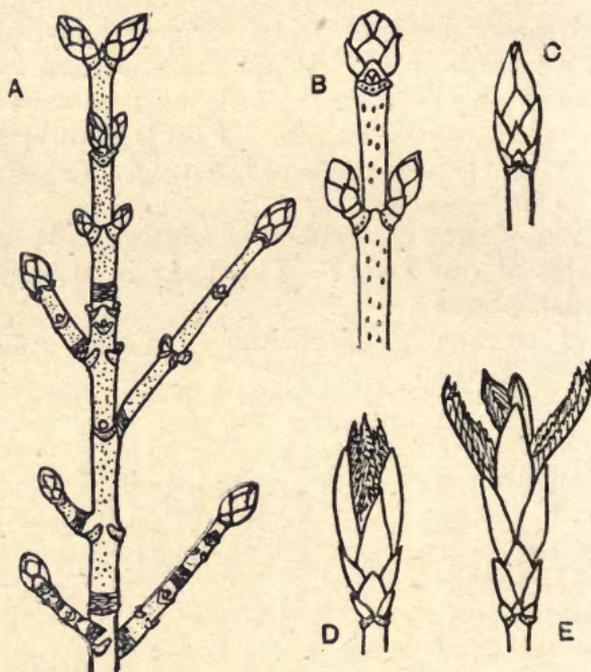


Fig. 129.—Twig of Sycamore. B to E, stages in opening of bud.

Were we able to cut microscopical sections we would obtain further proof of this. We do not find these structures on leaves for example. But on leaves there is no bark such as we find on twigs and stems. The little scars, our microscopical section shows us, are places where the cork which forms the most important part of the bark shows little breaks. The skin (epidermis) is here broken also, so that the soft tissue within is in direct contact with the outside air. If a twig is dipped in boiling water air will be seen to issue from these scars, which are known as

lenticels, and their use is to permit of the passage of gases to the interior of the twig. When the activities of the plant are almost at a standstill in winter, these lenticels are closed by the growth of ordinary cork tissue across them (Fig. 128).

On the terminal section of the twig are a number of buds; they occur in pairs, and each pair is placed at right angles to the pair below. There is also a bud at the tip of the branch. All the buds are enclosed in brownish red or reddish green scales. All this is easily verified.

Beneath each of the paired buds a pale somewhat crescentic scar is visible. On this pale scar a row of darker coloured dots occurs.

Can we tell what these scars are? They mark the place where this year's leaves were attached; their pale surface is due to the layer of cork which cuts off the leaf in autumn, and the small dots represent the now closed channels (fibrovascular bundles) along which the fluids passed to and from the leaf.

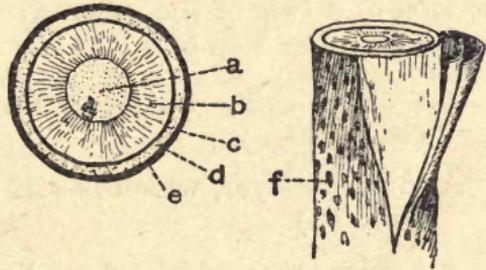


Fig. 130.—Portion of Sycamore twig: a, pith; b, wood; c, region of growth (cambium); d, cortex; e, epidermis; f, lenticel.

along which the fluids passed to and from the leaf.

In the lower portion of the twig in place of buds we observe short side twigs. These are paired, and generally are miniature representations of the main twig. They stand in the same position as do the buds, and have leaf scars below them; they themselves have small paired buds with leaf scars and a terminal bud.

Just above the place where the first (counting from the tip) of these side branches come out, the main twig shows a number of close set ring scars. These are evidently the scars of a number of leaves (scale leaves). On a long twig, if we trace backward from the tip, we find that ring scars of this type occur at regular intervals, although they become less distinct with age. Pupils on reflection may be able to suggest that these ring scars mark the position

of terminal buds of successive years. Or a tree may be marked by having a string tied around beneath the terminal bud of the year, when in due course the correctness of this suggestion will be proved. The ring scars are the marks of the bases of the scales which protect the buds through the winter.

Having verified this, we are now in a position to tell the age of any given section of a twig, provided the ring scars can be recognised. We note also on examining a large twig that there are many buds which remain quite small and do not become branches. Can we suggest their significance?

We may now examine the cut end of the twig. In a section of a twig of the present year's growth, I can distinguish with the help of a lens the following:—

An outer skin, which is also seen upon the surface (Fig. 130, e).

A greenish layer, which is soft and easily penetrated by a pin (d).

A harder layer, which offers distinctly more resistance to the entrance of the pin. It is pale green in colour, and is bounded by a very thin dark line (b, c).

A central soft layer intermediate between the other two, somewhat spongy in texture (a).

This is not, of course, the best method of examination, but if we supplement it by now peeling off the outer layer at the place where it yields easiest, we may be able to understand more readily some things about the twig. We find that separation takes place along the dark green line referred to above. It is easy to tell now from the texture of the cylinder remaining that it consists of wood, and that in the centre of the wood is the soft spongy substance known as pith. We might now profitably compare our section with one of a fairly stout branch when we find that the pith has gone and that the wood here extends to the centre. This is what happens to the pith in woody branches—it is crushed out.

We need not at this stage follow the section further in detail. If a similar twig is peeled in the spring in the way we have done, it will be found to be somewhat wet and sticky just against the wood. There is much sap here at this time, because this is the region where growth in thickness is going on, and although we cannot see it, this is the layer known as the *Cambium*. Just next to it on the outside (the dark ridge we noticed in our first section of the twig) is the region known as the *Bast*, down which the elaborated food passes from the leaves. The water with mineral salts in solution passes up the later made wood.

There are other things to be seen in a section of a twig, but we may leave these undescribed at present.

The foregoing points having been noted on a twig, others of different trees should be gone over and similar observations made. Pupils should also write down the distinctive characteristics of each. The following should be included in the description of a twig.

Season examined :

General habit of twig, *i.e.* diameter ; slender, stout, straight, angled, smooth, rough, or downy ; colour ; odour, if any ; etc.

Markings on bark, *i.e.* lenticels, longitudinal or transverse, large, small ; leaf scars, size, shape, arrangement (opposite, alternate, close, far apart) ; ring scars, distance apart ; etc.

Buds. Size, shape, colour, and any other distinctive feature.

THE FLOWERS OF SOME COMMON TREES.

In the following list the trees are given in approximate order of flowering. The notes refer chiefly to the flowers and their mode of pollination.

Hazel (*Corylus avellana*).—Male and female catkins formed in the autumn both on the same plant, the female protected by the bud-scales through winter; they are mature early in spring (February or March) before the leaves appear. Female catkins much smaller than male; stigmas crimson, spreading. Wind-pollinated. Fruit a nut, ensheathed in the leathery bracts. Leaves alternate, broadly ovate and pointed, serrate. Bark brown, smooth.

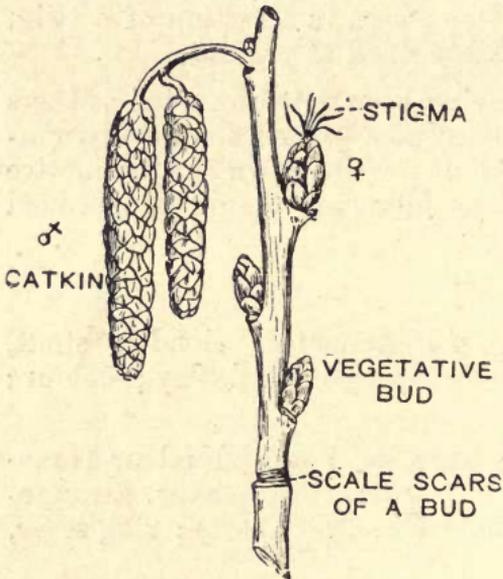


Fig. 131.—Male and female inflorescences of the Hazel.

become woody, persisting after the seed is shed. Wind-pollinated. Leaves obovate, serrate without tip, sticky when young. Bark rough, fissured. Buds flattened on one side—ruddy brown. Habitat—by streams. Seeds frequently distributed by water.

Wych Elm (*Ulmus montana*).—Flowers bisexual, sepals or petals 4 or 5, stamens 4 or 5, in clusters; ripen early in

Alder (*Alnus glutinosa*).—Male and female catkins formed in the autumn both on the same plant; ripen early in spring before the leaves. Female catkins globose,

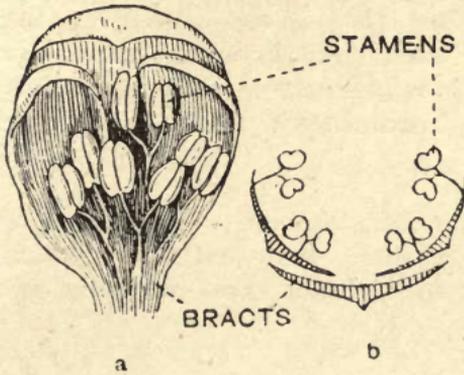


Fig. 132.—Hazel. a, male flower; b, diagram of same.

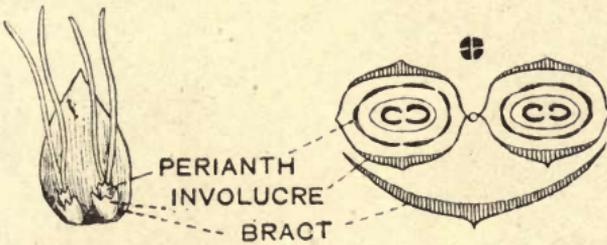


Fig. 133.—Two female flowers of Hazel (note the long stigmas) and diagram of same

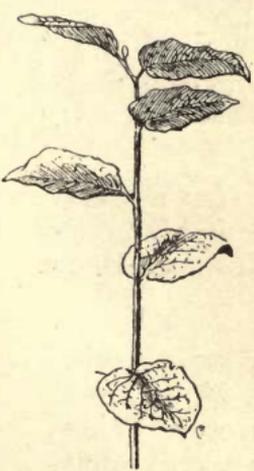


Fig. 134.—Young Hazel shoot.

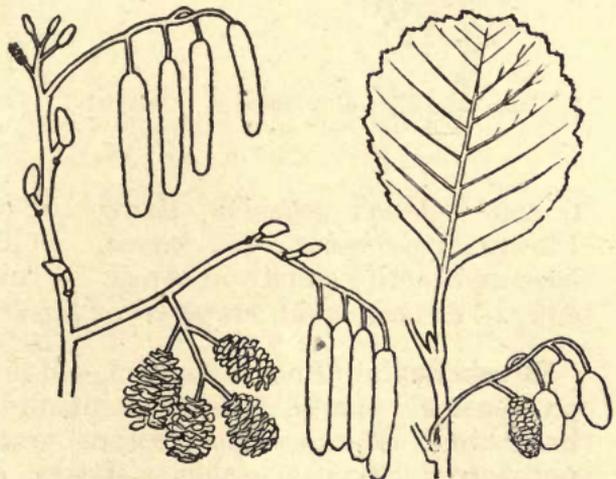


Fig. 135.—Alder. The male catkins are long, the female short. The female ones to the left are in the fruiting stage.

the spring before the leaves. Wind pollinated. Fruit single-seeded, with membranous expansion all round (samara). Leaves alternate, ovate, unequal lobed, pointed, serrated, veins prominent. Bark rough, longitudinally fissured.

Goat Willow (*Salix caprea*).—Male and female catkins upon separate plants. Male catkins golden yellow; each flower consists of a bract, two stamens and a nectary;



Fig. 136.—The Elm, with clusters of fruits.



Fig. 137.—The Willow, with male (lower) and female (upper) catkins.

female catkins greenish, flowers also with a nectary. Flowers ripe before the leaves. Pollinated by humblebees and moths chiefly in April. Fruit a capsule. Buds silky. Leaves ovoid, elliptical or lanceolate.

Black Poplar (*Populus nigra*).—Male and female catkins on separate plants. Stamens numerous (12-20), stigmas branching. Flowers ripe before leaves appear. Wind-pollinated. Fruit a capsule. Leaves on long stalks flattened, broad, tapering, sometimes almost triangular, smooth texture tough. Bark rough, grey.

Ash (*Fraxinus excelsior*).—Flowers in clusters, complete or male and female separate. Both kinds or one only on the same tree. Stamens reddish purple, pistil greenish yellow. In the complete flowers the pistil is mature before stamens. Leaves appear after flowers. Wind-pollinated. Fruit termed “keys” in bunches each with a long



Fig. 138.—The Poplar—twig and catkin.



Fig. 139.—The Ash with a cluster of fruits.

narrow “wing” with a slight twist. Leaves large, compound; leaflets four to seven pairs and one terminal, ovate, lanceolate. Branches stout, twigs curved upward at tip in winter. Bud scales black. Bark greyish, rough, longitudinally fissured.

Oak (*Quercus robur*).—Male and female flowers separate, male flowers in detached clusters in catkins, greenish; female singly on short erect stalks, flower surrounded by a number of overlapping scales (bracteoles) which become the “cup” of the fruit. Fruit an acorn. Leaves appear along with fruit. Leaves with sinuous margins. Bark rough, fissured.

Birch (*Betula alba*).—Male and female catkins separate on same tree. Male pendulous at tips of shoots, formed in autumn. Female catkins erect. Appear along with leaves. Wind-pollinated. Fruit, single-seeded, winged (samara). Three such occur on a single bract. Leaves long-stalked, triangular, serrate. Bark silvery, with brown patches and streaks.

Beech (*Fagus sylvatica*).—Male and female flowers on same tree. Male flowers in purplish brown, clusters at end of long drooping stalk (compare Oak, in which the male flowers are clustered along the stalk). Female flowers clustered in two to four in a cupule of overlapping scales which becomes hard and woody later. Wind-pollinated. Leaves along with flowers. Fruit a nut, occurring two within a cupule. Leaves ovate, glossy, thin. Bark smooth, greyish.



Fig. 140.—The Oak, with flowers.

Insect-pollinated. Fruit popularly termed "Haws," of the same type as the Apple (Pome). Leaves wedge-shaped, lobed. Bark reddish grey, scaly.

Mountain Ash or Rowan (*Pyrus aucuparia*).—Flowers bisexual like hawthorn but smaller, in creamy white clusters (corymb). Fruit a Pome like Hawthorn, scarlet, the rowan. Leaves large, compound; leaflets serrate. Bark smooth, scarred transversely.

Hawthorn (*Crataegus oxyacantha*).—Flowers bisexual in clusters (corymbs), petals white (or pink), stamens pink, fragrant. Appearing after leaves.

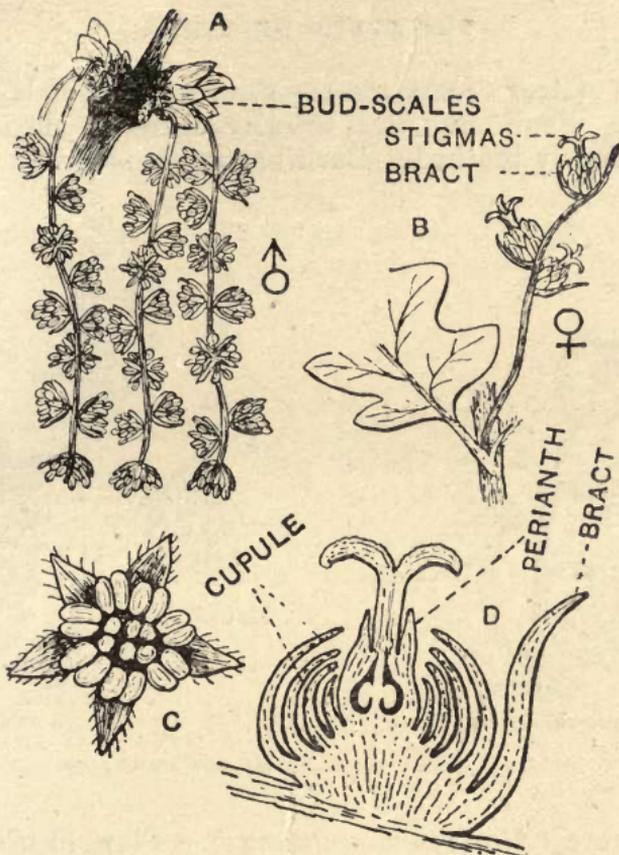


Fig. 141.--Oak. A, male; B, female inflorescences; C, male flower; D, female flower in section.

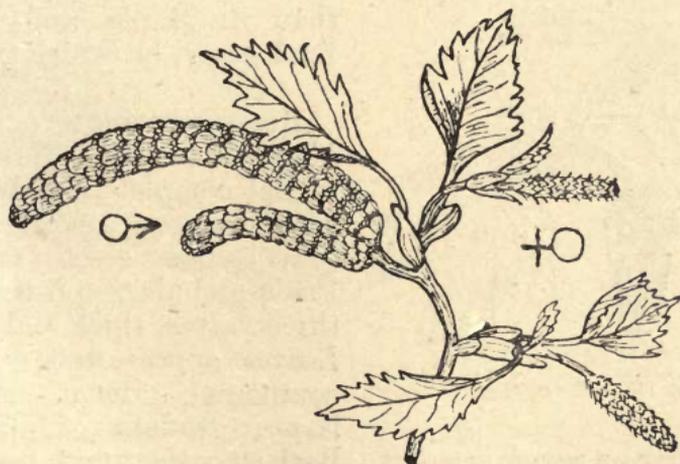


Fig. 142.—Birch twig, showing male (♂) and female (♀) catkins.

Maple (*Acer campestre*).—Flowers greenish in erect racemes. Fruit in pairs broadly winged. Leaves five-lobed, bluntly toothed. Bark brownish, scaly.



