HOUSE, GARDEN & FIELD

L. C. Miall.

Bij
May 1906.

*

HOUSE, GARDEN, AND FIELD

Water-Lilies in the Obelisk Pond, Bramham Park.

HOUSE, GARDEN AND FIELD

A COLLECTION OF SHORT NATURE STUDIES

BY

L. C. MIALL, F.R.S.

PROFESSOR OF BIOLOGY IN THE UNIVERSITY OF LEEDS
AND FULLERIAN PROFESSOR OF PHYSIOLOGY
IN THE ROYAL INSTITUTION

WITH ILLUSTRATIONS BY A. R. HAMMOND

SECOND IMPRESSION

LONDON
EDWARD ARNOLD
41 & 43 MADDOX STREET, BOND STREET, W.
1905

14249

10089982

CONTENTS

LIST OF ILLUSTRATIONS

HOUSE, GARDEN, AND FIELD

I. INTRODUCTION.

I HAVE received a good deal of advice from teachers and others as to the kind of book on Nature Study that is really wanted, and I will begin by explaining how it is that I have found it undesirable to attempt exactly what my friends expect. They expect, it would seem, ready-made lessons on a variety of interesting and easy topics. The teacher, they tell me, has neither the time nor the knowledge to prepare lessons of his own. Since lessons on Nature Study are demanded, they must be drawn up for him, and put into his hands complete. It is quite true, I sorrowfully admit, that many teachers have no time for study. That is almost the same thing as admitting that they have not time to teach well, for it is only those who are always increasing their own knowledge who can hope to become inspiring teachers. Knowledge, to be stimulating, must be kept alive by personal effort; it cannot be acquired once for all.

This is true, I believe, of all teaching, but it is especially true of Nature Study. For the primary aim of Nature Study is to set up the habit of observation, and to keep alive that love of nature which shows itself in most unspoilt human beings. If the teacher does all the observation himself, his pupils are defrauded of their fair share, though they may possibly catch something from him of the spirit of inquiry. But if the teacher too gets all his knowledge without effort, then the so-called Nature Study which he dispenses has no more power to excite the love of nature or the spirit of inquiry than a printed list of the kings of England with dates. These considerations lead me to believe that it will be a greater service to start, if I can, the habit of observation and inquiry in some few teachers than to furnish a great many ready-made lessons.

I do not, however, think it superfluous or mischievous to print from time to time examples of ready-made lessons. The most independent of teachers can profit by seeing how another man goes to work; and he will, it is to be hoped, be as solicitous to note faults which he is to avoid as merits which he is to imitate. Of course, the facilities thus afforded will be abused by some. There are persons in all professions whom no pressure of circumstances would induce to think for themselves. But a teacher of any spirit will at least throw the information and the hints which he gets from another into a form of his own, and will carry on many inquiries which cannot be expected to issue in school-lessons.

The belief is prevalent that the training of teachers in Nature Study means supplying them with a number of lessons which can be directly reproduced in the school-room. Several objections to this time-saving method force themselves upon the attention. The teachers are put into a servile attitude; they are made into vehicles for transmitting (no doubt with much dilution and some loss of accuracy) lessons which another person has drawn up. The lessons as given to the teachers are not real lessons, nor are the teachers really trained, for the laying up in a note-book of materials for future lessons does not deserve the name of training. A printed book would answer the purpose in view better than any lecture; the book is both more extensive and more accurate than old lecture-notes. I have understood my duties differently, and address a class of teachers in training as persons whose powers are to be cultivated. Such tasks are assigned to them as they are fit for; the explanations and questions are adapted to their present knowledge and capacity. To offer them a lesson suitable for a class of children would be impossible, and even if it were possible, would give a wrong notion of what the lesson should aim at. A lesson at its best is an inquiry, worked out between the teacher and his class. Train the teachers to observe, to reflect, to express their meaning in clear language, and to arrange the matter of their lessons in a good order, but leave them entirely free to choose their own subjects, and to handle them in their own way.

Though the teacher, even if fortunate, cannot expect to be able to devote a large part of his time to study, the hours that he can now and then spend in study will be of great use, both to him and to his pupils. If he is only able to get up with due thoroughness a single new lesson a year, that lesson will influence all the rest. I have heard of a schoolmaster who had mastered by his own efforts the movements and phases of the moon, and taught that one thing heartily and well. No mean result, I thought, but I should have been glad to hear that he was adding a fresh topic to his stock every year; less than that would not fix him in the right attitude.

Whether the living things that share our dwellings, or seek their food in our gardens and fields, make the best possible matter for school-lessons or not, the student of nature is bound to attend to them. They are what the mother-tongue is to the student of languages, what the fatherland is to the student of history. A man who knows nothing about the flowers of his own window-boxes and his own flower-beds, nothing about the plants which raise food for him, or the insects which devour what he had hoped to enjoy, nothing about the minute forms of life which bring fertility to the soil, or fatal disease to the household, nothing about house-flies and hive-bees and bacteria—such an one may call himself a naturalist, may indeed have a right to the name, but he has need of deep knowledge of some other kind to escape the accusation of blindness and indifference. What opportunities of enlarging his knowledge of life has he allowed to escape him!

A good method of Nature Study should exhibit some of the following features:—

1. *It should bring out the most remarkable properties of the objects studied.* How serious an oversight it is to lecture on a plant or an animal, and somehow to ignore the fact that it is alive! Development, growth and adaptation to surroundings should never be out of the thoughts of those who guide others in the study of living things.

2. *Common objects will be preferred to rare ones*, partly because they are more easily procured in large quantities, and partly because the inquiries which they suggest are more likely to be resumed in after-life.

3. *A good method of Nature Study will stimulate the curiosity of the pupils.* Too often the teacher is the only person present who is at all interested. The class are not likely to be interested unless their curiosity is now and then moved. Nor is it easy to keep their interest alive, unless we give them their full share of choice and responsibility. Never tell your pupils things which they can find out for themselves. Wherever you can, let them make their own observations, and draw their own conclusions. Curiosity in the child may be the germ of love of knowledge in the man, and what we call Science is, more than anything else, the habit of putting and answering questions in an orderly way. Something that really deserves the name of biological research may easily grow out of the Nature Study of the schoolroom. "La plupart des découvertes consistent à dire: regardez!"