Fig. 143.—The Beech, showing Fruit.

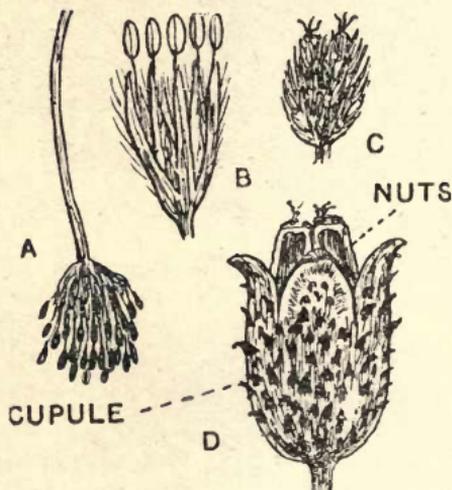


Fig. 144.—Beech. A, male inflorescence B, male flower; C, female inflorescence D, cupule with nuts.

Sycamore (*Acer pseudo-platanus*).—Flowers greenish in pendulous racemes. Fruit in pairs—broadly winged. Leaves more finely toothed than in Maple and larger. Bark scaly, brownish grey.



Fig. 145.—The Sycamore.

sizes, five or seven usually. scaly.

Horse - chestnut (*Aesculus hippocastanum*).—Flowers bisexual complete, petals white with crimson markings, in conspicuous erect racemes. Fruit globular, splitting into three valves, thick and spiny. Leaves appear first. Leaves compound, long - stalked, large; leaflets of different sizes, five or seven usually. Bark smooth at first, becoming scaly.

Hornbeam (*Carpinus betulus*).—Male and female catkins separate, greenish, male pendulous from axillary buds, female usually terminal. Fruit a nut attached to a three-lobed persistent bract serving for wind distribution. Leaves alternate, ovate, pointed, serrate. Bark smooth, grey.



Fig. 146.—The Horse-chestnut—leaf, flowers, and fruit.



Fig. 147.—The Hornbeam, with cluster of fruits.



Fig. 148.—The Lime—leaves and flowers.

Lime (*Tilia vulgaris*).—Flowers small, bisexual, yellowish green, in umbel-like clusters, attached to middle of the surface of a long bract which serves in the distribution of

the fruit. Fruit a nut. Leaves thin, tender, rounded with pointed tip, serrate, unequal sided. Bark smooth, dark in colour.

PUPIL'S DESCRIPTION OF A HAWTHORN TREE.

I examined a woody shrub or tree which I pass on my way to school. It is about fifteen feet in height; the trunk is about ten inches in diameter at the base. Its bark is scaly and of a reddish grey colour. Branches arise apparently in an irregular manner from quite near the ground. (I understand that buds sometimes occur on the roots.) The branches bear others again in turn, all of which give rise to short reduced leaf-bearing branches, the leaves of which have flower buds in their axils. The large branches are all woody, the reduced ones are softer but have a covering of brownish bark at their lower extremity.

The branches bear spines for protection. These are woody, sharp, about half an inch in length. They are



Fig. 149.

Series of leaf stalks of Hawthorn, showing grades of variation of stipules.

modified branches, and arise between two of the short leaf-bearing ones already referred to or alongside one of them. After these have fallen away, the spine frequently lengthens and produces short leaf-bearing branches itself, thus clearly showing its true nature.

The leaves are simple, alternate, and have stipules, which are very variable. On the younger leaves they are large and leafy, and a gradation may be traced through almost

linear forms to mere brown specks. They are also frequently unequal in size (Fig. 149).

The leaf-stalk is slender and has a median groove on its upper surface. The blade is cuneate and is lobed, three and five lobes being the usual number, but seven is also common. Gradations may, however, be traced from the undivided blade (Fig. 150).

There are a few soft hairs on the under side of the blade ; the upper surface is smooth.

The flower clusters are of the type described by botanists as a corymb. Those flowers in the centre of the cluster are furthest advanced, and those on the outside least so. The flower stalks are short and their tops are expanded into a cup on the edges of which are the five small tooth-like sepals.

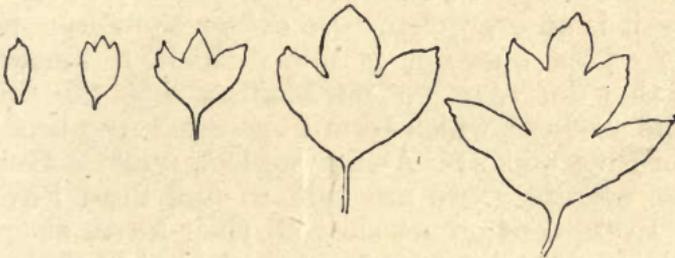


Fig. 150.

Outline of blade of leaf of Hawthorn, showing gradations of lobing.

There are five free white petals, imbricate in the bud, arising on the edge of the aforementioned cup. They are roundish in form with an irregular margin. There are about twenty stamens with pink anthers turning brown as they ripen. Within the cup are the seed vessels, one or more in number. The stigma on the top is slightly expanded and is sticky. The cup is hairy around the base of the style, and the whole inner surface seems modified as a nectary. The anthers split inwardly and tend to curl inwardly when ripe. The stigma is ripe before the anthers. The flowers have a pleasant odour.

THE SPRUCE FIR (*Picea excelsa*).

The Spruce Fir is probably most familiar to pupils as a Christmas tree. But many will also know it as a forest tree, *e.g.* in the north of Scotland. It is a tree which grows well in high situations; it is the principal forest tree in the higher districts in Germany, and on the Alps it grows at heights approaching 6,500 feet.

The lesson may be given about Christmas time, when most pupils will have an opportunity of examining a tree. It will of course be a young one, if used in connection with Christmas festivities, but that will not matter much.

What are our general impressions of the tree? First, may we not note its *greenness* in winter? Most trees in our country shed all their leaves every year, but the Spruce tree is an example of another type, which is never bare of leaves—it is an evergreen. Do evergreens never shed any leaves? This question is not difficult to answer. Of course they do. Are we not familiar with the thick felt of “pine needles” which form a spongy carpet beneath the trees in Pine woods? And if we look under a Holly tree, another evergreen, we are sure to find dead leaves here also. Evergreens do not shed all their leaves at one time. If we look at the inner parts of the branches of the Spruce Fir we shall see the scars left by the fallen leaves. These scars will be seen to be arranged in an orderly series of spirals around the branch.

Our second general impression is, I think, its shape. It is a very symmetrical tree. Its branches, if they have not been broken off, come out quite low down the tree, and there is a very regular gradation in size upwards, so that a marked pyramidal or conical form is produced. This symmetry is a mark of a very regular growth, and may also be regarded as an indication of the natural hardiness of this tree. Exposure on any one side does not seem to affect the form as it does on many other trees.

Some details are worth noting. For example, there is the shape of the trunk. It also tapers very evenly; it is, in fact, a greatly elongated cone. Note also the droop of

the main branches, a downward curve due to the weight and a rise again at the growing end. The side branches also show a similar droop. The uppermost branches stand more erect. These features are very noticeable in the firs.

Thirdly, we notice its smell. It has a pleasant resinous odour.

Let us examine a small twig; verify the following. At the end next the branch there are brownish scales. At the free end there is a small bud covered with similar scales. The former are evidently the scales of the bud, out of which the twig developed. There are also in the twig I am examining several lateral buds in the axils of leaves near

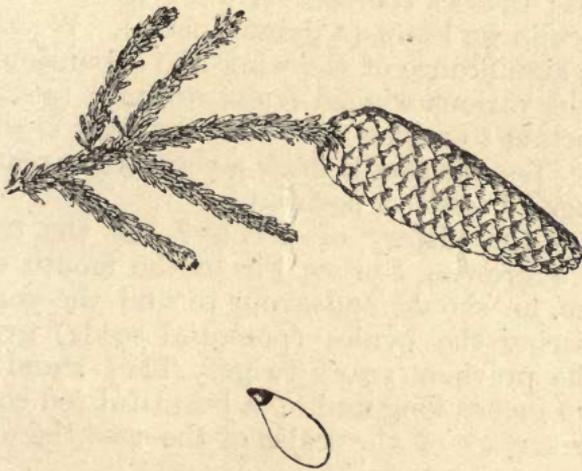


Fig. 151.—Twig of Spruce-Fir with cone attached. Below, a winged seed drawn upon a larger scale is figured.

the tip. The terminal bud and some of the lateral ones will develop new shoots the following spring. The leaves are arranged in close set spirals round the twig, they are linear, four-cornered in cross section, and show on their surface minute whitish specks, which are drops of resin.

When a grown tree is examined cones are found upon it. The Spruce, Pine, Larch, and a number of other trees are known as conifers or cone-bearers. What are these cones? If we examine an ordinary cone on a Spruce tree we find it hanging at the tip of a branch. It may be as long as five or six inches; it is brown in colour and consists of a number of strong, not very thick, overlapping scales. They are arranged in spirals. Pupils should trace the spirals round the cone.

If we examine these cones in the spring we will find that the scales stand slightly apart. With a little trouble we can cut out one or two when we find that beneath each there are two small seeds each with a thin membranous wing-like attachment. We thus see that a cone is a kind of fruit. It is important to notice that it is an open fruit; that is, the seeds are not shut in as they are in most fruits we know (a gymnosperm). We also understand the significance of the wing-like expansion, when we recollect the various winged fruits we know (p. 239). But it is important to notice that here the seed is winged, not the fruit. Let the pupils draw a cone and a scale with its two "winged" seeds in position.

What is the history of a cone? If the teacher has access to a growing Spruce Fir in the month of May or early June, he should endeavour to find the young cones. Those bearing the ovules (potential seeds) grow at the end of the previous year's twigs. They stand erect, are nearly two inches long and of a beautiful red colour. On the upper surface of the scales of the cone the ovules with their wings may be seen.

Amongst the leaves of other branches on the same tree are to be found the male cones. They are not terminal but lateral; they are smaller and green in colour. Beneath the green leaf-like covering are the red stamens, and on their under side may be seen the pollen sacs. When mature these pollen sacs split and the pollen is borne on the wind to the female cones, where it reaches the ovules and pollination thus takes place. The pollen grains are of special interest because each grain has a pair of small air-bladders attached which float it on the wind.

These grains with their bladders are too small to be seen with the naked eye, but the teacher should take some trouble to obtain the young male and female cones in season and to let the pupils examine them.

Let the pupils write out as many facts as they are familiar with which show how the wind is a great maker of seed and a planter of trees.

CHAPTER XXII.

ELEMENTARY STUDIES OF FERNS.

FERNS may be grown successfully in school for ornamental purposes. A place may also be found for them in any warm, moist, or shady corner of the school garden. Pupils will also be familiar with their occurrence in woods and other shady situations.

The following brief notes are given as suggestive of lines of simple study which might be followed with a view to developing intelligent interest. Let us ask our pupils a few questions. Have they ever seen flowers upon ferns? Most will answer no; but some one may have seen or heard of the "flowering fern." Ferns are non-flowering plants, and we shall for the moment put aside the question of the so-called "flowering fern."

Our next question is: What are the parts of the fern we are familiar with? The large green leafy "fronds." What are fronds? The fronds are the leaves. But we shall note that some of them serve a purpose not served by the foliage leaves of flowering plants. From what do the fronds arise? If we dig up an ordinary bracken fern out of doors or any of the usual ferns grown in pots, we shall see that the long stalks of the fronds arise from a somewhat stout dark-coloured "rootstock" underground, but near the surface. This rootstock is really an underground stem and from it there pass down into the ground fibrous rootlets.

Let us return to the fronds. Have we ever noted how they arise in the spring, or how they are folded in the

bud? The frond stalk is in most cases coiled in a flat spiral, like a bishop's crosier. If ferns are grown in school, endeavour to get drawings of the unfolding of the frond.

Make a series of drawings of the shapes of the frond in as many ferns as are available. Some are simple, e.g. Hart's-tongue. The common Polypody has a simply lobed frond (the lobes are termed pinnae); other ferns with comparatively simple fronds are the Hard Fern (*Lomaria spicant*) and the Royal or flowering fern (*Osmundia regalia*).

In most other cases the frond is very much divided. For example, in the Bracken (*Pteris aquilina*) near the tip the frond is cut into simple segments (pinnae), lower down these pinnae repeat the main structure and are themselves divided into segments or lobes (pinnules); still lower on the frond the pinnae are stalked, a foot or more in length, and again pinnate, the pinnules about 1 inch in length. All these points should be verified upon a frond.



Fig. 153.—Pinnule of Male Fern with sori.



Fig. 152.—The Male Fern.

On the backs of some of the fronds will be found small brownish masses, varying in size, position, and shape in different ferns (Fig. 153). These masses are clusters (sori) of spores. These spores are sometimes wrongly termed seeds. In the Royal fern some of the fronds bearing these spore masses are altered and contracted so that the groups of spores are clustered together forming a brownish red mass, resembling an inflorescence of a flowering plant. This is the supposed "flower" of this fern. But if we

examine it closely we shall see that it is not a flower.

What are spores? These bodies, when sown under

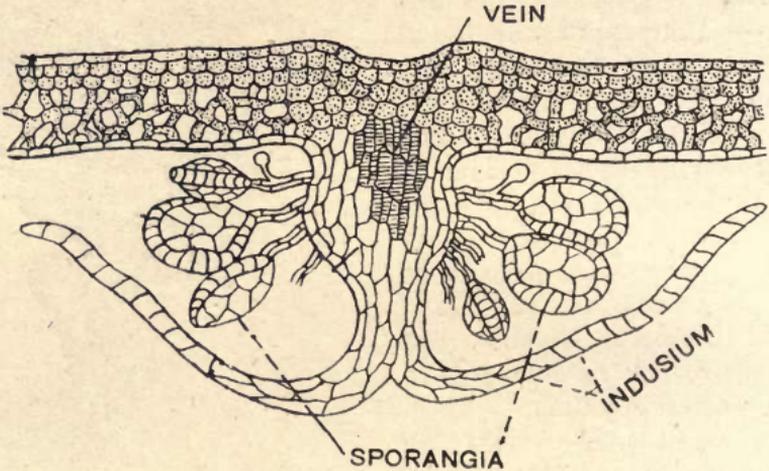


Fig. 154.—Sporangia of Male Fern.

Transverse section through a pinnule and sorus. The spores are within the sporangia.

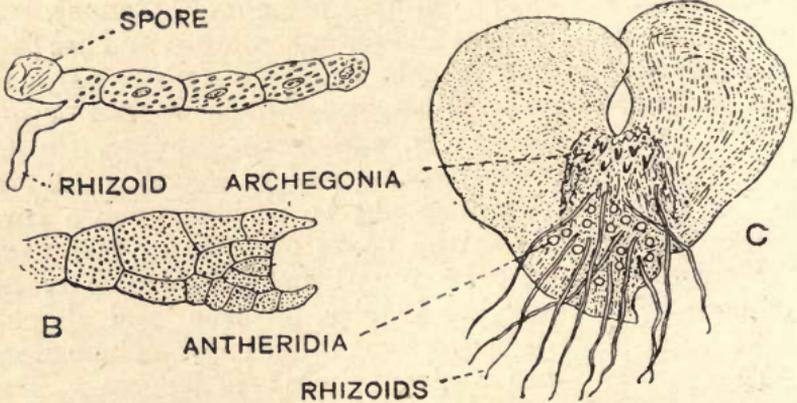


Fig. 155.—Germination of Spore and Development of Prothallus of Fern (A and B).

The archegonia and antheridia are the female and male elements respectively.

C, Under side of Prothallus.

suitable conditions of soil, moisture, heat and light, give rise to very small heart-shaped green blades, known to botanists as prothalli (Fig. 154). The prothallus is the

part in the life-history of a fern which may be compared to a flower of a flowering plant, because it bears on its under side the organs corresponding to pollen and ovules, and it is from the under side of this prothallus that the leafy fern arises (Figs. 155 and 156).

The arrangement of these spore masses is very definite in the different ferns and is made the basis of classification. Pupils might verify some of the following points.

(a) The groups of brownish spore masses (sori) are not covered by a membrane (indusium) in the common Polypody, Oak fern, or Beech fern.

(b) The spore clusters (sori) are on the under side of the pinnules and are covered by an indusium.

Examples: Male fern (indusium is kidney-shaped).

The Bladder fern (indusium, bladder-like).

(c) The spore clusters (sori) are on the back of the fronds, linear in form; the indusia are scale-like. Examples: The Lady fern, with many small sori, variously curved in outline; the Maiden-hair spleenwort, with numerous short sori, crowded and becoming confluent, the indusium pale brown, free, with entire edges; the Hart's-tongue with linear sori parallel at right angles to midrib.

(d) The spore clusters (sori) are upon the margin of the frond, which is recurved upon them. Examples: Maiden-hair fern, Hard fern, and Bracken.

(e) In the Moonwort and Royal fern the spore clusters are grouped in inflorescence-like masses.

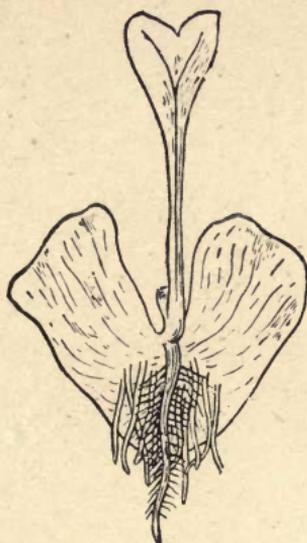


Fig. 156.—Young Fern still attached to the Prothallus, growing from an archegonium.

A simple comparison might profitably be made between the ferns and the mosses by showing how the leafy fern which bears the spores corresponds, not to the leafy moss, but to the stalk and capsule borne upon it, thus—

Leafy fern with spores	=	stalk and capsule with spores,
arising on prothallus		arising upon leafy moss by
		a sexual process.
Prothallus of fern	=	leafy moss.

CHAPTER XXIII.

PROCESSES OF DECAY.

(AN AUTUMN OR WINTER STUDY.)

THE decay and disappearance of vegetation in the autumn, as well as the death of many forms of animal life, suggests an inquiry into the agencies at work in the disintegration of organic bodies.

Our first question to our pupils in introducing this subject might well be, What becomes of the leaves which fall from the trees in autumn? The answer is, they decay in course of time. What is decay? In terms which our pupils will understand we say it is the breaking up of the substances which at one time formed part of a living body into simpler substances until out of them ordinary constituents of soil and air are formed, viz. carbonic acid, water, and ammonia. And the work of decay is carried out by microscopic plants known as bacteria, aided to a small extent by larger plants, the moulds, toadstools, and mushrooms (Fig. 157).

We cannot see the bacteria, but we may very easily demonstrate their effects. We perform the following experiment.

Experiment.—Take two small thin glass flasks, into which place some organic stuff, e.g. fruit juice, or chopped-up autumn leaves. To both add a little water. If fruit juice is used the demonstration will be made more effective

by filtering the juice free from all sediment. Label the flasks A and B, and note the date of the experiment.

Take flask A and boil the contents for some time. While the flask is boiling prepare from clean sterilised cotton wool (supplied by the chemist) a small plug with which to stopper the flask. When the liquid is boiling and *while the steam is issuing* from the flask, insert the

plug of cotton wool, screwing it in tightly. Flask B, which contains the same substance as A, is to remain open. Set the flasks aside and compare the contents from time to time.

If the experiment is properly performed, the substance in A will remain perfectly fresh for years, whilst that in B will decompose owing to the presence of bacteria and the spores of moulds, etc. By boiling, all bacteria adhering to the inside of the jar, or present in the water or in the organic substances, are destroyed, and the cotton wool acts as a filter, keeping those outside from

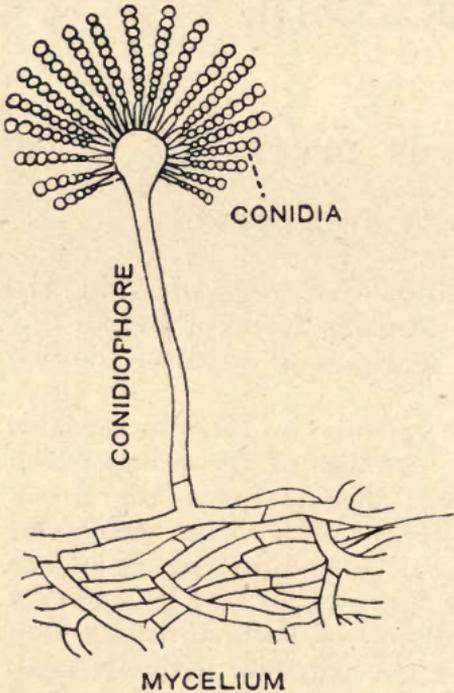


Fig. 157. — Mycelium and spore-producing branch of a common mould (*Eurotium*).

getting in. The spores of some bacteria are not readily killed, and sometimes it is desirable to repeat the boiling after a few days, but usually in an experiment of this kind one boiling gives convincing proof that the agents of decay have been destroyed.

Following this demonstration it is appropriate to refer to the widespread occurrence of bacteria, some of which enter the bodies of living human beings and animals, causing disease, and to the necessity of fresh air in

dwellings and clean bodies and clothes. Bacteria are more numerous in ill-ventilated rooms than in fresh air.

Other demonstrations of decay processes which may be given are the growing of moulds on damp bread or jam kept in a close atmosphere, *e.g.* in a closed tin vessel or under a bell jar. Pupils may be familiar with the occurrence of a fungus disintegrating wood, and sometimes causing serious damage in houses—the Dry Rot fungus.

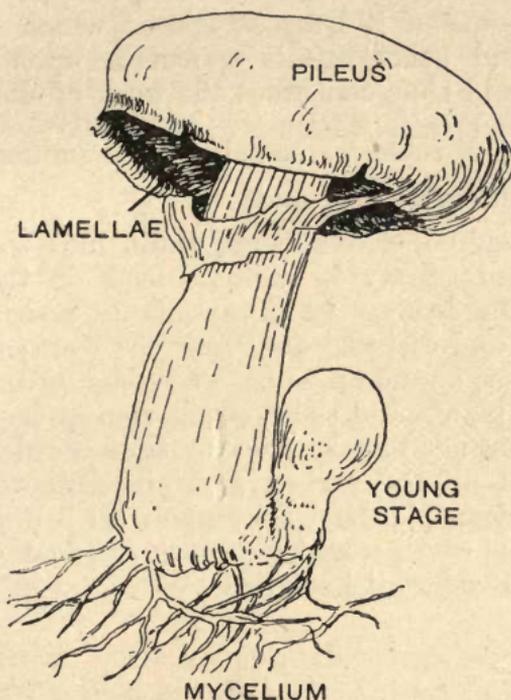


Fig. 158.—Mushroom. The spores are borne on the lamellae or gill-like plates below the cap (Pileus).

A note should be made of the appearance of toadstools in the woods amongst decaying leaves or tree stumps. A lesson should be given on the parts of a toadstool or mushroom (Fig. 158). The following experiment should be performed:—

Experiment.—Gather some toadstools, cut them up, and placing them in a clean porcelain vessel, char over

a spirit lamp flame or Bunsen burner. When all moisture has evaporated, cool and note the black residue. This is carbon.

From what source did the toadstool obtain the carbon? From the atmosphere? No, because these plants do not have any green colouring matter, without which carbon cannot be obtained from the air by plants. From the soil? Yes, from dead vegetation chiefly. Eventually the great bulk of the toadstool becomes subject to bacterial forces, but some of it lives as spores, which scattered by the wind and other agents sporulate upon other dead vegetation, and thus continues the work of disintegration.

In conclusion these lessons should be summarised thus:

Note the circulation of matter.

Soil and air constituents are built into the bodies of plants. Plants decay or animals feed on them: eventually animals decay. In decay plants and animals are decomposed and disintegrated into the compounds carbon dioxide, water, ammonia, etc. These again are made use of by living plants and the cycle is re-commenced. Were decomposition not to take place a time would eventually come "when all the carbon and nitrogen would be imprisoned in dead plants. Thereupon all life would cease, and the whole earth would be one great bed of corpses" (Kerner). Beneficent bacteria!

CHAPTER XXIV.

ELEMENTARY STUDIES OF SOME COMMON ROCKS.

GRANITE.

THEORETICALLY, perhaps, the expert teacher of nature study should cull his lessons from the material most ready to hand about the school. But in actual practice there is no question that the most effective geological lessons will be taught from carefully chosen material—selected with a view to its fitness for clear instruction wherever it comes from. Local material may of course be discussed during excursions or when pupils bring it in, but it does not necessarily make suitable material for indoor lessons merely because it is local.

Now a lesson on Granite should be given off specimens of as coarse-grained a granite as is procurable. Fairly good types are the well-known granite of Shap (Westmorland) or Colcerrow (Cornwall); they may easily be got from any dealer, or by writing to the quarries direct. Still better is the “giant granite” (Pegmatite) found in veins traversing granite quarries, and used in some localities for building rockeries. Each child should, if possible, have a specimen. The lesson may be conducted as follows:—

1. Emphasise the difference between a mineral and a rock. It would be well for this purpose to procure a tolerably big specimen of each of the three minerals,

quartz, felspar and mica, and show them to the class as individual mineral types. Point out that a mineral is a single substance, with uniform* characters throughout its mass, such as colour, hardness, transparency, lustre, and so on. On the other hand, rocks like granite are mixtures of minerals. This is more especially true of igneous rocks.

2. This leads to an enquiry as to how many constituents are present in the granite that is being studied. In normal granites the characteristic ingredients are three. They can be identified, and their leading characters be determined by the pupils themselves, if they are guided to look for the following points :—

- (a) Quartz—glassy, shapeless, colourless or less commonly brownish, not scratched by pin-point or knife however hard pressure be applied, transparent, broken faces rather rounded or shell-like, unaffected by a drop of acid laid on it.
- (b) Felspar—frequently two differently coloured felspars are present, the commonest tints being a flesh-red and a white or bluish-grey, shape less rounded than quartz leaning to four-sidedness, lustre more pearly than glassy, opaque, very hard but not quite so hard as quartz, breaks in some directions with nearly flat faces, unaffected by a drop of acid.
- (c) Mica—a mineral familiar to children as “sheep’s silver.” In a granite there may be two micas, a black and a silvery white; both are very soft, easily scratched with a pin, they split (“cleave”) into very thin scales which are flexible. The flat faces are very bright and shining. The shape is six-sided, but it is only sometimes possible to see this in a rock.

* This is only approximately correct.

Besides these three normal constituents of granite, other minerals will at times be detected, which may be recorded but they need not be discussed in detail, unless the teacher himself happens to know them.

After a careful study of the individual constituents, the general characters of the rock may be discussed—the colour as a whole, generally determined by the felspars, the coarseness or fineness of grain, the size of the individual constituents, the relative proportions of the ingredients in a square inch surface, and any other points the teacher may see fit to raise. The general crystalline character of granite may be emphasised by comparing it with a bit of clay or chalk or other sedimentary rock.

The question of the origin of granite is one that must be left to the discretion of the teacher. Perhaps it is too difficult a subject to discuss in any detail. But the attention of the children may be called to the industrial uses of the ingredients of granite and of granite itself. Thus mica, which is mined in huge sheets in Russia, India and elsewhere, is used in lamp-chimneys, in glossing wall papers, and so on. Quartz is used in making “pebble” spectacles and in other ways, and its coloured varieties form the amethyst, the cairngorm, and other gem stones. The uses of granite itself will be familiar to most pupils.

Attention may be directed to the weathering of granite on hillsides into artificial-like masses—“tors.”

CLAY AND SLATE.

Material.—One or more specimens of clay for each pupil.
 “ “ “ slate “ “

An indoor lesson on rocks may either take the form of a purely observational exercise, or the exercise may be made the text of a subsequent lesson in which the history or the uses of the rock may be explained to the pupils. The time at the teacher's disposal will determine the method he adopts. But the pupils' interest will be best secured if

the latter aspect is not entirely omitted. For an isolated specimen of a rock may not have much to arrest attention, but its history or its use may at once supply the required stimulus to intellectual interest. "Clay" is not, to most people, a particularly inspiring theme, but the history and the uses of clay and slate are both interesting and instructive.

(1) An exercise in observation.

The pupils may be put through a series of simple tests as follows :—

Clay—its colour—its fine grain—its crumbly, meagre feeling in the fingers—its earthy odour when breathed upon—its power of adhering to the tongue—its softness under the knife or any sharp edge—its glossy surface when cut—its absence of lustre as compared with glass—its willingness to split or cleave—its degree of porosity, how far it admits water—its plasticity when wet—its purity, that is, how far it contains foreign minerals like "sand" and mica—its behaviour with hydrochloric acid—its rate of sedimentation in a jar or test tube, as compared with sand.

Slate—as compared with clay :—Same fine texture—often same colour—but relative hardness under knife or pin-point, though easily scratched—its greater compactness—its flatness—its remarkable proneness to split ("cleave") in one direction—the varying glossiness of its surface—the bands or stripes sometimes seen on flat faces. A slate may be powdered down and the characters of the powder compared with those of clay.

These are all points which the pupils, with judicious guidance, may be led to find out for themselves. But there are some things a child may wish to ask about, which cannot be readily answered from an examination of the specimens before him.

(2) The origin of clay.

The question is one that cannot be fully discussed with children. But the teacher can easily procure, say from one of the clay pits in Cornwall (St. Austell), a specimen of granite, showing the decomposition of the felspar into white Kaolin (China clay).

This will demonstrate to the class clearly enough that clay, or at any rate some kinds of clay, arise from the decomposition of one of the constituents of granite.

The cause of the decomposition is an inquiry beyond the limits of the school course.

(3) The origin of slate.

It has been abundantly proved that slate is just clay hardened and altered by pressure. Slates are commonly found on the flanks of mountain ranges where tangential pressure has been great.

It can be shown experimentally that if wax, for example, be mixed with iron filings and subjected to severe tangential pressure, the filings take up a position with their flat faces perpendicular to the direction of pressure. This illustrates what has happened in the production of a slate.

The pressures of mountain-making cause the particles of an original clay or shale to rearrange themselves perpendicular to the direction of pressure and therefore with their flat faces all parallel, and hence slates split or "cleave" readily parallel to these flat faces.

Of course in nature the process takes place on a great scale and extends over long periods of time, and the slate may undergo other changes.

The teacher will find the origin of slate described in any elementary text-book of Geology.

Again, attention might be directed to the different

(4) varieties and uses of clays.

There are many different kinds of clay :

China-clay (used in porcelain manufacture),

Brick-clay (used for bricks and tiles),

Fire-clay (used for fire-bricks and anything that has to resist high temperatures),

Terra-cotta-clays, pipe-clay, Fuller's earth, and so on.

It is the commonest things in nature that are the most useful.

SAND.

Material.—One or two samples of sand for each pupil, laid out in a watch-glass or on a slip of paper.

Sands are easily gathered and easily stored ; they are clean and easily handled and in other ways very suitable for lessons with children. The teacher will find, if he once begins to make a collection of them, that they vary remarkably in appearance and character. Some are rough and gritty (Peterhead, etc.), some are rather finer (Aberdeen) and show nearly the same constituents as granite, some are crowded with broken or complete shells and other organic contents (St. Andrews), some contain bits of limestone, ironstone, etc. (Scarborough), some have abundant fragments of flint (Yarmouth), some are remarkably varied in colour (Alum Bay, I.W.), some are rich in heavy metallic ores like tin (St. Ives), some have a proportion of very round grains like little balls (Soudan).

The leading constituents of most sands are quartz (glassy, often clear) and felspar (opaque, more pearly, red and other colours), but not a few contain white mica, and some sands even in this country are nearly entirely made of calcareous matter, and therefore dissolve away in hydrochloric acid.

If the teacher is not disposed to collect samples during the holidays, he can easily procure them from friends who live in coast towns, or through dealers.

(1) A simple exercise is to ask the children to describe the one or two samples placed before them. They will note such points as the colour of the sand as a whole—the coarseness or fineness of the grains—the degree of rounding or angularity of the grains—the number of different ingredients—the most abundant constituent—transparent grains and opaque grains—the presence of shells, spines of sea-urchins or organic constituents of any kind—whether any grains are attracted by a magnet (magnetic iron-ore)—whether the light or the dark grains sink fastest in a test-tube with water—whether acid affects any grains—the difference between the grains of sand and of clay when rubbed on glass, and so on.

All these points can be discussed though the teacher knows nothing of the composition or characters of the minerals that make sands. But for his own comfort of mind it would be better that he should have an elementary acquaintance with minerals.

But too much of this type of exercise might become tedious. The teacher should vary the work and interest the children by referring to other aspects of sands. Two illustrations will here suffice.

(2) The drifting of sands, and the formation of dunes.

Reference may be made to the destructive action of dunes, exemplified in so many places along our coasts, where sand hillocks are gradually encroaching upon agricultural lands and have even been known to bury villages (Eccles, Norfolk).

(3) A comparison of sand with sandstone.

The child should be told, or led to find out for himself, that sands and sandstones are essentially the same thing. Crush a sandstone and you produce sand. Sandstones are simply ancient beds of sand compacted into solid rock. This opens out a wide field of inquiry about stratified rocks and their history, into which the teacher may wander as far as he dare.

CHAPTER XXV.

THE SCHOOL GARDEN.

AN important adjunct to the nature work is the school garden. It has a place in education which is quite distinctive, especially in rural schools where the industrial aspect of it receives prominence. Apart from this, the school garden is most appropriately an important centre of interest both for teachers and pupils alike who are engaged in nature studies. It is a place in which horticulture is practised and the art acquired in such a way that pupils obtain an understanding of nature's processes and of the effect of varying external conditions upon vegetable life. School gardening wisely taught ought to foster an intelligent interest in country life.

Incidentally the garden should also be used for general nature work. It may be used as a place in which to study the interrelations between plant and animal life as well as those of the plant and its inanimate environment. It ought also to prove a fruitful source from which to draw materials for detailed examination and study indoors. In town schools in particular, where the best type of nature study is admittedly difficult, the school garden goes a long way to solve the problem.

Local circumstances will generally determine the particular form the work in school gardening is to take. In most cases emphasis is naturally laid upon the practical aspect of such work, and whilst this is no doubt a sound principle to go upon, the aesthetic value of gardening should be recognised. It is possible so to arrange a garden that flower-beds, trees, and shrubs give it a pleasing aspect

without interfering with the cultural plots worked by the pupils.

For the guidance of teachers whose duty it may be to introduce or work a school garden the following hints, quoted by the kind permission of the authors, are submitted. The Report* from which the extracts are taken is the result of an inquiry into the general practice followed throughout Great Britain.

“On behalf of school gardening it is maintained that, apart from its purely educative value, it gives to boys backward at bookwork an opportunity to excel, and awakens in them a keener desire for general improvement. In some cases it has been found that the arousing of the interest of the duller boys by gardening has resulted in better attendances and an improved moral tone in the schools.

Types of School Gardens.

The following types of gardens are to be found in different parts of the country:—

(1) The Common Garden, where the pupils co-operate in working the whole garden according to the direction of the teacher.