4. *Various powers of mind and body will be exercised.* Nature Study should not only train the powers of observation and reflection, but find work for hand and eye as well. Special gifts, such as mechanical ingenuity, or skill

in drawing and modelling, should find due exercise. We ought to encourage our pupils to draw to scale, to plot experimental results as curves, and to make with their own hands as many as possible of the boxes, stands and glass tubes which their experiments require. Photography and other methods of impartially recording natural fact are often of great service in the schoolroom, and later on, in the laboratory.

Nature Study should co-operate with other kinds of school-work, and I would here lay stress upon one particular discipline, which may well be closely associated with the observation of nature; I mean the study of the pupil's mother-tongue. It is a national peculiarity of ours that we cannot set forth our meaning clearly and concisely, without embarrassment. Perhaps this is in some measure due to the habit of repeating school-lessons from books; at any rate, the constant repetition of the words of a book in all spoken class-work has its effect in producing men who are timid and awkward in expressing their own thoughts. I am not without experience of the deficiency in English schoolboys which I here point out, but am comforted by finding that the deficiency is more one of education than of nature. The English schoolboy is not incurably dumb; after a short course of training, which encourages him to think, and to express what he thinks, he becomes in a measure vocal. His school has generally been unkind to him in this matter. I could wish that the schoolmaster would more often cultivate the power of expression in his boys, and Nature Study, among a score of other things, gives the opportunity. If only the schoolmaster, when he has a plant, or an animal, or a little scientific experiment in hand, would give his class a little drill in the useful art of description! Can he not make it clear that the description must not begin anywhere, and that there are certain essential points which every good description must include? With pupils who are altogether untrained, I have been accustomed to use a formula for biological description, such as this :—*Kind of thing—situation—form, size, colour—general structure — minute structure — function.* The formula, like formulæ of other kinds, is useful to the beginner, but must not be too rigorously imposed, nor continued too long. Even before the days of regular instruction are ended, the formula often needs to be mitigated, and at length replaced by a more elastic method.

Teachers now and then ask me how they are to teach Nature Knowledge to a class of seventy, eighty, ninety or even a hundred children. I am obliged to reply that in my opinion the thing cannot be done at all. You may keep order while you are instructing some few, but the lesson to such a crowd is at best an unsatisfactory make-shift. Not long ago I attempted to teach a class of sixty teachers in training. Though the circumstances were more favourable than one would find in school, we were compelled before long to divide the class. With so large a number, inattentive pupils escape notice, and attentive ones are not called upon often enough for the teacher to judge of their progress. These enormous classes are advocated in the name of economy, but I fear it is economy of the sort which pays half the price and gets a quarter of the value. I know of no way whatever in which fifty persons can be soundly instructed at the same time.

What I have seen of the present generation of teachers in training shows that they are much better instructed in drawing than their predecessors ; I believe that nearly all can draw as well as Nature Study requires. Further improvement is to be looked for in small points, such as the more frequent use of washes of colour, and in the art of drawing to scale, useful for so many purposes. Drawings on the black board, copied by the class, are often extremely mischievous in Nature Study. Coloration by chalks is facile and seductive, but spoils the quality of the outline. Shading of all kinds is best left out, as a rule. Faults which I find prevalent are the frequent use of india-rubber, and the inking-in at home of drawings made in class. Both spring from a love of mechanical tidiness, which is apt to obstruct greater virtues. Trial-lines need not be erased at all; the drawings of the great masters often show them without disguise. Erasure spoils the surface of the paper, besides encouraging a timid manner. A drawing made from the object should be treated with a certain respect, and never tampered with when the object is no longer at hand.

We want fresh helpers for the preparation of new Nature Studies. There must be a large number of teachers who could now and then write a good one. The difficulty (and a very serious difficulty it is) would be to pick out the really useful lessons from the rest. Such questions as follow might be some guide in the estimation of merit.

Has the writer made out anything, great or small, which was not known before? Does he employ new methods of inquiry, or new methods of teaching? Is the plan of the lesson natural, attractive, and likely to aid the memory? Is the language simple and expressive? Can the pupils do work for themselves upon the subject of the lesson? Does the lesson contain any good experiment? Is it illustrated by new and careful drawings?

I am quite sure that there would be no difficulty in getting any lesson published which came out well from such an interrogation, and I believe that to write once in a way with all possible care a lesson which was to appear in print would be a valuable discipline for the more ambitious of our young teachers. I should like to see the preparation of new Nature Studies organised a little.

Those who seek after educational reforms meet with frequent discouragements. The world does not love reformers of any kind, and one must in candour admit that they have their disagreeable side. But the reformers, among whom I should be proud to be reckoned, enjoy their little triumphs now and then. I can look back upon forty years of teaching, and the improvements which the

English people have adopted in that time are great and lasting. From what I have lived to see I draw the most cheering assurances as to the future of education in this country.

II. LIFE IN THE HOUSE.

The naturalist does well to keep his eye on the animals and plants of his own home. Even if he has chosen some other province of natural history for serious study, he will find it profitable to spend part of his time in watching the behaviour of the living things which are close about him. It is a shame, said Linnæus, to dwell in the fatherland and know nothing about it. It is a shame, we may add, to live in a house and know nothing about any of its inhabitants except such as can talk.

Indoor life is so peculiar that no animal or plant of ordinary habits can endure it. What, let us inquire, are the conditions which make the inside of a house deadly to the great majority of living beings? We may be led to appreciate better than we do, not only the effect of such conditions upon our favourites and captives, but also upon ourselves, the lords and owners of the dwelling.

The house is warm and dark, the air which it contains more or less impure. Persons who attend closely to their own sensations can nearly always perceive a decided smell on entering a house from the open air, a smell of human breath, or of cooking, or of mice, or of tobacco-smoke, or of ill-consumed coal-gas, or of decaying wood. It is true that we have improved a little upon the ways of our grandfathers. We no longer shudder to admit the night-air. We no longer fence our beds with close-drawn curtains, or close every window and fireplace to keep out the bare suspicion of a draught, but we are still far from living according to nature. The recovery of consumptive patients who have been made to live practically out of doors day and night shows how much more exposure we might safely face than we ever do when unalarmed about our health. It gives us also a hint that some of the greatest risks to health may possibly arise from excessive precautions against cold.