(2) The Plot Garden, where the garden is divided into plots and two or three boys are allotted to each plot.

(3) The Individual Plot Garden, where each boy of the class is given a plot.

(4) A combination of the Common Garden and the Individual Plot Garden.

Each of these types has its advantages, but there is much to recommend a further modification of the Common Garden (1) and the Plot Garden (2).

* *Report to the Governors of the Aberdeen and North of Scotland College of Agriculture*, by R. H. N. Sellar and G. G. Esslemont.

Plan and Size of Garden.

A School Garden is commonly a rectangular area enclosed by a simple fence, and as a rule is in a corner of a field near the school. The size of the garden varies with the number of pupils and with the system adopted. In general from one-eighth to one-fourth of an acre is sufficient, and where there is a difficulty in getting ground gardens are even smaller.

In the plot systems, which have been most generally adopted, the garden is divided into rectangular plots varying in size from about one rod or square pole (ten yards by three yards) in the case of individual plots, to one and a quarter or two rods where the plots are worked by two or three boys. Experience has shown that smaller plots, besides being too small to furnish scope for the pupils' energies, are likewise too limited to provide a sufficient variety of crops and give a useful quantity of produce—a most important point when the produce is sold. Usually a gravelled path runs the length of the garden, on either side of which the plots are arranged. A space of one and a half to two feet divides each plot.

For a modified type of garden, as already suggested, from one-seventh to one-eighth of an acre would be sufficient for a class of twenty pupils.

The plan on page 291 illustrates a garden of this type for a class of twenty boys.

Garden Crops.

Gardening, as seen at the different centres, is mainly confined to the growing of the ordinary vegetable crop suitable to the district. In most cases the boys are encouraged to grow a few hardy flowers in their plots, and occasionally a herbaceous border forms part of the common garden. So far there has been little done in fruit culture.

Teachers with experience are much against complicating the work by too great a variety of crops and by manurial tests.

Although individuality is encouraged in this work it is generally found desirable to insist on the same crops being grown in the same order in each plot. Otherwise the greatest difficulty is found by the teacher in maintaining discipline, arranging the lesson for the day, and supervising the class at work. This arrangement also facilitates order and tidiness in the garden.

The disposal of the produce rests with the teacher. In some instances the boys sell the produce of their plots and the money thus obtained goes towards the annual upkeep of the garden. Very often the produce is given to the boys as a reward.

Plan and Size of Plot with Crops.

The plan on page 293 illustrates two adjoining plots, suitable for two pupils each, with a suggested scheme of cropping for a School Garden in the North of Scotland.

The Work of the Garden.

Instruction and practice in the use of tools is a necessary preliminary to work in the garden, which embraces such operations as: The manuring and digging of plots in autumn; the preparation of the soil for seedlings in spring; the sowing of seeds; the thinning of seedlings in beds and of crops generally; transplanting; weeding; hoeing and the stirring of soil; the care and management of crops; the proper harvesting of crops when ripe; the storing and useful disposing of crops; the weighing of crops; general tidying of the garden, etc.

In addition each boy keeps a note-book provided for the purpose, in which he draws a plan of the garden to scale with his own plot distinctly marked, usually by a light wash of colour, and enters an account of the work as it proceeds, with dates of the more important operations, such as seeding, planting, thinning and harvesting of crops, etc. Coloured drawings of plants and parts of plants grown in the plots are also made in these books.

Plan to illustrate a Suggested Scheme of Cropping for a School Garden.

<i>No. 1 Plot.</i>		<i>No. 2 Plot.</i>	
2 ft.	Beans.	2 ft.	Beans.
3 ft.	Cabbages.	3 ft.	Cabbages.
1 ft.	Carrots.	1 ft.	Carrots.
1 ft.	Parsnips.	1 ft.	Parsnips.
2 ft.	Peas.	2 ft.	Peas.
8 ft.	Potatoes (four varieties). Curled Kale to follow early varieties.	8 ft.	Potatoes (four varieties). Curled Kale to follow early varieties.
2 ft.	Radish. Leeks. Lettuce.	2 ft.	Radish. Leeks. Lettuce.
1 ft.	Onions and Shallots.	1 ft.	Onions and Shallots.
2 ft.	Turnips.	2 ft.	Turnips.
1 ft.	Beet.	1 ft.	Beet.
3 ft.	Brussels Sprouts. Broccoli. Cauliflower.	3 ft.	Brussels Sprouts. Broccoli. Cauliflower.
4 ft.	Individual. Individual. Flowers. Senior Pupil. Junior Pupil.	4 ft.	Individual. Individual. Flowers. Senior Pupil. Junior Pupil.
30 ft.		Space 1½ ft.	
9 ft.		9 ft.	

Total area of the plot, 30 feet by 9 feet with intervening space of 1½ feet.

The artificial germination of seeds sown in the plots, water and pot cultures of the same, with a study of the progress of growth, the estimating of seeds required per acre, and the yield per acre of any particular crop, also serve to show how the work of the garden may be transferred to the schoolroom, when the weather makes outdoor work impossible, and how it may be linked to other school subjects.

Since garden operations are so dependent on the weather it is found impossible to adhere rigidly to a time-table as in the case of indoor subjects. Teachers are allowed considerable liberty in this respect.

Equipment and Annual Upkeep.

The initial equipment of a school garden embraces—

(1) A set of tools for each pupil consisting of a spade, fork, rake, Dutch hoe, draw hoe, trowel and dibber, at an approximate cost of 8s. to 10s. per pupil.

(2) A tool-shed to cost from £3 to £5.

(3) A barrow, two watering-cans, lines, etc., to cost £1 5s.

(4) Fencing to cost from £2 to £3.

(5) Assistance in the heavier work of laying out the garden to cost £1.

The total initial cost of a garden thus equipped for a class of twenty boys is about £18.

The annual upkeep including seeds, manures, rent, etc., of such a garden seldom exceeds £3.

In England, where the County is the Educational authority, tools are supplied free. The pupils are taught to take every care of these, and an inspection of tools is made from time to time by a County Official. Where there is a workshop in connection with the school the boys make many useful articles for the garden and also repair their tools.

This is done on wet days and at other times when work in the garden is impossible. So many articles that are dear to buy but quite easy and inexpensive to make are continually being wanted for the garden, that a workshop is an absolute necessity to its economical working.

The Instructor.

The Instructor is usually the head teacher or a member of the school staff, but there are instances where a practical gardener is employed. As a rule, the trained teacher who has a fair knowledge of the subject is the most successful instructor."

FIELD AND GARDEN WEEDS.

The study of weeds is a study in the struggle for existence. Cultivation may be viewed as an interference on the part of man with the balance of nature. He attempts to favour particular plants which if left to maintain themselves would in most cases be ousted from the field in a short time. The wild plants which are continually seeking hold in the soil prepared by man for the growth of his crops he terms weeds.

First of all let us note a few typical weeds, occurring in gardens or in the fields.

Shepherd's Purse (*Capsella bursa-pastoris*).—Common by roadsides, garden ground, fields, etc. Flowers throughout most of the year. An erect annual, with small white flowers in a raceme; sepals 4, petals 4, stamens 4 long and 2 short. Fruit a triangular "pod" (silicula). Rosette of simple leaves, deeply cleft (pinnatifid) at base, stem leaves sessile, toothed, arrow-shaped. *Order: Cruciferae.*

Chickweed (*Stellaria media*).—This is the commonest of the various "chickweeds." It also flowers throughout most of the year. A plant of rapid growth, spreading fast, and seeding abundantly. May be distinguished by the

single line of hairs running along the stem; small white starlike flowers, sepals 5, petals 5 deeply cleft, stamens 5-10. Leaves opposite. Stem procumbent. *Order: Caryophyllaceae.*

Groundsel (*Senecio vulgaris*).—Common in neglected gardens and waste ground. Flowers throughout the most of the year, and each plant continues flowering over several months. Seeds distributed by the wind. Small yellow flowers in short cylindrical heads. Stem furrowed, leaves long, sessile, and irregularly lobed (pinnatifid). *Order: Compositae.*

Daisy (*Bellis perennis*).—Flowers through most of the year. Has a perennial underground stem with runners by means of which it spreads effectively as well as by means of seeds. The "rosette" arrangement of radicle leaves is an adaptation securing both light and room for the plant. *Order: Compositae.*

Dandelion (*Taraxacum officinale*).—This is another plant which flowers early (March) and persists through the greater part of the year. A perennial with storing tap-root giving rise to fresh shoots each year, and which buds new shoots when cut. Seeds distributed by the wind. Leaves generally a radicle rosette. *Order: Compositae.*

Docks (*Rumex acetosa*, *R. acetosella*, *R. crispus*, etc.).—The docks are mostly perennials with strong storing roots, which like that of the dandelion give rise to buds when cut. Cutting the roots is therefore of no avail in attempts at eradication. Fruits 3-sided. *Order: Polygonaceae.*

Thistles.—Of these there are several occurring on cultivated land, e.g. the Spear Thistle (*Cnicus lanceolatus*) and the Creeping Thistle (*C. arvensis*).

The former plant is a biennial producing a rosette of radicle leaves the first year. In the second year a tall, stout, erect winged stem from 2 to 4 feet high is produced. Leaves pinnatifid, sessile, spiny. Flowers purple with

spiny bracts. Seeds furnished with feathery pappus are wind-distributed. On production of seeds the plant dies down.

The Creeping Thistle is a perennial which spreads from a branching root below ground as well as by means of seeds carried by the wind. It is a troublesome weed, difficult to eradicate. Stem erect, flower heads light purple, numerous, of two kinds on separate plants, male globular, female ovoid. Leaves narrow, pinnatifid. *Order: Compositae.*

Charlock (*Brassica sinapis*).—This is one of the commonest weeds in cornfields. It is an annual with rough stem of 1 to 2 feet, usually branched. Upper leaves rough, toothed or lyrate, sessile; the lower stalked, ovate or lobed. Flowers pale yellow, $\frac{1}{2}$ - $\frac{3}{4}$ in. diam. Sepals 4, narrow, spreading; petals 4; stamens 4 long and 2 short. The fruit a siliqua from 1 to 2 inches long, with three faint veins on the valves, and with cylindrical straight beak. *Order: Cruciferae.*

Charlock germinates early in spring, and besides being a prolific and troublesome weed, is indirectly the frequent cause of loss to agriculturists in harbouring the fungus causing "finger and toe" disease in turnips. By maintaining this parasite in the years intervening between the turnip crops, it renders the disease difficult to eradicate.

Charlock further serves in the spring to maintain the turnip beetle ("turnip fly," "flea-beetle") before the turnips are sown. This is a critical time for this beetle, which on awakening to activity in the spring flies to the charlock and related plants where it feeds. These small beetles, on the turnip-seed leaves appearing above ground, forsake the charlock for them, and when numerous they may eat these up before the ordinary foliage leaves have time to appear. If such happens the turnip plant is killed (Fig. 159).

Besides the foregoing weeds pupils should be set to identify others which are common in their neighbourhood,

and a list made of all which from their numbers on cultivated land may be regarded as important.

It may be well at the next stage to elicit from the pupils the various ways in which weeds do harm. Such an

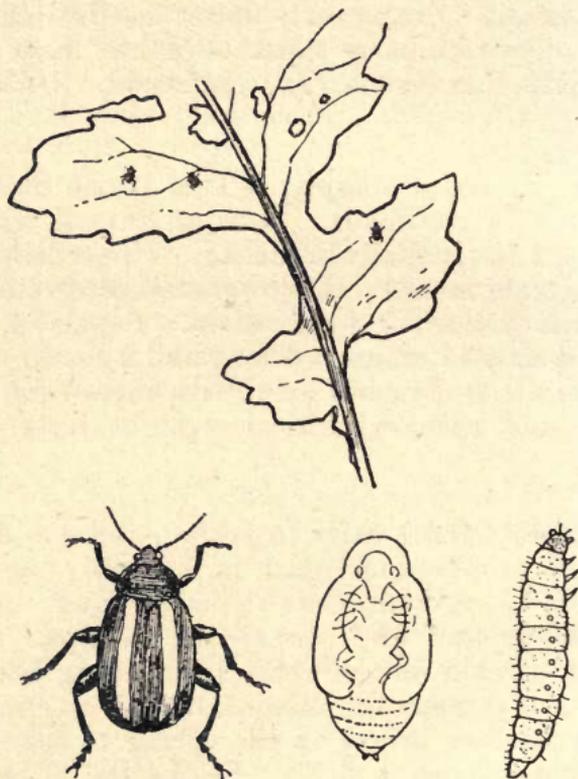


Fig. 159.—Turnip Beetle (*Phyllotreta nemorum*), adult, pupa, and larva.

The beetles figured on the leaf above are slightly less than natural size. The larva burrows in the soft tissue of the leaf between the upper and under sides.

enumeration will but emphasise the needs of all plants in order that they may successfully maintain existence.

Weeds rob the cultivated plants of room. This involves loss of food material from soil, including fertilisers; from the atmosphere, light and carbon dioxide.

Some special adaptations to note here are the rosette leaves of Daisy and Dandelion for securing light and room for themselves. Sometimes, *e.g.* amongst corn crops when tall weeds are numerous, the corn is apt to draw to length, and is thus liable later to fall over. The presence of weeds in numbers also tells particularly upon slow growing crops, which naturally suffer most, *e.g.* clovers.

Weeds which climb, *e.g.* Bindweed (*Convolvulus arvensis*), are apt to drag down the cereals amongst which they grow, and by winding around them impede the leaves from proper functioning.

In being mixed up with cereal and other crops weeds contaminate the seeds of these, lowering their market value, or being sown with these perpetuate the mischief.

Lastly, weeds may serve as centres of dissemination of fungus pests amongst cultivated plants, *e.g.* Charlock and "Finger and toe," or serve to maintain insect enemies of crops, *e.g.* Charlock and turnip beetle.

Some of the special adaptations favouring the commoner weeds should be emphasised. Note from the foregoing list and from others not included in it:

Plants appearing early in the year and persisting for a long time.

Plants with special modes of seed distribution, *e.g.* by wind.

Plants with rootstocks which bud—vegetative propagation.

Plants which seed over long periods of the year.

Perennials which store reserves.

Plants which germinate quickly.

Any other adaptations for perpetuating the species.

SOME ANIMALS OF THE GARDEN.

Our garden is a common one, in which there are flowers, vegetables, and fruit bushes and trees. We cannot hope to deal with all the animals which may be found there either as welcome or unwelcome guests, but we aim at becoming familiar with the commoner examples; we seek to discover something of their life and habits, and to learn more exactly the effect of their presence.

ANIMALS IN OR ON THE SOIL.

Underground as we turn over the soil usually the first animal we meet with is the Earthworm. We have already had a talk about this remarkable creature (p. 176).

Centipedes.—Another common type of animal we discover early is the *Centipede*, of which we may quite likely find two or more different kinds. These animals are readily identified by the large number of feet they possess (Fig. 160). They may be an inch or nearly two inches long, golden yellow or brown in colour, and run actively when disturbed. Their bodies are flattened, and they should be clearly distinguished from their relatives the millipedes.

Centipedes do not interfere with the growth of cultivated plants. On the other hand they attack ground insects, snails and slugs and such like, most of which are destructive in the garden. Indeed so carnivorous are their tastes that the male of a certain common genus (*Lithobius*) will devour the eggs laid by his mate. To prevent this she rolls the egg, which is sticky, in earth as soon as it is laid, so that it becomes coated and resembles a particle of soil. *Lithobius* is about an inch long and about one-eighth of an inch broad. A longer and more slender form is *Geophilus*.

Millipedes.—The *Millipedes*, which occur in the soil, also possess numerous feet. They are rather darker in colour and are mostly rounded in the body, not flattened. They feed on all kinds of roots, bulbs, and tubers, and may frequently be found within them. They coil themselves up when disturbed. A very destructive millipede, known as *Julus pulchellus*, is about half an inch long, of a pale pinkish colour, spotted with purple or crimson. It may be

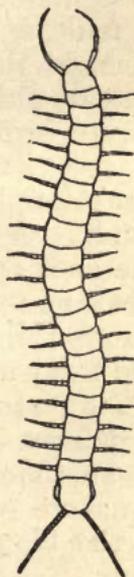


Fig. 160.—A Centipede.

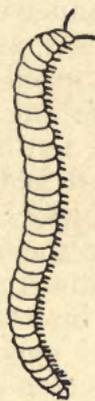


Fig. 161.—Millipedes. The upper one is coiled in the characteristic manner of this animal.

found attacking bulbs or potato tubers. There is one species of *flattened millipede* (*Polydesmus complanatus*) which may also be found engaged in the same kind of destructive work.

When any of these creatures are observed they should be captured and examined with the help of a lens at first, so that their exact nature may be made out. A comparison of the diagrams (Fig. 160, 161) will show that apart from

shape a millipede differs from a centipede in having two pairs of legs to each joint of what may be termed the hind body. Since the habits of these two animal types are so opposite in character, the question of their recognition is one of importance. They are not difficult to distinguish.

Earwigs.—Concealed under stones, in crevices, especially in untidy places, *earwigs* abound. They are also to be found about plants, *e.g.* concealed in the floral disc of sunflowers, chrysanthemums, etc. They are vegetable feeders and are frequently destructive to flowers, fruit, and leaves. Earwigs are insects, usually classed amongst the grasshoppers, cockroaches, etc., *i.e.* as Orthoptera, although it is likely they should be grouped as a separate Order. The young are very similar to the parents.

The manner in which the wings, in those examples which possess them, are folded is well worth study. A common earwig dropped from the hand will sometimes spread its wings in falling, when the hind pair will be seen to be quite large and fan-like. On reaching the ground the fan is closed, then folded transversely and tucked away under the fore wing, which is quite small though firm in texture. The forceps or shear-like organs are used in defence and probably in attack also, for earwigs are said sometimes to feed on other insects. They are not of the nature of poison fangs, but appear to be adaptations of the filament-like structures seen at the tail of various insects.

Surface Caterpillars.—Many insects winter in the soil, and by digging around the stems of fruit bushes we may find both larvae and pupae. We have already noted the occurrence of the larva of the magpie moth. In cabbage, carrot, and other vegetable beds *surface caterpillars* may also occur. These are the larvae of the turnip moth and heart and dart moth. These hide below the surface of the soil; they usually attack the parts of plants just below or at the surface, feeding at night. These caterpillars are brownish or greyish, with longitudinal bands. The moths have brown fore wings and white under wings. They are inconspicuous-looking insects.

Beetles.—Various beetles will be found in the soil. Of these we can note only the so-called ground beetles (*Carabus*). See Fig. 162. These beetles are active nocturnal creatures, hiding under stones, etc., during the day and hunting in the night. They mostly attack other insects and small animals, and are on the whole of service to man. When interfered with they squirt a disagreeable smelling fluid from the hind body. The rove beetles, of which both large and small ones may be found, are interesting. In these the wing covers are short and leave the hind body exposed. They may also be readily recognised by their habits of rearing their tails (compare earwigs) when alarmed. A well known large form is the Devil's Coach Horse (*Ocypus olens*), which also discharges an offensive-smelling fluid when excited.



Fig. 162.—A Ground Beetle (*Carabus*).

Bees.—An interesting type which should be looked for is the burrowing bee (*Andraena*). In the spring or early summer these bees attract attention by their activity upon the ground. When watched they are seen tunnelling into the soil, where they deposit their eggs along with pollen, on which the young bees feed when hatched. (For an admirable account of these and other wild bees see *House, Garden and Field*, by L. C. Miall.)

Wood-lice or Slaters.—In damp mouldy places, amongst stones, decaying wood and rubbish, these creatures also abound. They are sure indicators of untidiness, although they cannot be regarded as harmful. They belong to the Crustacea, the vast majority of which are aquatic animals.

Snails and Slugs.—The garden snail is a familiar sight, sometimes occurring in very large numbers. This species (*Helix aspersa*) has a somewhat rough brownish shell, which to be seen to advantage should be washed and examined wet. The snail itself is over two inches long, being the largest to be met with in gardens in this country. Snails are vegetarian in habit, and when numerous may be very destructive. They hibernate in companies, closing the mouth of their shells with a dried mucus-like secretion. Some snails form a porous limy plate, like the shell of an egg, which they use for this purpose.

Snails make interesting objects of study, and some should be kept under observation in school. They are very hardy and live quite well in captivity. They may be kept in a box and fed with ordinary vegetables or weeds, e.g. lettuce, cabbage, dandelion, etc. The atmosphere of the box should not be allowed to become too dry.

For a practical study of a snail see p. 150.

Amongst slugs, the most familiar in gardens is the grey field slug (*Limax agrestis*), about four-fifths of an inch long, which should be compared with the snail as regards structure. Slugs have no spiral shell, but most have, embedded in the oval patch known as the mantle, just behind the head, a thin plate-like structure or detached limy granules. The breathing opening of a *Limax* is situated in a notch of this area at its posterior right side. Another slug sometimes found in gardens, although oftener about ditches or in damp woods, is the fine large black slug (*Arion ater*).

Slugs are fond of damp, they lie concealed during the day, coming out at night to feed; they are frequently to be seen, however, after a shower of rain, if the weather is mild, during the day.

Slugs are mostly injurious animals in the garden, the greatest amount of harm being done in wet seasons. There is one type, known as *Testacella*, which is carnivorous, feeding on worms and insect larvae in the soil, which on the whole may be looked upon as beneficial. *Testacella* is readily recognised by the cap-like shell it carries at the posterior tip of the body.

Pupils should make drawings of two groups of the small animals inhabiting garden soil—a useful, and an injurious group. Teachers will do well to make a collection of such, and with the help of a lens to examine the various types. Familiarity with the detailed appearance is the first step towards fuller knowledge regarding them.

ANIMALS FOUND ON VEGETATION.

Caterpillars.—Caterpillars are scarcely ever absent from a garden. We have elsewhere (p. 153) dealt with the structure and habits of these; here we append notes of a few of the commonest—apart from the surface caterpillars named above.

All types of caterpillar found in the garden should find a place in the rearing boxes. Before removing examples

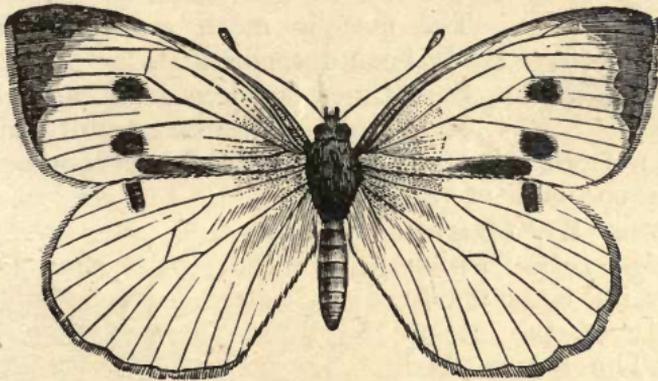


Fig. 163.—The Cabbage Butterfly—female, natural size.

of new kinds from the garden, care should be taken to discover their nature (Fig. 163).

Caterpillars of the large white butterfly, *Pieris brassicae*. The eggs of this caterpillar are laid usually in clusters on a cabbage leaf. They may occur elsewhere, e.g. nasturtium leaves. The caterpillar is a familiar one and scarcely needs description. Above it is greyish green, below green.

There are longitudinal yellow bands. The skin is warty, with short whitish hairs. Two generations of this caterpillar occur in the year, in June and July and in September, consequently we may find both summer and winter chrysalids. (The chrysalis is angular, greyish green, with black and yellow markings. It occurs fixed, usually in a horizontal position, to walls, under roofs or doorways, etc.) (Fig. 164.)

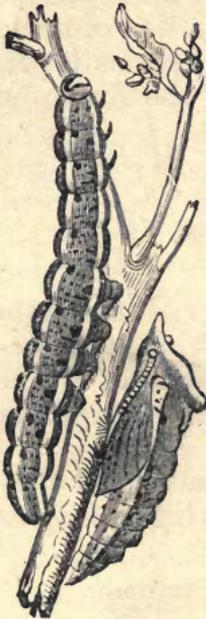


Fig. 164.—Caterpillar and Chrysalis of the Cabbage Butterfly.

Caterpillar of the small white butterfly: *Pieris rapae*. This caterpillar, which also occurs on the cabbage leaves, is about $1\frac{1}{4}$ inches when fully grown. It is of a dull velvety green above, paler below. There is a deep orange line along the back, and orange spots on the sides. In this case the eggs occur separately. There are two generations here also.

The magpie moth caterpillar has already been described (p. 153).

Sometimes beside a dead caterpillar or the chrysalis of the large white butterfly may be noticed a heap of small yellowish cocoons. These are the cocoons of an Ichneumon fly (*Microgaster glomeratus*) which deposits its eggs inside the body of the caterpillar. The larvae feed upon the substance of the caterpillar and are ready to become pupae about the same time. They bore through the skin and pupate. The caterpillar usually dies; even if it should succeed in entering the pupa stage, the adult butterfly is not formed (Fig. 165).

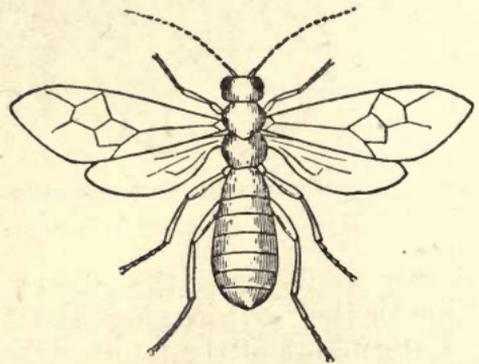


Fig. 165.—The Ichneumon Fly of the Cabbage Butterfly, magnified.

Various caterpillars or caterpillar-like creatures will be found upon currant and fruit bushes, trees, etc. As already suggested, if their real nature is unknown, specimens should be transferred to the insect boxes in school and the development traced.

Green Fly or Plant Lice (*Aphides*).—These insects are extremely common; they occur on fruit, peas, roses, as well as upon various field crops. They belong to the order of Bugs (Hemiptera), and if they are turned over and examined with the help of a lens, the long pointed boring snout which they insert into the plants they infest can be seen. By means of this borer they suck up the juices of the plant, and since they occur in considerable numbers they are capable of a large amount of destruction. They also injure the plant in other ways, *e.g.* they excrete a sugary fluid (honeydew) which coats the surface of the leaves, making them sticky, clogging the stomata and thus further injuring the plant.

These insects have a remarkable history. It will be observed that most plant lice are wingless; only occasionally are winged examples to be seen. The winged forms appear chiefly when the host plant is overcrowded, and these fly away to a new plant and there start a fresh series of generations. Throughout the season there are no males, only a succession of generations of females. In the autumn, however, males appear. These mate with females and the eggs subsequently laid remain dormant all winter. In the spring there develop from these a generation of females, which give rise to young, also all females, and this is continued throughout the summer. "There are species in which each female bears from eighty to one hundred young, and nine to sixteen generations succeed one another in the year" (*Ritzema Bos*).

The *Aphides* thrive best and multiply to the greatest extent in dry warm weather. Spraying the bushes as soon as they are noticed with some destructive fluid is the usual method adopted for their removal, *e.g.* a mixture of paraffin water and soft soap. Even liberal spraying

with water from a garden hose regularly will be found effective as a check.



Fig. 166.—The seven-spotted Ladybird.

These Aphides have various natural enemies. The small almost hemispherical spotted beetle, known as the ladybird, and its larva feed on these (Fig. 166). So also do the larvae of Hover flies—starlings and sparrows are also said to attack them.

For notes upon some of the commoner birds which visit our gardens see p. 113.

CHAPTER XXVI.

SOME INSECTS OF ECONOMIC IMPORTANCE.

FLIES OF THE FARM.

AMONGST the insects abounding in the neighbourhood of cultivated fields or domestic animals, flies are probably of chief importance. From the characters given on p. 168 it will not be found difficult to distinguish flies from all other insect types.

In general it ought to be noted that flies are of considerable economic importance everywhere. Mosquitos, so abundant all over the world, are important as transmitters of malaria; tse-tse flies in Africa communicate the dread disease of sleeping sickness as well as analogous diseases to domestic animals; the house fly, although not a biting fly, from its indiscriminate visits to all sorts of places and substances, including human food, is an ever present danger to health.

We shall not here attempt to enumerate more than a few of the flies which may be in evidence on the farm in the warmer seasons of the year. And we shall classify them according to their habits.

1. Biting Flies, i.e. Blood-sucking.

(a) The *Stable fly*.—Superficially very like the house fly, and so termed by the uninitiated. It is most readily distinguished from house flies by having a black slender proboscis projecting in front of the head and visible from above. This is the blood-sucking organ. It is common,

about farm buildings and fences, etc., around fields from August to October. It sucks the blood of horses, cattle, and human beings. The bite is painful.

(b) The *Cleg* or *Brimp*.—A well-known fly attacking horses and cattle during the warmer months. Only the females are blood-sucking. This fly has dusky spotted wings, body flattish and blunt behind. The head is much broader than long, and somewhat crescentic. A pair of feelers stand out in front, the terminal parts of which curve slightly outward. The fly of course does not sting when handled. The proboscis is not visible from above.

(c) The *Gad* or *Breeze fly*.—Very similar to the foregoing but larger. Head is even more crescentic, and antennae shorter than in the former, but with a distinct notch and curved tip. They bite cattle severely. Common near woods.

2. Parasitic Flies.

(a) *Bot flies*.—These are medium sized, hairy flies which deposit their eggs on the fore parts of horses. When the maggots emerge, the horse licks the place and swallows the maggots. These on reaching the stomach attach themselves, feeding and growing; they live here for about ten months. At the end of this period they pass to the outside along with the undigested food and pupate on the ground. In the course of a few weeks the adult flies emerge from the pupal cases and the life cycle recommences.

(b) *Sheep's nostril fly*.—A similar fly attacks sheep, depositing its eggs on the nose or face. The maggots creep into the nostrils, and in the upper spaces live for about the same time as the bot flies in the horse, feeding on the secretions of the cavity in which they lie. Their presence may cause difficulty in breathing, giddiness, and often a high stepping gait in the sheep. When the larval period is over the sheep is able to snort them out upon the ground, where they complete the pupal period in a few weeks. Sometimes the health of the sheep deteriorates so much that slaughter becomes necessary.

(c) *Warble flies*.—These deposit their eggs on the cattle. The maggots also are licked into the mouth and pass to the gullet. They do not, however, pass direct to the stomach, but bore through the gullet walls, migrating throughout the body. They eventually arrive at the tissue just under the skin in the neighbourhood of the backbone. They thus live within the ox for about ten months, when they find their way to the outside through the skin. The larva falls on the ground, pupates, and in a few weeks becomes an adult. The hides are thus injured by the exit of the fly and are known as “warbled hides.” The losses entailed through the activities of this fly are very considerable.

3. Flies attacking Crops, etc.

There is a long list of these, the most important of which is undoubtedly the Crane fly or “Daddy-long-legs.” Its life-history is outlined below.

The Crane Fly or Daddy-long-legs.

There is more than one species of fly of this type to be met with, but the habits of the two commonest are very similar. They may be seen on the wing from May to September, one species appearing early and the other later. A specimen should be caught and examined.

It will be found to be a true fly, *i.e.* it has one pair of wings only. Behind these there is a pair of slender, knobbed, rod-like bodies. These take the place of the wings occurring here in most other insects, and are known as “halteres” or balancers. Other structures worth noting are the large greenish compound eyes and slender feelers on the head, and the three pairs of long “spidery” like legs. Two kinds of insect will be noticed. In one the tip of the hind body tapers to a fine point. This is the female insect. In the male, which is smaller, the tip is blunt and appears slightly upturned.

These insects may be seen flying about pastures or by roadsides where long grasses abound. Sometimes they

are extraordinarily abundant. The eggs, which are laid in late summer and autumn, are deposited on the ground or upon grass close to it. The females may be seen engaged in the operation, when they seem to progress on their hind legs and tail, vibrating their wings meanwhile. With their long slender bodies and legs they appear to make rapid progress amongst long grasses and to get quite close to the ground with their abdomen. They probably lay a few eggs here and there as they move along.

The larvae which hatch from these in about a fortnight pass the winter in the soil, and in the spring and early

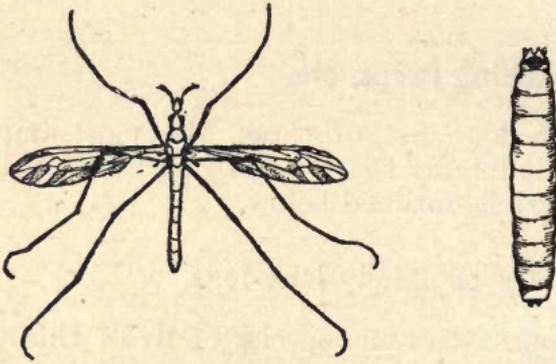


Fig. 167.—Crane Fly (*Tipula*) and larva ("leather-jacket"), slightly less than natural size.

summer feed upon the grass or corn crops chiefly, but they attack all sorts of vegetable substances. They are sometimes present in enormous numbers and prove extraordinarily destructive to cereals. They are known under the names of "leather-jacket," "grub," "tory worm," and possibly others (see Fig. 167).

When fully grown this larva, which structurally is a maggot, is about an inch in length, blunt at both ends, greyish brown in colour with two pale lines along its body. There are no legs nor true head. When it enters the pupal stage, curved horn-like parts appear on the head, and small spines on the body. By means of these last the

pupa wriggles itself to the surface of the soil when the adult is about to emerge. When emergence takes place the pupal husk is left sticking out of the ground. Rooks, gulls, starlings, lapwings, etc., feed largely on the larvae in the soil.

Since the Crane fly is an important agricultural pest and the relation between it and the leather-jacket is not clearly understood in many parts of the country, rural teachers may profitably utilise it for demonstrating the life-history. The larvae should be obtained in the spring. They may be kept in soil in a box. Corn should be sown in the box and the effects of the larvae noted. When the pupae appear above ground a cover should be placed on the top so that the adults may not escape.

Click Beetles and Wireworms.

These beetles are so termed because of the habit they have of throwing themselves into the air with a clicking sound when laid upon their backs. If one of these beetles is examined on the under side of the body, just behind the first pair of legs a pair of spines may be seen, fitting into a groove in front of the second pair. If laid on its back the beetle will bend the body so as to withdraw the spines, and then suddenly jerk them back so that the upraised part of the back strikes the ground and the beetle rebounds into the air. When it alights, it does so on its feet.

Amongst these beetles there are several of economic importance, the best known of which is the striped click beetle (*Agriotes lineatus*). This insect has a length of about $\frac{3}{8}$ of an inch and a breadth of about $\frac{1}{8}$ th. It is brownish in colour, and its wing cases have longitudinal parallel lines. It is widely distributed under stones, amongst pasturage, and on vegetation generally. They lie in concealed places during



Fig. 168. — Click Beetle (*Agriotes*), magnified $2\frac{1}{2}$ times.

winter and in spring they emerge and egg deposition takes place (Fig. 168).