The comparative darkness of the rooms in which we read or write may be roughly estimated by anybody who has practised indoor photography. An exposure fifty times as long as would be requisite out of doors has often to be allowed in order to get a tolerable picture of the furniture of a room. Green plants kept in our rooms, unless they are set directly in the windows, show by thriving so ill how feeble is the light in which we live and work. The strain upon the eyes caused by our incessant efforts to define insufficiently illuminated objects may be one cause of the early decay of our eyesight.

The air of the house is charged with dust. We see the motes dance in the sunbeam. They settle in all quiet corners. The housewife pursues them with a dry duster, capturing an insignificant proportion, and merely stirring up the remainder. Microscopic examination of floating dust reveals fragments of nearly all the organic substances which are used in the dwelling for food or furniture, as well as living germs of bacteria and fungi, most of them harmless to health, a few of them mischievous or even deadly. Take a bright lantern, and throw its beam across the air of an inhabited room by night. Innumerable floating particles are revealed. Try the same experiment in a field bordered by trees; very often you will fail to discover any floating particles at all. There is no better filter for purifying the air which we breathe than wet grass and leafy trees.

Our posterity will no doubt find a remedy for these evils. It may be that they will live in houses almost as well-lit as our green-houses, and filled with a constant flow of pure air. If so, they will look upon us with some such compassion as we bestow upon the wretches who sleep upon a heap of hot ashes in a cellar, giving up fresh air and cleanliness for the sake of mere warmth. They will perhaps sleep in rooms as far superior to ours, as are ours to the narrow sleeping cupboards, which we can still see in Pompeii or in Haddon Hall.

If steady progress in the past is a presage of progress in the time to come, we have much ground for hope. In the fifteenth century, just before the coming-in of the industrial and scientific age, a labourer's cottage could be built in a single day ; it had no chimney, no window, and no floor but the trodden earth. Four stout posts, four walls of straw and clay, and a roof of heather or reeds, were enough to lodge not only the labourer and his family, but his domestic animals as well. When long afterwards hardworking men of humble rank attained what they called comfort, they made it their first care to banish hunger and cold, the worst enemies they had known. Naturally enough they went too far, made their meals too frequent and too plentiful, and thought it dangerous to admit fresh air to their rooms, or to let cold water touch their naked skin. We are now steadily overcoming the love of coddling, and shall in time dare to live according to nature. For a hundred years past the well-to-do Englishman at least has loved the open window and the morning tub. His example spreads, slowly we must admit, but spreads nevertheless. Our posterity of the twenty-first century, not only the wealthy, let us hope, but all of them, may be able to boast like Remulus : "We are a tough race, accustomed to plunge our children into the river, and to harden them by the touch of cold water."

We pride ourselves in this country on using more cold water for washing than some other nations, but this excellent practice did not begin with any Englishman. In the days of the French Revolution, or indeed a little earlier, the gospel of the Return to Nature began to be preached, and among the converts were Englishmen who had the ear of the public, such as the Edgeworths, Day (author of Sandford and Merton) and Erasmus Darwin. Each apostle had his favourite doctrines and his own way of teaching, but there was a general agreement that fashionable conventions must be defied, and simple modes of living restored. Fresh air, cold water, exercise, temperance in eating and drinking, light clothing and free exposure of the skin to the air, abstinence from drugs and rational methods of early education were chief among the reforms proposed. Most of those who taught the Return to Nature counted themselves among the disciples of Rousseau. Rousseau, however, though he handed on the torch glowing with fresh ardour, did not kindle it. The best part of what he had to teach concerning health-practices he learned from Dr. Theodore Tronchin of Geneva, who is still remembered as Voltaire's physician. A sober and practical Swiss made the discovery, sober and practical Englishmen became its zealous exponents, but the intermediary between them was the most flighty of sentimentalists.

I will say no more about hygienic progress, but will go on with the animals and plants of the house, which are more in my way. Let us first run over them rapidly, in order to get a rough notion of their number and variety; afterwards we can consider some few in more detail.

A large and well-found house will very likely contain all the following vertebrates, with perhaps some additions or substitutes:—dog, cat, canary, gold-fish, rat, mouse. Among these the dog occupies a peculiar place; he has come of his own accord, for purposes of his own. The dog, it is probable, attached himself to man for the sake of food and shelter, made himself useful, and was allowed to stay. Food and shelter were not all that he wanted; his instincts demanded a companion and master as well. He came, we suppose, as a thief and a parasite; in the end he established himself as a servant and comrade. There is no other domestic animal on the same footing.

The cat is on less confidential terms with us. She would never have come to the house of her own accord;

her suspicion is too great for that. But being, it is probable, brought in as a kitten, and finding the house convenient both for lodging and for the capture of small prey, she has gone on as a kind of lodger with us. The cat cares more about the house than about her master and mistress; she has never lost the power to procure her own food; she has still many of the instincts of a wild animal. Individual cats no doubt exhibit strong attachments to persons, but that proves little; the cubs of wild beasts, when brought up in the house and kindly treated, become attached to their keepers. Our domestic cats are little altered from the cats which lived a free life, lurking in trees in order to pounce upon birds. Variety in the colour and length of the fur is the most conspicuous mark of domestication which they exhibit. Little pains have however been bestowed upon the methodical selection of cats and the establishment of pure breeds.

Birds in cages and fishes in bowls are captives stupefied by loss of liberty. The canary has been regularly kept in cages for four centuries, and has acquired by artificial selection a pure yellow colour. Wild canaries in their native islands have a song of their own, but tame ones are regularly taught to sing, being set beside a nightingale or a woodlark until they have picked up the song by imitation. The gold-fishes kept in Europe are rather uninteresting pets, but in China pains have been taken to establish varieties, many of which are incredibly odd, though not beautiful.

The rat and the mouse are robbers, which prey upon the householder against his will. Some further account of them is given in a separate place (see p. 78).