The larva is known as a wireworm and is a very destructive pest. It grows to nearly an inch in length, and is of a yellowish colour. The three pairs of thoracic legs are very short, and there is a pair of very rudimentary feet upon the last segment of the body. These wireworms have biting jaws with which they attack the underground stems and roots of cereals and various other crops. They live a long time in the soil, the larval period extending from three to five years, consequently they are capable of doing very great damage. The pupal stage lasts only a few weeks (Fig. 169).

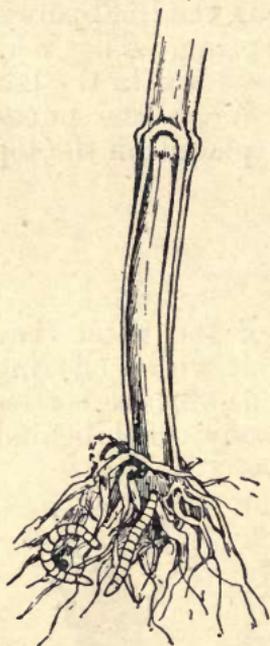


Fig. 169.—Wireworms attacking roots of cereal.

Lapwings, jackdaws, rooks, and starlings are amongst the chief natural enemies of the wireworms.

Both beetles and wireworms should be collected and examined. The latter are good examples of true grubs.

An important point to note in connection with attacks of these flies is that the larva is the active injurious agent. There are insects which attack onions, carrots, man-golds, celery, cabbage, etc.; in each case a distinct species of maggot feeds upon the plant.

In cases of insect attack upon field or garden crops the recognition of the larval type is therefore of importance. The presence of maggots indicates a fly as the insect type which lays the eggs upon the plant. In all cases of doubt the larvae should be reared in captivity and the adults captured for examination when they hatch out.

CHAPTER XXVII.

SUGGESTIONS FOR WEATHER STUDY.

IN a previous chapter general hints are given with regard to weather study chiefly from the seasonal point of view, and with reference to the compilation of local calendar records. We shall now here summarise the more important ways in which the various observations may be tabulated and examined indoors, and indicate how the wider study of the weather may be encouraged amongst the senior pupils.

As a preliminary exercise there should be explained to all grades of pupils of suitable capacity, the latitude and altitude above sea level of the school itself, the directions N., S., E., W., the altitude and direction of any hills, large plantations, lakes, etc., within a five-mile radius of the school. This information can be got from an Ordnance Survey Map of the neighbourhood. Such a map upon a reasonably large scale should hang upon the school-room wall. Pupils in senior classes should reproduce a fairly large plan drawn to scale of the relative positions of such points as are suggested above. If thought desirable contour lines might be introduced showing altitudes.*

* There are many excellent suggestions which are on the best lines as recognised for Nature Study to be found in Text-books on Geography as taught by modern methods.

A further preliminary is the encouragement amongst all grades of pupil of the following:—

(a) A general impression of the kind of morning gathered on the way to school. The weather description as given in the Beaufort Scale, which is within the capacity of the pupils, should be adopted in their records as affording a ready and standard mode of description. This scale (abridged) is as follows:

Blue sky, recorded in school charts simply as b.			
Clouds (detached)	„	„	c.
Drizzling rain	„	„	d.
Fog	„	„	f.
Dark, gloomy	„	„	g.
Hail	„	„	h.
Hoar frost	„	„	h. f.
Lightning	„	„	l.
Misty or hazy	„	„	m.
Overcast	„	„	o.
Passing showers	„	„	p.
Rain	„	„	r.
Squally	„	„	q.
Snow	„	„	s.
Thunder	„	„	t.
Visibility, unusual trans- parency	„	„	v.
Ugly, threatening	„	„	u.
Dew	„	„	w.

Degree of intensity may be distinguished by the figures 0 and 2, the former indicating “slight” and the latter “strong,” *e.g.* f⁰—slight fog; s²—heavy snow.

(b) Determination of the wind direction and force. Force is somewhat difficult to express, but some agreement should be come to with teacher and pupils as to the degree signified by the following terms:—calm, light breeze,

moderate breeze (corresponds to a velocity of 14 miles per hour), strong breeze (25 miles per hour), moderate gale (31 miles per hour), storm (64 miles per hour).

(c) Clouds, their identification, proportion, direction of movement, height. Pupils will require with regard to this to receive definite instruction from the teacher. Photographs are not needed by the pupils. The teacher should seize the opportunity as it arises of demonstrating the various simple types.

Those which should be pointed out first are the Cirrus and Cumulus. The former, popularly known as mare's tail, is a very high cloud (from 27 to 50 thousand feet), white, long-curved streaky bunches, feather-like. The Cirrus is a cloud of ice. The Cumulus is the familiar thick heavy banked-up cloud, dome-shaped above and white, generally darker underneath. It is known also as wool-pack cloud. Its height is given as from 4,500 to 6,000 feet. The next in point of simplicity and ease of recognition is probably the Nimbus or rain cloud. This cloud is dark, and from it continued rain or snow generally falls; its height is from 3,000 to 6,400 feet. The Stratus also, a low flat cloud, "a horizontal sheet of lifted fog," below 3,500 feet, is not difficult to recognise. After the pupils are expert in recognising these, other more complicated forms may, if desired, be added to their list.

The school should be equipped with the following instruments of as satisfactory quality as possible:—Barometer; Thermometers, wet and dry bulb, and maximum and minimum; Rain Gauge. The classes to which work in reading of instruments and recording are allotted should have work assigned to them at regular intervals of plotting in graphic form such items as the daily temperatures for each month, maximum and minimum, the daily barometric pressure, diagrams of the wind direction for each month. These again might be utilised for the making of a composite wind diagram for twelve months, and from the results of a series of years the direction of the prevailing winds would in course of time be exhibited on the charts (Fig. 170).

The total rainfall for each month should be noted and comparative tables of the same drawn up.*

The teacher will be able in course of time to indicate from a study of the charts, besides the direction of the prevailing winds already noted, such points as a relation

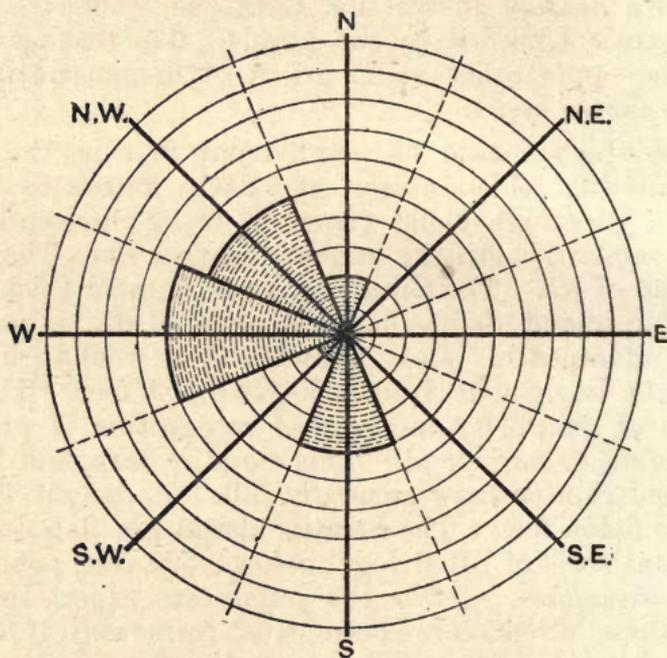


Fig. 170.—Wind Star : it records 2 days N., 5 days N.W., 6 days W., 1 day S.W., 4 days S. wind. (Adapted from F. Mort.)

between rain and certain directions of the wind, or between certain types of cloud and certain kinds of weather. But these things can only be arrived at after continued experience of a district, and conclusions should not be forced.

* The teacher will find many useful suggestions in *Hints to Meteorological Observers*, prepared under the direction of the Council of the Royal Meteorological Society by Wm. Marriott, F.R.Met.Soc. London: Edward Stanford.

EXAMPLE OF WEATHER CHART.

Date.	Barometer.		Temperature.					Wind.	Weather, past 24 hours.	Cloud.	Rain- fall.
	Uncor- rected Reading.	Change since yesterday.	Dry.	Wet.	Change since yesterday.	Max.	Min.				
1909	Ins.		°	°	°	°	°	*			Ins.
Aug. 3	30·24	-13	64	59	+4	70	53	S.S.E.	c.p.b.o.	Cumulus	·01
„ 4	30·04	-20	59	57	-5	69	51	0	o.u.c.	Cumulus	—
„ 5	29·94	-10	54	52	-5	68	51	N.N.W.	c.o.p.c.	Cumulus, nimbus	·06

* These letters indicate the weather according to the Beaufort Scale (p. 316). The chart may, of course, be modified to a simpler form if desired.

Cyclones and Anticyclones.

For senior pupils exercises in the charting of the weather over a large area should be given. This kind of exercise is valuable in demonstrating to the pupils the existence of cyclones and anticyclones, and in rendering them familiar with the general basis upon which weather forecasting is carried out. Two exercises of this kind are appended, one to illustrate the existence of a cyclone, and the other of an anticyclone.

Maps for the purpose of weather charting on these lines may be bought very cheaply from the Meteorological Office, 63 Victoria Street, London. Their official designation is M.O. Form 227.

Fig. 171 represents this map—reduced to a scale of $\frac{2}{5}$, with some of the details omitted. It shows the various meteorological stations in Western Europe where the records are taken of height of barometer, direction and force of wind, etc., from which the weather forecasts are prepared. The direction and force of the wind are indicated on the chart by means of various types of arrows as shown in the “explanations” on Figs. 172, 173.

Exercise.

From the data supplied on p. 321 fill in upon the map in clear figures and symbols the barometric pressure, direction and force of wind at the stations shown. Connect by isobaric lines the regions of equal pressure. The lines need not be carried directly through the stations upon the map, but when the *general line of equal pressure* has been determined by a careful examination of the figures entered on the map it should be indicated by a sweeping curve along it (see Figs. 172, 173).

Barometric Readings, Direction, and Force of the wind as registered at the Stations named on the dates mentioned. The barometric readings have been corrected to 32° F. and to mean sea-level. For key to the figures indicating Force of Wind, see map.

Station.	14 January, 1904. 8 a.m.			3 August, 1908. 7 a.m.		
	Barometer.	Wind.		Barometer.	Wind.	
		Direction.	Force.		Direction.	Force.
Haparanda ...	Inches. 29·36	S.E.	2	Inches. 29·88	N.	2
Hernösand ...	29·06	S.E.	6	29·93	N.E.	2
Stockholm ...	28·80	S.	4	29·88	N.W.	4
Wisby ...	28·86	S.W.	6	29·87	N.N.W.	3
Karlstad ...	28·68	E.	2	30·03	—	0
Bodö ...	28·96	E.	4	29·99	E.	2
Christiansund ...	28·62	E.S.E.	2	29·95	—	0
Skudesnaes ...	28·54	S.	8	30·13	W.N.W.	4
Sumburgh Head	28·33	N.E.	1	30·09	W.	4
Stornoway ...	28·49	N.W.	2	30·27	W.	4
Malin Head ...	28·69	W.N.W.	6	30·37	W.	3
Blacksod Point...	28·91	N.W.	7	30·42	S.S.W.	2
Valencia ...	29·02	W.	8	30·44	—	0
Holyhead ...	28·85	W.	7	30·41	W.S.W.	1
Scilly ...	29·25	W.	7	30·40	N.E.	1
Aberdeen ...	28·43	W.N.W.	3	30·24	S.S.E.	1
North Shields ...	28·63	S.W.	3	30·33	S.W.	2
Yarmouth ...	28·89	W.S.W.	6	30·40	N.N.W.	2
Nottingham ...	28·84	S.W.	2	30·40	W.	1
London ...	29·00	W.S.W.	6	30·39	—	0
The Skaw ...	28·72	W.	5	30·04	W.S.W.	1
Fanö ...	28·90	S.S.W.	4	30·20	N.W.	2
Cuxhaven ...	29·04	S.S.W.	6	30·25	N.W.	3
Brussels ...	29·17	S.W.	5	30·37	N.E.	1
Berlin ...	29·30	S.W.	4	30·15	W.	3
Frankfort ...	29·37	S.	4	30·32	N.E.	3
Munich ...	29·63	S.W.	6	30·28	N.W.	2
Brest ...	29·43	N.W.	6	30·39	N.E.	3
Rochefort ...	29·73	W.S.W.	7	30·20	N.E.	4
Biarritz ...	30·00	W.S.W.	4	30·11	E.	1
Paris ...	29·43	W	6	30·36	N.E.	2
Belfort ...	29·62	W.S.W.	7	30·23	E.N.E.	7
Lyons ...	29·85	S.	3	30·20	N.N.W.	3
Nice ...	29·99	N.W.	2	30·01	—	0
Perpignan ...	29·99	S.W.	1	30·04	—	0
Lisbon ...	30·32	S.W.	3	29·92	N.N.E.	1

On the completed map note the following:—

Cyclone.—Chart of 14th January 1904.

As we follow the general directions of the wind as indicated by the arrows, we note they move anti-clockwise with an inward bias. This is the characteristic type of wind in a cyclone. The differences in force of the wind as indicated by the different types of arrow are due to local factors at the various places, but it will be noted that the general trend is not altered.

Next we observe that the lowest pressure is in the centre of the area swept by the isobaric lines and that the pressure increases regularly outward. This is the second distinctive feature of a cyclone. At the centre there is a dead calm. In this particular case the isobars are very close, indicating a steep gradient of pressure. In a cyclone the air rises; in cooling by expansion, water vapour is condensed and rain falls. As it progresses over an area, the wind gradually changes its direction, and after the centre is passed the weather clears (see Fig. 172).

“The succession of the weather is the same in each cyclone; but the intensity of it depends on the gradient of pressure. If of very great size and the diminution of pressure in the centre very slight, gentle winds and light showers only will be produced. If the cyclone is of small dimensions (less than 100 miles across) and the diminution of pressure in the centre is great, terrific winds and deluges of rain result.” (Mill.)

Anti-cyclone—Chart of 3rd August 1908.

Following the general wind directions we see here that their trend is opposite to that of the cyclone; that is, they move in the directions of the hands of the clock. Further, the arrows tend to point outward from the centre.

Secondly, the highest pressure is in the centre, whilst there is a regular fall outward. In this particular case the gradient is much less steep than in that of the cyclone quoted above. As to the weather characteristic of an anti-cyclone we cannot do better than quote from Mill. In an

M.O. Form 227 (slightly modified and greatly reduced).



FIG. 171.—Map showing principal stations at which meteorological data are collected for British Meteorological Office. Such a map should be drawn upon blackboard and the exercises on p. 320 carried out. For the completed charts see Figs. 172, 173.

anti-cyclone in summer "the weather is brilliant, hot, calm, with haze at night or heavy deposits of dew, on account of great cooling by radiation." In winter "an anti-cyclone is calm and clear, and by intense radiation the land cools down greatly at night and the temperature of the air falls. This is the condition required for long spells of frost, and in large towns and over lakes and estuaries it produces dense, low-lying fogs."

With regard to weather studies to be made in connection with times of leafing, etc., of trees, habits of animals, agricultural operations, etc. (phenology), see pp. 10, 41.

CHAPTER XXVIII.

SCHOOL EQUIPMENT AND ITS MANAGEMENT.

AESTHETIC SURROUNDINGS.

WE have emphasised as an important aim in these studies the cultivation of an appreciation of the aesthetic aspects of nature. This aim is to be attained in a measure by passive means, and of these aesthetic surroundings play an important part.

Outside the school, if there is a garden, let it be as far as possible a garden beautiful, with trees, shrubs, and flower-beds well kept. In planning such a garden, however small it may be, try to plan it so that the practical experimental plots do not occupy too obtrusive a place. In school gardening cultivate an interest in flowers as well as vegetables.

Within the school grow ferns and flowers in pots and have cut flowers in season. Pains should be taken to rear healthy and beautiful plants. Further, as already suggested, it is important that such plants be used for lesson purposes, and that the pupils should learn something of their nature and general life-history. These objects will thus be noticed more closely, and are thus more likely to exercise a beneficent influence upon the pupils. The ideal under this head should be the existence of an aesthetic atmosphere about the school, or at all events about certain of the classrooms which are more especially devoted to nature work.

AQUARIUM.

Under this somewhat high sounding title is here indicated the vessel or vessels in which fresh-water animals and plants are kept. According to circumstances it may mean simply a moderately sized glass jar in which there is a supply of water, sand or mud from a neighbouring pond or ditch—selected in spring time in the first instance, perhaps because of the minute animal life seen to abound

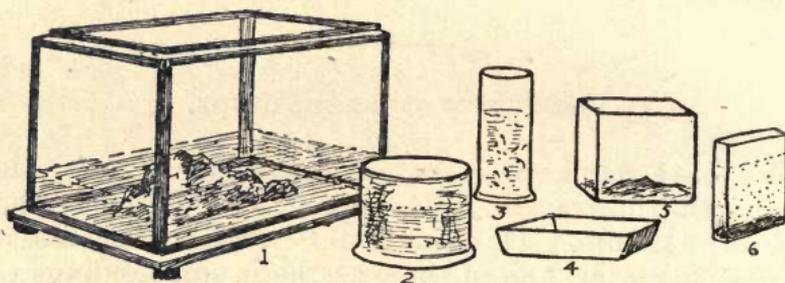


Fig. 174.—Various types of Aquarium Jars.

1, consists of wooden frame, slate base, glass sides, and lid of wire gauze. Within are some rough stones rising above the level of the water. Change of water is effected by siphon. This type is suitable for newts, sticklebacks, water beetles, etc. Size about 28 by 18 by 18 inches. 2, glass jar for gnats, etc.; 3, younger tadpoles; 4, frogs' spawn; 5, older tadpoles; 6, water fleas.

in it. Some of the water weed growing in the pond or ditch should also be included. Of course, if it is so desired, a large tank, which in such a case should be more or less ornate externally, may be used.

The writer has found that for teaching purposes a series of ordinary glass jars of various sizes, preferably with flat sides, has many advantages, and that such an arrangement is by no means detrimental to the inmates. For a beginner they are certainly most suitable. Such a series is figured above (Fig. 174).

In these jars the following animal types may be successfully kept. For particulars of lessons to be taught see p. 182.

Newts.—If these cannot be conveniently obtained out of doors in the school neighbourhood, they may be obtained at a small cost from naturalist dealers. Newts should be kept in a fairly large vessel containing water with a muddy or sandy bottom. A quantity of moss should be placed in the water. This must be so arranged that the newts can swim in the water or leave it and creep amongst the moss at will. A moderately sized flat stone, on which the animals can rest out of the water, is also useful. In the same vessel may be kept a few water beetles, but in all cases overcrowding must be avoided (Fig. 174¹).

Feed the newts by placing from time to time a few tadpoles in the water. Watch how the slow-moving newt stalks and eventually captures its youthful and much more active relative. When tadpoles are not available the newts may be fed upon a small (live) earthworm. Dangle quietly the worm over the snout of the newt; if hungry it will seize it. Should the worm not be taken after a reasonable interval do not leave it in the water; take it away and try again the following day. Guard against overfeeding, and do not allow dead flesh of any sort to lie long in the jar. If water beetles are present, these will attack such flesh, but the presence of much material of this kind must be avoided. A few examples of the so-called fresh-water shrimp (*Gammarus*) might also find a place in this jar, especially if the bottom is at all muddy.

Frogs' Spawn, Tadpoles.—In the spring a dish of frogs' spawn and another of toads' should be obtained. Spawn keeps well in a shallow dish such as an enamelled basin or pie-dish shape, of size about 12" × 8". Some water weed, e.g. duck weed (*Lemna minor*) or starwort, should be placed in the vessel. The spawn should be kept in a moderately warm place and in a good light. In its early stages it may be given direct sunlight for a short time daily. It must of course not be neglected so as to become dry. The hatched embryos may be left in this dish until they become free swimming tadpoles requiring to be fed. Then they may be removed to a taller vessel with a muddy bottom containing pond water rich in minute vegetable and animal

life. Some weed, *e.g.* Canadian pond weed, water starwort, should be growing in the vessel.

In their later stages tadpoles may be given very small particles of meat, bread or fish, but great care must be taken that such is not left to rot and pollute the contents of the vessel. Have some fresh-water shrimps (*Gammarus*) present. After the hind limbs have appeared the tadpoles will thrive better in a shallow dish which contains moss or stones, enabling the tadpoles to rest with their nostrils above water. When the frogs are developed, and their final changes from the tadpole stage demonstrated, *they should be taken to the side of a ditch or pond and set at liberty.* This is a point of great importance, and should on no account be omitted.

Water Fleas.—These can usually be found in great abundance in pools on moors or marshy places. A jar containing a supply of these constitutes a pleasing centre of observational interest and study. For observational purposes they are best kept in a flat jar of the shape shown in Fig. 174⁶. Mud should be placed at the bottom, and from time to time the “fleas” should be given a little direct sunlight. Examine with the help of a magnifier mounted on a handle.

Gnats, Pond Skaters, Whirligig Beetles.—A jar exposing a large surface of water and of moderate depth is best for these. A sandy bottom with weeds growing out of the water around the margin is also conducive to success with these and also give an attractive appearance to the vessel. The surface of the water should be some distance from the top of the jar. Such a vessel containing larval gnats, pond skaters, whirligig beetles, pond snails, affords excellent opportunities for the study of the properties of the surface film of water, and of the various uses small animals make of it. This jar should have a wire gauze (small mesh) or muslin cover, to prevent the escape of the inmates.

Various other common inmates of pools may be found by the enthusiastic collector, such as water boatmen, water scorpions, water spiders, water mites, flat worms, pond

snail of various types, and so on. These, along with water fleas and fresh-water shrimps, may be kept together in a vessel similar to the foregoing.

In general aquarium jars should be kept away from direct sunlight, *e.g.* in a north window. They should all contain water weed, of which a variety of kinds should be kept. The weeds not only render the vessels more attractive-looking, but they act as a shelter from too strong light, and to some extent enable hunted creatures to escape

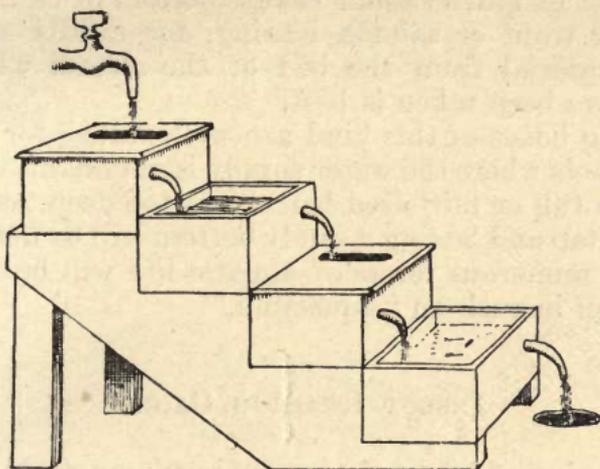


Fig. 175.—Salmon or Trout Boxes.

In the bottom of each box there is a layer of clean sand. A piece of wire gauze covers the opening (on the inside) of each outflow pipe, preventing the escape of the young fish. A constant drip of water is sufficient.

when pursued. They further serve the important purpose of aerating the water, and in some cases also serve as food to the inmates of these artificial pools.

The foregoing remarks apply exclusively to fresh-water aquaria. Marine aquaria are a little more difficult of management, but for schools situated near the sea these difficulties can be overcome. Teachers desirous of equipping a marine aquarium should commence by growing the commoner and more attractive-looking sea-weeds. When these have established themselves, animals such as sea

anemones, crustacea, molluscs, small fish, may then gradually be introduced.

In schools where a supply of running water is available a series of boxes arranged as shown in Fig. 175 affords opportunities for the rearing of young trout or salmon, the keeping of caddis-fly, may-fly, and stone-fly larvae, and other forms of aquatic life which thrive best in running water. Trout or salmon larvae may be purchased quite cheaply and the development can be followed for some months, and constitutes a fascinating study (Fig. 176). Such a set of boxes should have a bottom of clean sand or gravel for trout or salmon rearing, for caddis and other larvae material from the bed of the stream whence the larvae have been taken is best.

Rearing boxes of this kind are well suited for work in town schools where the water supply is abundant, but in the country a tub or fair-sized barrel, not too deep, set below a dripping tap and having a sandy bottom will be found excellent, and numerous forms of aquatic life will be found to thrive well in such an "aquarium."

INSECT REARING CAGES.

The rearing of insects is now so much practised in school that little advice is required on this subject. Various types of cage have been devised, illustrations of which are given below. These are all intended for Lepidoptera.

Besides Lepidoptera, it is desirable that one or two other types of insect life should be studied in this particular way. As an illustration of a beetle life-history an excellent case is that of the "meal worm" (*Tenebrio molitor*). The larvae may be had from bird and animal dealers, who use them for feeding purposes. A dozen or two of these should be placed in a clean glass vessel amongst clean bran.

If the vessel has flat sides and is not too wide, the movements, feeding, etc., of the larvae will be under observation. They may also be kept in a cardboard or wooden box. In any case the stages in the life-history can be followed

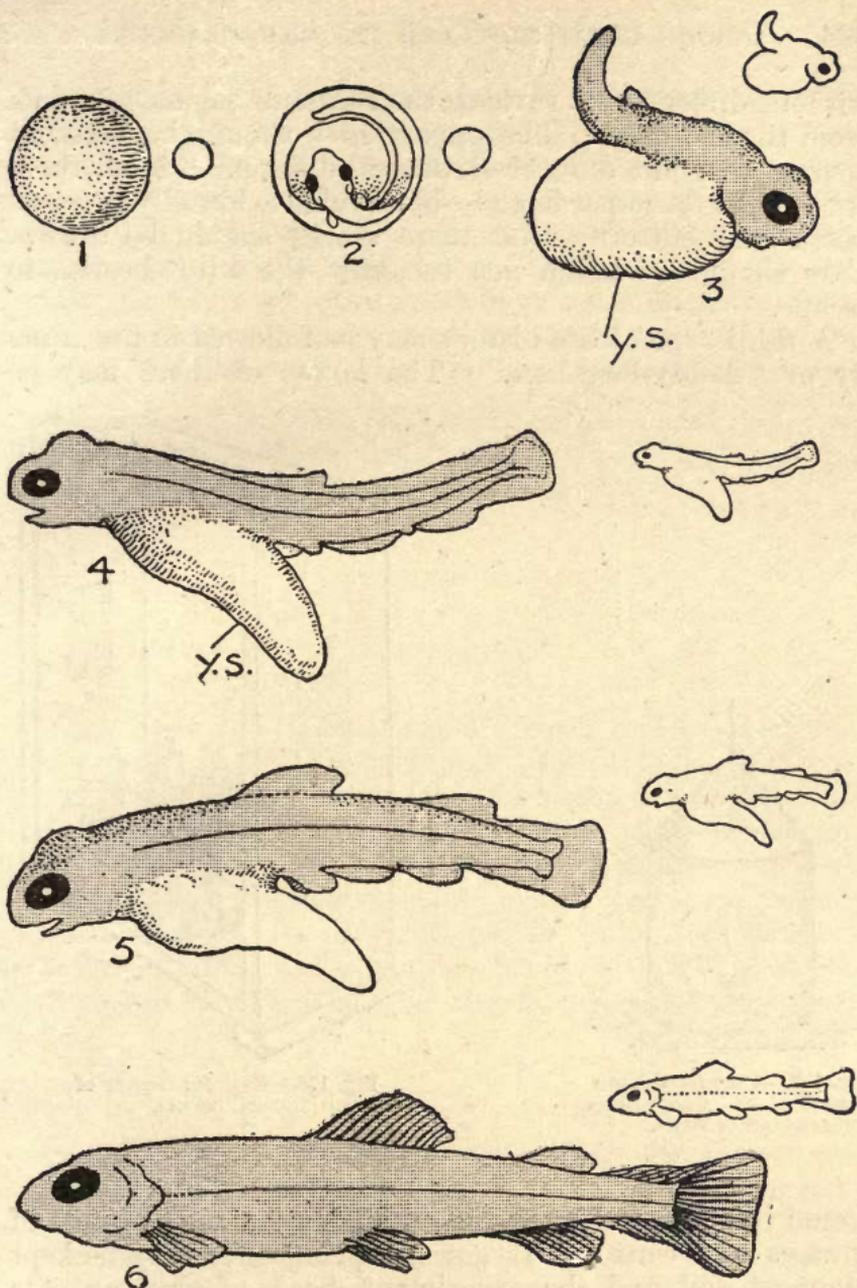


Fig. 176.—Stages in the development of the Salmon which may be followed in rearing boxes at school.

1, the egg; 2, the egg just before hatching; 3, the newly hatched salmon; 4 and 5, stages of growth illustrating the gradual absorption of yolk; 6, the young salmon with yolk all used up; only now does it commence to feed. From stage 3 to 6 occupies about six weeks. The small figures at the side indicate the natural sizes (*y.s.* = yolk sac).

without difficulty by turning the contents out on to a dish from time to time. The opportunity should be used, of course, to point out the structural differences in all three stages—larva, pupa, imago—observable externally between beetle and butterfly, and these stages should be drawn. Care should be taken not to allow the adult beetles to escape.

A third type of life-history may be followed in the crane fly or "daddy-long-legs." The larvae of these may be

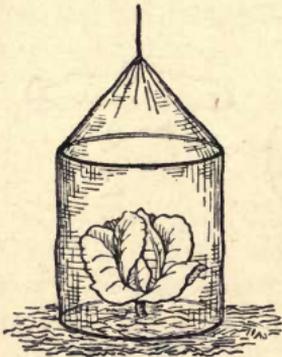


Fig. 177.—Cage for the protection of Caterpillars reared out of doors.



Fig. 178.—Cage for rearing of Insects indoors.

found in old pastures and in cornfields feeding on roots of grasses and cereals. If got in spring they may be kept amongst soil and the experiment tried of growing oats therein. It will be found that they feed upon the roots of the growing corn. Endeavour to complete the life-history by keeping them supplied with food—grass and corn roots.

The soil may be turned over from time to time and the increase in size of the larvae noted. Here again the structural feature of the three stages should be compared with other types. The adults may appear any time between June and September, depending upon the species, weather, and other circumstances. This study is an important one for a school situated in an agricultural district, since the destructive nature of the crane fly or "daddy-long-legs" is not sufficiently well known (see p. 311).

Observational beehives or formicaria.—These may be obtained from various dealers, and where they can be afforded are most interesting objects of study.

COLLECTIONS.

When once the enthusiasm of pupils and teachers has been aroused it will not be found difficult to make a collection of natural objects suitable for lesson demonstrations. Such collections will be found useful when weather conditions are unfavourable for outdoor work or when fresh lesson materials are scarce. They are of special importance in town schools. As illustrations the following are mentioned as of value, but of course this is a case where opportunities will largely determine the nature of the collections made.

Teeth.

Set of molar teeth (one of each type)—of dog or cat, (flesh cutting or bone crushing), horse (grain or herb bruising), ox (herb bruising or teasing), rabbit (herb bruising), pig (omnivorous type), man (omnivorous type). Such a group might profitably be extended to include incisors and canines as well.

This collection is useful as illustrating the structural adaptations in mammals to different types of diet.

Coverings of Animals.

- (a) *Hairs and their modifications*.—Fur of mole (burrowing type); piece of hedgehog's skin with spines (specialised protective type); skin of weasel (ordinary fur); skin of stoat, summer and winter varieties (seasonally adapted type); wool of sheep; bristles of hog; fur of rabbit, hare, or squirrel; seal's skin; skin of porpoise or dolphin (aquatic type).
- (b) *Feathers*.—Set of pigeon's feathers from different parts of the body mounted on a card. Large quill feather dissected on card to show different parts. Wing of pigeon, dried expanded on a board, and then displayed to show arrangement and kinds of feathers on this organ. Set of feathers to show brilliance in colouration.
- (c) *Scales*.—An interesting object, if it can be obtained, is the moulted scales (slough) of a snake. This is sometimes to be found on the moors or hillsides. It may be more readily obtained from an animal dealer.

To complete such a set, a few scales of different fishes might be mounted on a card with a glass front.

Collections of shells.—Such a collection, owing to its value in different ways, should be part of the nature study equipment in all schools. Foreign shells often exhibit great beauty of colour and sculpturing, and these are not difficult to obtain, but an endeavour should be made to secure a set of British examples, both marine and terrestrial, such as are referred to in the lesson on shells. See p. 147.

Collections of butterflies and moths.—These can be built up in part from the types reared in school. An interesting set can be made of a large number of individuals of the same species, e.g. of tiger moth or magpie moth. These are useful to illustrate the important fact of variation.

Other natural objects, e.g. common minerals, stuffed mammals or birds, etc.

METEOROLOGICAL INSTRUMENTS.

The school should certainly be supplied with a good barometer with thermometer attached, a wet and dry bulb thermometer, and rain gauge. A maximum and minimum thermometer will also be found useful. The barometer should be placed in a secure position about five feet from the ground, away from any source of artificial heat likely to affect the readings unduly. The thermometer should be fixed at a convenient height for reading facing the north out of doors. The rain gauge must be placed in an open space, clear of all buildings, and fixed in the ground so that it cannot be overturned. A useful and attractive adjunct is a series of water-colour drawings of the typical cloud forms. These should be of a good size and hung in a good light in the school-room.

THE TEACHER.

There are some rare individuals, generally spoken of as born naturalists and teachers, whose presence and conversation are sufficient to impart to their pupils an interest in the subject of their discourse. They carry with them all the charm of nature. They may not really be born naturalists: only a few of them are. But they have pondered much over Nature's ways, they have drunk of her spirit, they have probed her secrets, and have fought their way to a clear understanding of them. With leaf or flower, insect or pebble in hand, out of a mind enriched with nature lore they can attract attention, quicken the intellect, impart knowledge, create abiding interest.

In treating of school equipment it is well to emphasise the importance of the attitude of the teacher to his subject. Enthusiasm is essential to the highest success in teaching generally; without it "Nature Study" is in danger of becoming "stale, flat, and unprofitable." Let the teacher

cultivate an enthusiasm born of first-hand acquaintance with the facts and phenomena of which he has to speak, let him learn if need be along with his pupils. Let him cultivate the fine art of seeing; next, that of appreciating, not forgetting to appreciate the beautiful; once begun, he will pass to wonder, that is to inquiry. If he ask questions, if he seek to understand, and especially if he put his questions to Nature directly, he will gain that authority which is born of understanding and that love of his work which commands success.

GLOSSARY OF TERMS USED IN THIS WORK.

The terms included here are exclusively such as it has been found necessary to use in the foregoing work. The list embraces all likely to puzzle the average reader unfamiliar with Biology. Some have been incidentally explained in the text and are again included here. The list may be taken as representative of the minimum of terminology necessary for those engaged in Nature Study, and it is hoped that teachers to whom the expressions are unfamiliar will take pains to master their exact significance.