One mollusk may be said to be a domestic species. In a good many houses a slimy track is frequently seen on the kitchen-sink, and any one who sits up to watch, finds half an hour after the lights have been put out a great orange cellar-slug, which comes forth from its hiding-place to feed on potato-parings and cabbage-leaves.

The insects of the house may be either slightly or closely connected with it. Some are mere casual visitors, which, like wasps or humble-bees, enter through a door or a window, and find themselves caught in a trap. They may escape after a time, or exhaust their strength in vain efforts to fly through the window-pane. These casuals enter the house by mistake, and many enter it only to starve. Next may be mentioned the insects which are parasitic on man. Some of these make use of the house as a shelter and breeding-place, but there are others which belong rather to the inhabitant than to the house, and multiply just as freely out of doors, as for instance in camps, or among armies which bivouac in the field. A third class consists of insects which are bred out of doors, but regularly enter the dwelling for shelter and food ; the house-flies are the best example. Lastly we come to the insects which better than any others deserve to be called insects of the house. They are born and bred in the house, and obtain all their food from it. To this class belong cockroaches, crickets, furniture-beetles, clothes-moths and silver fishes, besides others which are less easily remarked.

House-spiders of more than one kind have made themselves quite at home in our dwellings. Mites attach themselves rather to the food of man than to his houses. One true crustacean, the wood-louse, which frequents out-houses and gardens, now and then establishes itself in a cellar.

No green plants can permanently maintain themselves in the darkness of an ordinary dwelling, but moulds and bacteria often find the conditions favourable, and multiply so greatly as to affect the health and prosperity of the owners. Most of them are injurious, but a few have their uses in the preparation of food, and thousands of years ago, long before their real nature was suspected, were enlisted in the service of man. Of these last some account will be found in a later chapter (p. 50).

III. JULY SHOOTS.

The season of 1903 was unusually trying to the leaf-expanses of my trees. Until after Easter the weather was favourable to growth, and I have rarely seen such a profusion of blossom on the fruit-trees as I saw this spring in Yorkshire, in the Severn valley, and in Somerset. Then came a killing frost, with snow-showers and cutting winds from north and east. The promise of the year was blighted in a week, and the fruit-crop ruined. Other trees besides fruit-trees suffered. When the horse-chestnut leaves expanded, it was seen that many of them, and especially those which had first broken from the bud, were disfigured by brown patches, which lay in rows between the lateral veins of the leaflets. A long course of windy weather followed, and the rubbing of the leaves against one another fretted the brown patches into holes, sometimes reducing the leaflet to a comb-like skeleton.

In 1904 we had no frosts in early summer ; the flowering trees put forth magnificent blooms. But there were high winds at the time of leafing and afterwards. Horse-chestnut leaves in exposed places were fretted almost as badly as in 1903. I am now inclined to attribute more to wind and less to frost than I did a year ago (June, 1904).

A sycamore in the same garden and equally exposed to wind, showed no holes or brown patches on its leaves. Few trees of northern and central Europe bear wind so well as the mountain-bred sycamore. But the flower-spikes of the sycamore were nipped by the frost of 1903, and very few " keys " were produced the following autumn. Even the leaves of the sycamore, which endure wind so well, are often attacked by mildews—funguses which fasten on them and form large black spots, and by galls.

Oak is much injured by insects, more, I think, than any other common tree. The leaves are often ruined by the Tortrix-caterpillar ; galls form on the leaves or in the buds, and in these galls are found the grubs of various insects; oak-apples and oak-spangles are familiar examples. Many beetles too infest the oak. I remember a great oak-tree which stood hard by the cricket-field of my boyhood. The lowest bough was high above the ground, and it was long before I enjoyed the satisfaction of climbing into that tree. The day on which I first accomplished the feat was a hot summer's day when the oak was in the glory of its fresh foliage. The first thing which struck me was the number of beetles which lurked among the leaves. I soon had a bottleful of miserable captives, and no doubt sweetened with them the dull preparation-hour; two of those beetles I still recollect well enough to give them their proper names. One would have thought that the astringent flavour of all parts of the oak would have sufficiently defended the tree, but the defence is little heeded.

These and other trees whose leaves are blighted by frost, or wind, or mildew, or insects, have the means of repairing the injury. They hasten the development of some of their buds, and put forth July or Lammas shoots, which are often conspicuous from the contrast between their fresh green leaves and the faded leaves around. Oak, sycamore and horse-chestnut are among the many trees which regularly put forth July shoots, but ash, which comes into leaf very late and rarely has its foliage defaced, seldom if ever produces them.

IV. LEAF-MINING INSECTS.

Search the leaves of a bramble in July, and see if you can find the mines of any insect-larvæ in them. One kind begins very narrow, but gradually widens as it proceeds, and turns this way and that upon the leaf, until its tortuous course extends to nearly three inches. This is the work of a small caterpillar, which eats away the soft inner green substance on the leaf, but spares the transparent epiderm. The mine becomes filled with air, and at length shows up strongly against the dark ground of the leaf. When the larva begins to mine it is very small, but as it grows bigger, it excavates for itself a wider and wider gallery. It is easy to turn it out with a needle, and observe the yellow, translucent body, tapering behind. The usual three pairs of thoracic legs are wanting, but there are some imperfect abdominal legs. Legs are often deficient in such insect-larvæ as are enclosed in their food, and have no motive for moving far. When the season for pupation is at hand, the larva quits the leaf, which has hitherto provided it with food and shelter, and spins for itself in some safe retreat a flattened cocoon, within which it changes to a pupa. After two or three weeks the moth emerges. It is only about a quarter of an inch long, with brownish-yellow fore wings, becoming purple towards the tips, and a pale yellow band beyond the middle. I know of no English name for it, but its technical name is Nepticula aurella. The hind wings are furnished with long fringes, a peculiarity not uncommon in insects of different kinds.

Another minute, fringe-winged moth (Tischeria marginea) is also common on the bramble. The larva is most often found in winter, and may be recognised by the shape of its mine. Beginning very narrow, it soon expands into a large irregular blotch, which occupies perhaps a third or a fourth of a leaflet. The insect pupates within its gallery.