- achene**: a dry single-seeded non-splitting fruit.
- actinomorphic**: rayed in form, *i.e.* with radial symmetry.
- adnate**: applied to the union of unlike parts, *e.g.* stamens and petals.
- adventitious**: generally applied to roots or buds developed on unusual parts of the plant; adventitious roots may in the absence of a taproot develop from the base of the stem.
- ala**: wing; **alate**: winged.
- angiosperm**: a plant in which the ovules are contained within closed carpels, in contrast to gymnosperms, where the ovules develop in an exposed position.
- Annelida**: a class of ringed or segmented worms.
- anther**: the portion of the stamen in which the pollen is formed.
- anthidium**: the organ producing male elements in the group to which ferns and mosses belong.
- anthocyan**: a type of pigment widely distributed amongst higher plants.
- archegonium**: the organ producing female elements in ferns, mosses, and liverworts.
- arillus**: a growth upon a seed, commonly fleshy or hairy, *e.g.* the fleshy cup upon the seed of the Yew.
- assimilation**: the process in living bodies in which food materials are transformed into living substance.
- awn**: a bristle-like structure occurring in the flowers of certain grasses.
- bast**: the tissue in the fibrovascular bundles which serves to conduct elaborated food materials.
- berry**: a fruit in which all the parts around the seeds except the skin become fleshy.
- bract**: a leaf in the axil of which a flower or flowering branch arises.
- bracteole**: a small bract sometimes found on the flower-stalk of plants (secondary bract).
- bud**: an undeveloped shoot.

- bulb** : a reduced underground shoot whose leaves are thick and fleshy with stored food.
- calcar** : a small nodule occurring on the inner side of the hind foot of frogs and toads.
- calyx** : the outer whorl of a flower, viz. the sepals.
- cambium** : the layer between the wood and bast in which growth resulting in increase in thickness of stems and roots takes place.
- capsule** : a dry fruit opening when ripe to allow of the escape of seeds.
- carina** : a keel; applied to the ridge upon the breastbone of a flying bird. Also to the anterior petals in a papilionaceous flower.
- carpel** : the part of the flower in which the ovules develop (*see ovary*).
- catkin** : a close-set, more or less elongated inflorescence in which the flowers are unisexual.
- cell** : the unit of living matter, plant or animal. It consists of at least a nucleus and surrounding plasma.
- chalaza** : the thickened cords of albumen to be seen in a fowl's egg.
- chlorophyll** : the green colouring matter in plants.
- chloroplast** : the small protoplasmic bodies in plants containing chlorophyll.
- chrysalis** : the stage between larva and adult in lepidopterous insects in which metamorphosis takes place.
- cocoon** : the case of silky hairs which encloses the pupa of many insects. Also applied to the cases in which the eggs of spiders and other invertebrates are enclosed.
- conidia** : non-sexual reproductive bodies occurring in certain moulds.
- Coniferae** : cone-bearing trees.
- cork** : an impermeable tissue arising under the epidermis in stems and roots.
- corm** : a reduced swollen underground stem containing food reserves.
- corolla** : the inner whorl of floral parts, next to the calyx—usually coloured,—the petals (*see perianth*).
- cortex** : the layer of tissue in a stem immediately below the epidermis.
- corymb** : a flat-topped inflorescence, in which the individual flower-stalks arise at different levels (contrast umbel).
- cotyledon** : the leaf or leaves of the embryo within the seed.
- Crustacea** : a class of Arthropod animals, almost entirely aquatic, whose cuticles contain carbonate of lime and which have thus a hard shell-like exterior.
- cuneate** : wedge-shaped.
- cupule** : a cluster of bracts (involucre) united to form a kind of cup investing certain fruits, *e.g.* acorn.
- cuticle** : a layer secreted upon the outside of epidermal cells.
- decussate** : an arrangement of leaves in pairs crossed at right angles to each other.
- dicotyledon** : having two embryonic or seed leaves.
- drupe** : a fleshy fruit whose innermost layer (endocarp) is hard and stony.

- ecology**: the branch of study which considers the relations of organisms and their environment.
- embryo**: the young plant or animal prior to the stage at which it feeds itself.
- endosperm**: a nutritive tissue occurring in some seeds and absorbed by the young plant at germination.
- epicalyx**: a ring of bract-like leaves occurring on some flowers just outside the true calyx.
- epidermis**: the outermost skin layer.
- epigynous**: a type of flower in which the head of the flower-stalk grows around and above the ovary uniting with it, so that the remaining parts of the flower arise upon its margin.
- fertilisation**: the union of male and female elements which results in the development of a living organism.
- fibro-vascular bundles**: the system of vessels which conduct nutrient materials in all higher plants, including ferns, etc.
- filament**: the slender portion of the stamen which bears the anther.
- floral diagram**: a diagram to illustrate the relations of the several parts of a flower to each other.
- floral formula**: a formula to illustrate the numbers of the parts of a flower and their relations.
- follicle**: a dry fruit consisting of a single carpel, which opens when ripe along the ventral or seed-bearing margin.
- frond**: a leaf of a fern.
- funicle**: the stalk of the ovule or seed.
- germination**: the commencement of growth of the embryo within a seed.
- gland**: an organ which produces (secretes) a substance or substances of use to an animal or plant.
- glumes**: the scales or bracts enclosing a grass spikelet.
- gymnosperm**: a plant in which the ovules develop in an exposed position (*e.g.* Coniferae), in contrast to angiosperms where the ovules are contained within closed carpels.
- haemoglobin**: the red colouring matter in blood.
- heterostyly**: applied to flowers which exhibit styles of more than one length, *e.g.* primrose.
- hypogynous**: the type of flower in which the whorls occur in succession upon more or less elongated receptacle, the ovary being uppermost, *i.e.* superior.
- igneous**: of fiery origin.
- imago**: an adult. Generally applied to the mature insect after metamorphosis.
- imbricate**: overlapping, *e.g.* sepals or petals in bud.
- indusium**: the membranous covering of the sporangia in ferns.
- inflorescence**: the whole part of a plant upon which flowers are borne.
- invertebrate**: without backbone. Invertebrates have no bones of any kind.
- involucre**: a close-set series of bracts around inflorescence or flower-head, *e.g.* Dandelion.
- isobars**: lines of equal barometric pressure.

- lamina** : the thin flattened portion of a leaf; the blade.
- lanceolate** : narrow and pointed; lance-shaped.
- larva** : the active young of an animal when it is in structure and habits unlike the parent, *e.g.* caterpillars or tadpoles.
- lateral line** : a line which may be seen on the side of a bony fish's body. It is sensory in function.
- legume** : *see* pod.
- lenticel** : a place in the bark of a tree where the cork cells are loosely packed, permitting interchange of gases.
- lipochrome** : a group of pigments occurring in organisms. They vary from red to yellow.
- lymph** : that part of the blood plasma which conveys nourishment to the tissues. It is the intermediary between the tissues and the blood.
- Mendel's law** : a law of inheritance according to which mated individuals exhibiting certain mutually exclusive characters give rise to offspring amongst which these characters are distributed in definite proportions.
- metamorphosis** : the change of form undergone by some animals before reaching the adult state.
- mollusca** : soft-bodied invertebrate animals, mostly with limy shells, *e.g.* Snail, Oyster.
- monocotyledon** : having only one seed leaf (sometimes a second, in a vestigial condition, is present).
- mycelium** : the substance of a fungus distinct from reproductive parts, consisting of a mass of interlacing branching threads (*hyphae*).
- nectary** : a part of a plant producing sweet stuff for the attraction of visitors.
- nut** : a dry non-splitting fruit having woody walls, and containing a single seed.
- obovate** : a reversed ovate form; broadest at free end, *e.g.* leaves of Alder.
- orbicular** : rounded, approaching the circular in outline.
- ovary** : the hollow part of the carpel or carpels in which the ovules develop.
- ovate** : approaching the shape of an egg in outline. Applied to leaves which are rounded, longer than broad, and broadest towards the base.
- ovule** : the developing seed, prior to fertilisation.
- palea** : the scale or bract adjacent to the flower in a grass (the glumes occur outside the palea).
- palisade layer** : the close-set layer of cells, longer than broad, lying below the upper epidermis of a leaf.
- palmate** : shaped like the palm, with spreading lobes.
- pappus** : the circlet of soft hairs seen on the fruits of many compositae, *e.g.* Dandelion. It represents the calyx.
- pectoral** : relating to the breast, *e.g.* pectoral muscle; pectoral fin.
- pedicel** : the stalk of a single flower.

- peduncle** : the stalk or axis of an entire inflorescence.
- pelvic** : relating to the hip girdle, *e.g.* pelvic fins of fishes.
- pendulous** : drooping, *e.g.* many catkins.
- penninerved** : a type of leaf having the veins arranged like the barbs in a feather.
- perennial** : persisting for three or more years.
- perianth** : the outer parts of a flower, a term generally used when calyx and corolla cannot be separately distinguished.
- pericarp** : the wall of the fruit. It generally consists of three layers — epicarp, mesocarp, endocarp.
- perigynous** : a type of flower in which the receptacle is flat or cup-like, and the sepals, petals, and stamens are placed apart from the ovary.
- petals** : the parts of the corolla usually showily coloured.
- petiole** : leaf-stalk.
- phenology** : the study of the periodic appearances of plants and animals in relation to the seasons.
- pinnae** : the lobes into which fern fronds are usually divided. They may be simple or themselves divided into pinnules. Also the external ear lobes of mammals.
- pinnate** : a type of leaf in which the lobes or leaflets are arranged in serial pairs.
- pinnatifid** : a type of leaf having slight lobes cleft in series like the parts of a feather. The notches between the lobes extend about halfway to the midrib.
- pinnule** : the lobes into which the pinnae of fern fronds may be cut.
- placenta** : the part of a plant on which the ovules develop.
- plumule** : the young shoot which emerges from the seed at germination.
- pod** : a dry fruit, consisting of a single carpel, which opens along both ventral (seed-bearing) and dorsal margins.
- pollen** : the fertilising substance of flowering plants.
- pollination** : the application of the pollen grains to the stigma.
- pome** : a succulent fruit whose fleshy part is formed from the receptacle, *e.g.* Apple, Rowan.
- prickles** : sharp spiny structures arising from the epidermis of plants. They do not contain wood. Contrast spines.
- proboscis** : a general term applied to the mouth parts collectively of insects.
- procumbent** : applied to stems lying along the ground but not rooting.
- prolegs** : the temporary locomotor structures occurring upon the hind body (abdomen) of insects.
- proterandry** : male elements maturing before female.
- prothallus** : the body which bears the sexual organs in the fern and allied plants. The sexual generation.
- protogyny** : female elements maturing before male.
- pupa** : the stage between larva and imago in which metamorphosis in insects takes place. It is of more general significance than the term chrysalis.
- raceme** : an elongate inflorescence in which the flowers are borne on simple stalks.

- rachis** : the main axis (midrib) of a compound leaf or of an inflorescence. Also applied to the shaft of a feather.
- radicle** : the root of the embryo plant which emerges from the seed on germination.
- receptacle** : the top of the flower-stalk from which the parts of the flower arise.
- rhizoid** : the structures which perform the work of roots in mosses and in the prothallus of ferns. They are not true roots.
- rhizome** : an underground stem or rootstock giving rise above to buds and leaves, and to adventitious roots below.
- runner** : a creeping shoot growing along the surface and rooting and giving rise to buds at the nodes.
- samara** : a dry, non-splitting winged fruit, *e.g.* as in Ash, Elm, Birch, etc.
- sepals** : the parts of the outermost whorl of the flower, *i.e.* the calyx.
- serrate** : toothed like a saw.
- sessile** : without stalk.
- silicula** : a short and broad fruit of the siliqua type, *e.g.* fruit of Shepherd's Purse.
- siliqua** : a slender pod-like fruit, whose two valves split off leaving the seeds attached to the margins of a middle membranous partition, *e.g.* fruit of Wallflower.
- sorus** : a cluster of spore-containing capsules (sporangia) occurring on the fronds of ferns.
- spine** : a sharp woody structure ; a modified branch, leaf, or leaf stalk.
- spiracle** : an opening leading into the breathing system of insects.
- sporangium** : the spore-containing capsules on the fronds of ferns.
- stamen** : the essential male structure in a flower. A stamen consists of a stalk (filament) which bears an anther (pollen-producing part) at its tip. The filament is continued up the back of the anther as the connective.
- stigma** : the part at the terminal portion of the style which is modified for the reception of the pollen grains.
- stipules** : leaf-like appendages at the base of the leaf stalk, characteristic of certain plants.
- stomata** : openings upon the epidermis of leaves and young stems for gaseous interchange and transpiration of moisture.
- style** : the upper part of the carpel or carpels, usually elongated, which bears the stigma.
- tarsus** : the ankle region in vertebrates. The terminal joints in the legs of insects.
- testa** : the coat of the seed.
- thorax** : the chest region. In insects the middle division of the body consisting of three fused segments.
- transpiration** : the giving off by leaves of water absorbed by the roots.
- tuber** : a portion of an underground stem or adventitious root thickened with food store.
- umbel** : a flat-topped inflorescence in which all the flower-stalks arise at the same level, laterally from a reduced main axis.

umbilicus : a term applied to the pillar-opening in univalve shells ; also to the openings at the base and top of the quill of a feather.

valvate : an arrangement of the outer parts of the flower bud where the edges meet but do not overlap.

venation : the arrangement of the veins in a leaf.

versatile : a mode of attachment of anther to filament in which the former has free movement and swings readily, *e.g.* anthers of grasses.

vertebrate : the division of the animal kingdom which is characterised by the possession of a backbone.

whorl : a circle of similar structures, *e.g.* leaves or floral parts, arising at the same level.

xanthophyll : a yellow vegetable pigment occurring in association with chlorophyll.

zygomorphic : divisible in one plane only into two similar parts, *i.e.* showing bilateral symmetry.

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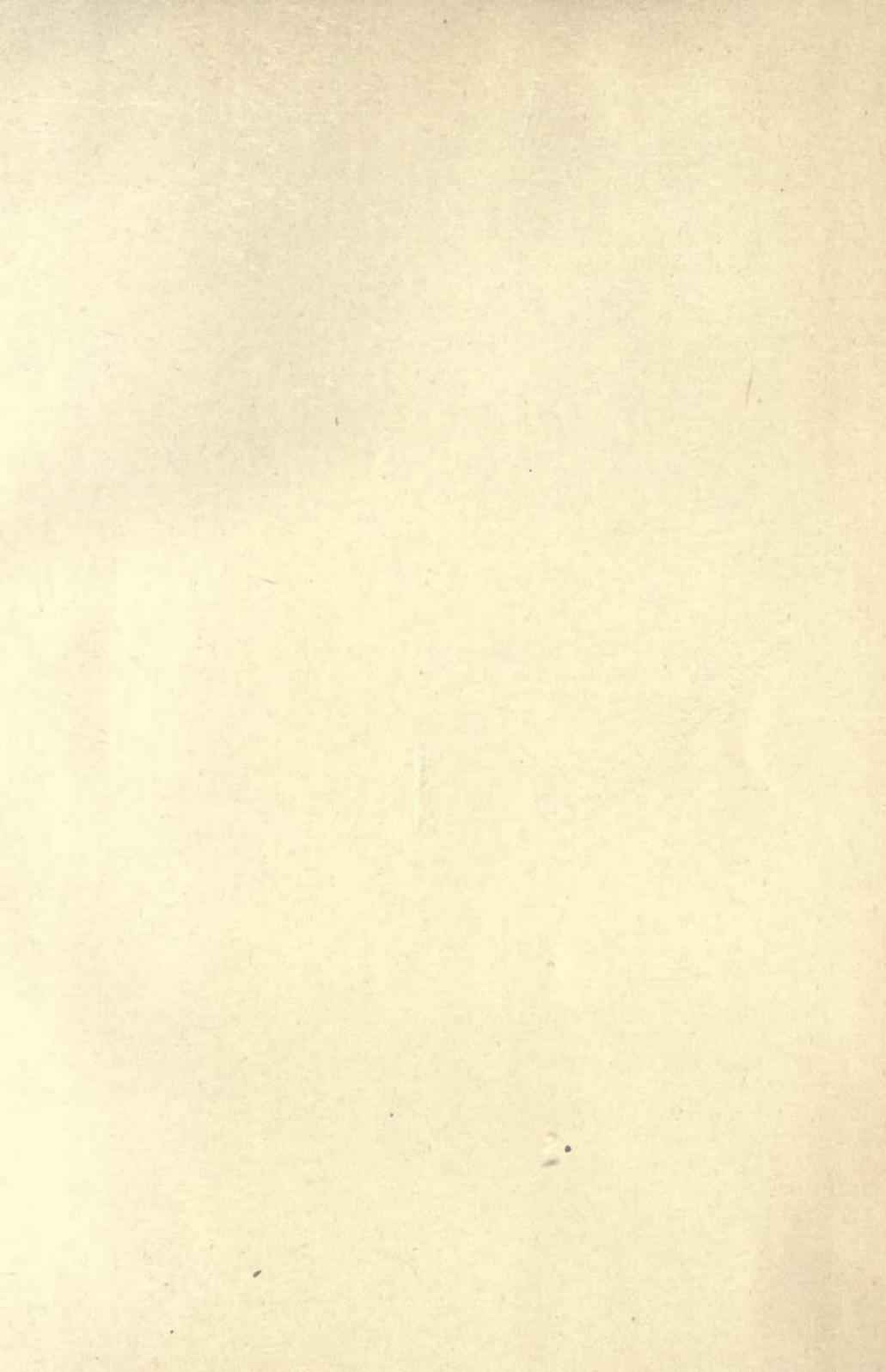
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