When you have once begun to notice leaf-miners, you will see them everywhere, on buttercups, cow-parsnep, dock, celery, and many other plants of the field and garden. You will find that most of the leaf-mining larvæ turn either to moths or to two-winged flies. Each species keeps as a rule to its own kind of plant. There are also leaf-mining saw-flies and beetles. The mischievous turnip-flea is a small beetle, whose larva mines the leaves of the turnip.

It is not difficult to rear leaf-mining insects in captivity. A wide-mouthed bottle, with a little damp earth or sand, suffices for some; or you may stick the cut end of the plant into wet sand, and cover all with a glass shade. Some of the moths or flies will come out after a few summer weeks; others must be kept all through the winter. Do not be satisfied with rearing the winged insect and making out its name; that is only a preliminary. Try to investigate the structure and habits of the larva. Think over the various difficulties which it has to face, and then see for yourself how those difficulties are overcome. The work, though not to be called easy, has a fascination which is strengthened by experience. Instead of giving more advice, a drug of which the patient soon tires, I will give an example. The next lesson contains an account of what I have been able to make out concerning the history of a very wide-spread leaf-miner, the holly-fly.

V. THE HOLLY-FLY.

The holly-trees in my garden and in the hedges around are regularly mined by the larva of a two-winged fly. In spring, summer and winter many a holly-leaf is seen to be blistered, the blister sometimes extending over a considerable fraction of the upper surface. When the blister is opened with a needle, one or two minute yellowish-white larvæ, with black heads and tails, are found within. They pupate in April or May, and form flattened oval cases, of a rusty colour, and smooth, shining surface. Each case shows a number of regular transverse lines, which mark the segments of the larva, for this is one of the very numerous Dipterous insects which form their outer pupa-case from the dry and contracted larval integument.

In June the fly is ready to become free and lay its eggs in the young leaves. But how can the fly, which is minute and unprovided with a biting mouth, escape through the tough epiderm of the holly-leaf ? The aperture by which the egg or the larva passed in was extremely minute, and is now choked up by dead vegetable matter ; even if it remained open, the fly would have to ramble up and down in a very low passage, at the risk of damaging its gauzy wings, in order to discover the way out. The problem is not to be solved thus. Consider for a moment how you would provide for such a difficulty, if it had been left to you to arrange the life-history of the holly-fly. Some people to whom the question has been offered as a puzzle, have found it too hard, and nobody has succeeded who had not knowledge of the behaviour of other insects in like emergencies. Yet it is really as easy as making an egg stand on end. When the fly has come forth, you see a hole torn in the blistered epiderm, and in that hole the empty pupa-skin is left sticking. If we watch the leaves daily, we sometimes detect, not an empty but a full pupa-skin, still lodging the body of the future fly, and wedged in a good-sized hole. The last act of the larva, before it ceases to feed and move about, is to bite through the epiderm, and thus all the rest becomes easy. Do not fail to remark what we can hardly help calling the forethought of the larva. If it were to fail to force a passage beforehand, the future fly would be hopelessly imprisoned. Just in the same way a wood-boring larva comes to the outside of the tree-trunk, a leather-jacket (larva of daddy-long-

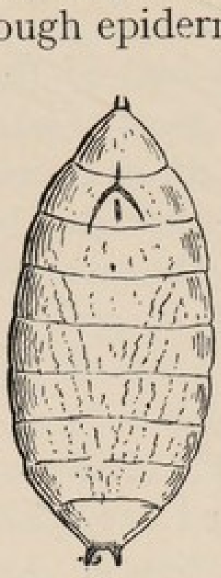

FIG. 1.—Pupa of holly-fly, enclosed within protective larval skin.

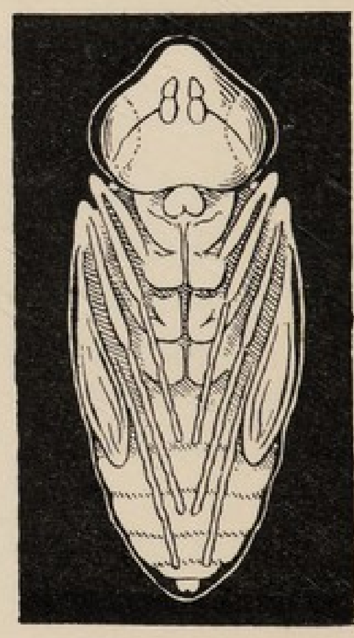

FIG. 2.—Pupa of holly-fly removed from the protective larval skin. The ventral surface, with the head, legs, and wings, is seen.

legs) to the surface of the ground, shortly before emergence, and when the fly has become free, the empty case is often seen half-protruded from the burrow.

This difficulty is no sooner overcome than another appears. The last larval skin in this, as in all the more specialised flies, is not cast at pupation, but retained as an outer defence during the resting-stage; it usually hardens to a shining brown or black cylinder, tapering at both ends, and somewhat resembling a seed (Fig. 1). Inside this the fly develops, shrouded within a soft white covering, which is the proper

FIG. 3.—Holly-fly, emerging from the leaf. In the lower fig. the pupa-case is shown within the leaf. Both figs. show the bladder on the forehead, the compound eyes, antennæ, &c.

pupal skin (Fig. 2). All goes well until the moment for emergence arrives. The fly is then so tightly packed within its double case that it cannot move a limb; its skin is soft and flexible; how is it to force its way out? You might study this problem for a long time without hitting on the expedient which nature has provided—an expedient which has this chief merit, that it hardly ever fails of its purpose. Upon the head of the newly formed fly is a bladder-like expansion (Fig. 3), which can be so greatly distended with liquid as to exceed in size the head itself. The liquid is the transparent, colourless blood of the fly. So great is the pressure within the bladder, that the end of the hard outer shell is torn open, a specially prepared cap being often detached (Fig. 4), and through the orifice the fly creeps out. During the act of extrication the bladder can often be seen alternately swelling and collapsing. Blue-bottles, house-flies, cheese-flies (see p. 114), and many more escape in the same way from the barrel-like case within which they were developed.

The holly-fly (Fig. 5) belongs to the enormous family of the Muscidæ, and is not very unlike a diminutive house-fly, being only $2\frac{1}{2}$ mm. (one-tenth of an inch) long. It is nearly black, but the proboscis and halteres (balancers) are white. The female fly lays an egg upon a young holly-leaf, and thus starts the new generation.

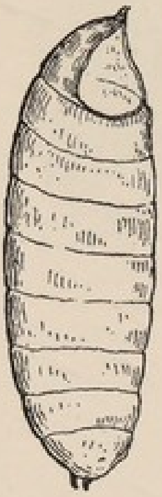

FIG. 4. — Cast skin after emergence of holly-fly. The place of escape is seen near the upper end.

The little maggot feeds all autumn, winter and spring, devouring the soft green cells of the evergreen leaf. Its body is sufficiently transparent to show a green line traversing it from one end to the other; this is the alimentary canal, filled with fresh green food. By the help of the microscope we can see that the head, as in other maggots, is reduced to a vestige; even the paired jaws have disappeared, and the biting apparatus is a simple arrangement of hooks or teeth, which serve to loosen and bruise the soft leaf-cells. Two or three galleries are often run through the same leaf, and as many pupæ are of course developed. They seem at first sight to share the gallery between them, but if the leaf is minutely examined, it will generally be found that partitions are left, and that each pupa inhabits a separate cavity. The larva of the holly-fly is preyed upon by two parasitic Hymenoptera, which subsist upon the tissues of their living host. Shortly before the winged fly is due, an insect of a quite different kind may emerge from the blister made by the holly-fly larva.

For a long time I could find no trace of this insect—egg, larva, pupa or fly—during late summer and autumn. The flies emerged in June, but the blisters never appeared on the holly-leaves before November. What went on during the interval? Was there perhaps a second brood, fed upon a totally different plant? Every likely method of observation was tried without success. Once our attention was directed to little dots on the under side of the holly-leaves, which looked like the holes made by a small, egg-laying fly, but these turned out to be only the pricks

FIG. 5.—Holly-fly, magnified.

of other holly-leaves, made in a season of high winds. The puzzle was at last solved by Mr. T. H. Taylor, who discovered the young and minute larva in September, and thus supplied the part of the story which had escaped our notice. The egg is laid in June by the newly emerged female fly on the under side of the midrib of a holly-leaf lately come to its full size, never on an old leaf. The place where the leaf is pierced (probably by the larva) afterwards becomes conspicuous as a red spot. As soon as it hatches out, the larva bites its way into the vessels of the midrib, and no doubt finds itself very well off there, getting complete protection and an abundant supply both of liquid food and air, without trouble or anxiety. It travels slowly along the vessels, and may take four months to cover half an inch. At length it turns sideways, quits the vessels of the midrib, and passes into the web of the leaf, where it begins to feed on the green cells. Soon after this a small blister begins to show, and this first catches the eye of the poring naturalist, who had been searching all the time for blisters, and never dreamt of examining the midribs of the leaves.

VI. A GENERAL KNOWLEDGE PAPER ON COMMON THINGS FOR GROWN-UP PEOPLE.

1. How may the waxing moon be distinguished at a glance from the waning moon ?

2. How does a cat wink ?

3. Why do the black keys of a piano run in twos and threes ?

4. Walking under some trees on a summer day, I find a great number of bees lying helpless on the ground ; some have lost their heads. What has happened ?

5. Why does dust rise from the road with a light wind, while the heaps of stones (of the same weight for a given bulk) lie still ?

6. What differences can you point out between the skin of the palm and the back of the hand ?

7. Draw from memory and in side-view the surface of the mercury in a barometer-tube, and the surface of water as seen in a tube of the same size.

8. Why does the moon look bigger when near the horizon ? Prove that her apparent diameter, as measured by instruments, must be less when she is near the horizon than when she is high in the heaven.

9. On a frosty morning, when the ground is thinly covered with snow, I have remarked that the snow lies longer than elsewhere on a low bridge over a dry gully ; that it melts early on a low bridge over a stream ; and

that the mud is quite soft under a railway-bridge. Explain these differences.

10. Why is the breast-meat of a fowl white, and the leg-meat dark? Mention birds which come to table whose breast-meat is dark.

11. Why does a pan of milk boil over sooner than a pan of water?

12. In how many different ways can you tell the north?

13. Of what advantage is it to a horse-chestnut that its young leaves droop, and hång vertically?

14. Design two wheelbarrows, one suitable for wheeling garden rubbish, the other suitable for wheeling lumps of iron or lead.

15. Why do we slide the hand toward the coal when lifting a heavy lump with a pair of tongs?

16. Why do we swing the hands to and fro, when walking fast?

I will add a question which I cannot answer fully, though I have puzzled over it for years. Why do the leaves of the aspen and some other poplars quiver? It is easy to see how they do it; a glance at the leaf-stalk is enough. But what is the advantage of the quivering leaves? (See p. 195.)

Many years ago Charles Waterton set the fashion of puzzling his readers with hard questions. Why, he asks, has one cow horns and another none? Why does a dog lap water, and a sheep drink it? Why has a horse large warts on the inside of his legs? Why does cock-robin sing for twelve months consecutively, whilst his companion, the chaffinch, warbles but half the time? [1]

"A boy or girl," says Herbert Spencer, "rising in the teens, might with advantage be asked—How happens it that in hilly counties such as Devonshire, the lanes are deep down below the surface of the adjacent fields; whereas in flat counties the surfaces of the lanes and of the fields are on the same level? What is the definite

[1] Essays on Natural History.

and unmistakeable distinction between running and walking? Why do horses and cows drink as human beings do, by sucking in the water; whereas dogs and cats drink by lapping? What is the adjustment of the parts of the eye which gives the infantine stare, as contrasted with that adjustment which gives the calm gaze of the adult? What advantage does a plant get from having a hollow stem or stem filled with pith? and why is this advantage, which many short-lived plants avail themselves of, unavailable by trees, save when young and afterwards in their shoots? Why, in a river, is the water next a convex shore usually shallow, and the bottom often sandy?

"A teacher who understood his business would be continually devising questions of these and countless other kinds, to which no answers could be found in books, and would persistently refuse to give the answers: leaving the questions to be puzzled over for years if need were. The mental exercise which solving one such question implies, is of more value than that implied by a dozen rote-learnt lessons."[1]

VII. HONEY-DEW.

All through the summer, when the weather is warm and dry, honey-dew may be seen on the leaves of the sycamore-maple. Sometimes it is found on bushes which are overhung by sycamores, and in a city the pavement under a sycamore may be seen to be spotted with drops or patches of the same kind. If you are able to use the tests for sugar, it is worth while to sponge the leaves or pavements, then to squeeze out a little liquid from the wet sponge, and satisfy yourself that it really does contain sugar. Naturalists of old times judged by the taste, found it sweet, and concluded that the honey fell from heaven, or was exhaled from plants. The first serious

[1] Autobiography, vol. ii. p. 321.

investigation of honey-dew was perhaps made by Réaumur, who in the course of his studies on aphids observed that these little insects discharge a sweet liquid from the intestine. He remarked further that ants are fond of the liquid, and protect or caress the aphids for the sake of it. Linnæus supposed that the aphids discharge the drops of honey-dew from two tubes, which stand up from the abdomen, and the statement has been repeated again and again down to our own times. It appears to be altogether baseless; the tubes in question do indeed discharge drops of viscid fluid, but these are defensive, and only serve to annoy the many insects which come to prey upon aphids. The proof of this is to be found in the pointing of the tubes towards any threatening object, and the occasional clogging of the face and jaws of the assailant with the sticky secretion. Even after Réaumur had put forth his clear and well-founded account of the origin of honey-dew, the question was not finally disposed of. The belief was strongly held, even by naturalists so recent and so careful as Boussingault, Hooker and Darwin, that besides the honey excreted by aphids there is a honey which exudes from the sycamore. Several years ago this generally received belief was thoroughly tested by Büsgen in his "Honey-dew; biological studies on plants and aphids" (Jena, 1891). He shows that the liquid is squirted out, and falls not only on leaves, but on pieces of paper or glass set below the places where aphids are feeding. The drops form, not on that surface of a glass slip which is in contact with the leaf, but on the surface which is turned upwards, and appear suddenly, instead of gradually oozing from pores. Büsgen described fully the process by which aphids draw from the sycamore their supply of sugary food. The proboscis is armed with long and extremely flexible bristles, which seem to have the piercing powers of the slenderest imaginable steel needles, and are able to penetrate by winding passages the tissues of the leaf, until they reach the vessels of the bast. Thus the nutritive fluids, elaborated in the leaf, and meant to supply the growing tissues of the sycamore, are tapped, and drawn into the mouth of the aphid by capillarity, the closely applied bristles acting like the threads of a lamp-wick. The only insects which can avail themselves of this source of sugary food are Homopterous, such as aphids, scale-insects and cicadas. The cicadas of tropical South America emit showers of liquid from certain trees which they regularly haunt, and which are called "rain-trees" because of the fine drops which seem to distil from them.

The spreading of the drops of honey-dew into the films which glaze the leaves of the sycamore is caused by dew or fine rain, which moistens the drops and afterwards evaporates. Sycamore is not the only tree from which honey-dew can be extracted by aphids; lime, plum, cherry and other common trees can be tapped in the same way. There is no doubt that the trees infested by aphids suffer; they lose food-substances which are required for new growths, and their leaves are overspread by a sticky substance which checks the exchange of gases, and favours the growth of moulds. It has been ingeniously suggested, however, that the sprinkling of the leaves with honey-dew may be in some measure beneficial to the tree. There are plants which possess honey-glands on their leaves or stipules, "extra-floral nectaries" they are called. These attract ants, which are thought to protect the plant from such dangerous enemies as leaf-eating caterpillars. In certain cases the utility of the ants thus attracted to the plant is unquestionable. Most observers of the sycamore as it grows in English fields and gardens would, I think, come to the conclusion that while the mischief caused by the aphids is real, the protection afforded by the ants is very doubtful. This is not quite decisive of the question, for the sycamore is not an undoubted native with us, and there may be countries where caterpillars are more injurious enemies to the sycamore, and ants more valuable allies than our local experience would show. A multitude of facts have now established the possibility of plant-protection through the encouragement of ants, but as yet I have not found any proof that sycamore is protected by ants from leaf-enemies.

VIII. THE HUMAN HAND; A SCHOOL LESSON.

The hand consists of an undivided broad part and five fingers of different lengths. One of the fingers is called the thumb; it is shorter, fewer-jointed and more freely moveable than the rest. Owing mainly to the irregularity of the thumb, the hand is unsymmetrical, and cannot be divided into similar halves by a line drawn in any direction whatever. The hands make a pair, and the left hand looks like the right hand seen by reflection from a looking-glass. We can see that the hand is covered by skin, and we can feel that there are bones within.

The skin of the hand consists of two layers. The outer layer (epiderm) contains neither bloodvessels nor nerves; it does not bleed nor feel pain when wounded. It is easy to show by scratching or scraping any thick part of the epiderm that it contains no blood, but perhaps you will not at once agree with me that it cannot feel. In many parts of the body (the back of the hand is one) we seem to feel the slightest touch. But there are reasons for what I have said. Rowing may bring out blisters on the hands; walking may bring out blisters on the feet, and when a blister forms, the epiderm becomes separated from the derm or inner layer by a small quantity of water. If you prick the epiderm to let the water out, no pain is felt, but if the needle is passed into the derm, we suffer pain. No blood comes when the epiderm is pierced, but the slightest wound causes the derm to bleed. Though the epiderm itself feels nothing, it can transmit pressure or heat to the sensitive derm within. Press a sheet of thin paper against some part of your own skin, and then stroke the paper with the point of a pin. The movement of the point can be felt through the paper, though paper cannot feel, and in the same way we can feel pressure through the epiderm, though it can no more feel than the paper itself.

The skin of the finger-tip shows a special pattern, which can be made very evident by pressing it first on a plate spread with printer's ink, and then on white paper.[1] After a few trials we get a sharp impression or print of the finger-tip. There is a central point, round which a great number of lines are arranged, so as to form either spiral or concentric figures. Each line is a ridge, with a steep slope facing the centre, and a broad slope facing outwards. The ridges sometimes branch or run out to a point, and new ones come in, so that the arrangement is not perfectly regular. All these details can be seen by carefully examining a finger-print, or better still by studying the finger-tip itself with a good lens.

[1] To get good and sharp impressions some trouble must be taken. The necessary appliances can be borrowed from a printer. The ink should be more fluid than is used for letter-press printing, and must be spread out on a slab of glass or polished copper with a small printer's roller. Pains must be taken to get a very thin and uniform layer; it is best to begin with very little ink, and add more if required. "The right hand of the subject, which should be quite passive, is taken by the operator, and the bulbs of his four fingers laid flat on the inked slab, and pressed gently but firmly on it by the flattened hand of the operator. Then the inked fingers are laid flat upon the upper part of the right hand side of the card, and pressed down gently and firmly, just as before, by the flattened hand of the operator. This completes the process for one set of prints of the four fingers of the right hand. Then the bulb of the thumb is slightly *rolled* on the inked slab, and again on the lower part of the card, which gives a more extended but not quite so sharp an impression. Each of the four fingers of the same hand, in succession, is similarly rolled and impressed. This completes the process for the second set of prints of the digits of the right hand. Then the left hand is treated in the same way" (Galton). By laying a sheet of thin paper on a pad, and pressing the inked hand upon it from the wrist to the finger-tips, a print of the whole palm can be taken. The fingers can be cleansed by turpentine. Indian ink, rubbed thick and black, will do, but not so well as printer's ink.

No two fingers show precisely the same pattern, but the same finger preserves its pattern hardly changed throughout the whole of adult life. Hence a print of the finger-tip is one of the best signatures that can be devised, for it is always the same, and it cannot be imitated. In Bengal deeds have sometimes been signed by thumb-marks to prevent forgery. It has been proposed to use the finger-prints of pensioners to prevent personation by others, finger-prints of soldiers as a means of identifying deserters on re-enlistment, finger-prints of criminals as a proof of previous convictions, and finger-prints of ordinary citizens as a certain means of identification in case of loss of papers or death by accident.[1]

Study the palm of your own hand in a good light, and

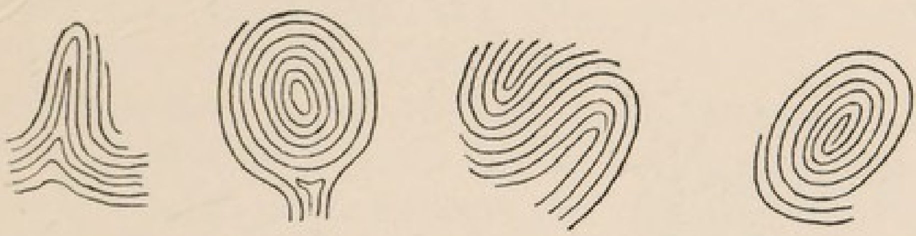

FIG. 6.—Patterns of finger-tips.

if necessary with the help of a reading glass. Put a spot of ink on every pattern-centre that you can find. You will probably make out one to each finger-tip, one in or near the fork between adjacent fingers, wherever such a fork exists, a partial concentric system at the base of the thumb, and another, sometimes with a distinct centre of its own, about half-way between the base of the little finger and the wrist. In many quadrupeds there are horny pads, which protect the palm and the sole, and these pads may occupy just the same positions as the spirals and circles in man. In the fore foot of the cat, for instance, the pads on the finger-tips (if we may speak of the fingers of a cat) are quite plain; three of the four pads in the forks between the fingers have run together into one big

[1] See Galton's *Finger Prints* (London, 1902).

pad; the fourth, which should come between the thumb and the forefinger, has disappeared; and there is a little pad between the little finger and the wrist.

If you examine with a lens the ridges of the palm, you will see a row of pores running along every one (Fig. 8). What are these pores? Now and then, when we are heated by exercise, drops of watery fluid can be seen to exude from them, and a thin section of the finger-ball

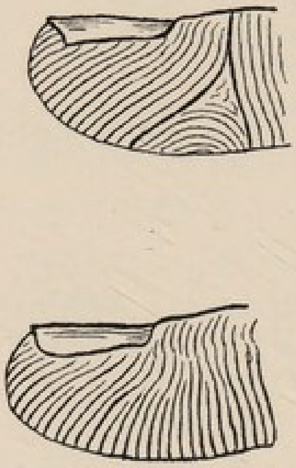

FIG. 7.—Patterns of finger-tips (side-view).

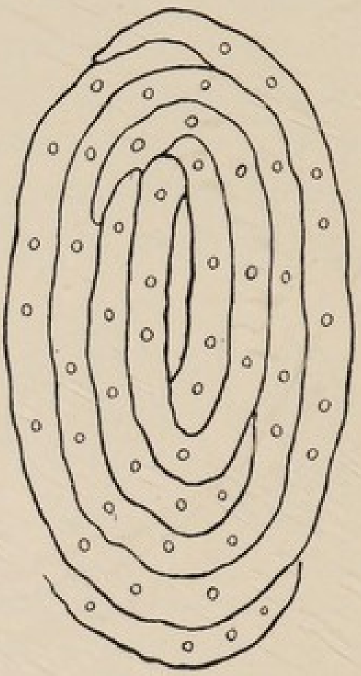

FIG. 8.—Ridges and sweat-pores of finger-tip, magnified.

shows fine tubes coming up to the pores from coiled sweat-glands, which are deeply sunk in the derm. The pores are the outlets of the sweat-ducts.

Different parts of the skin are not equally sensitive to touch. Try, by stroking with a fine water-colour brush, whether the tip of the finger or the knuckle most easily perceives the lightest possible touch. You can distinguish, without the help of the eye, sheets of paper of slightly different degrees of roughness by stroking them with the finger-tip, but if you try with the knuckle, you will not succeed so well. The greater or less acuteness of the sense of touch in different parts of the hand may be more accurately ascertained in the following way. Take a hair-pin, or a pair of blunt-pointed compasses, and open the points until they can just be distinguished as separate by the finger-tip. Read off the distance of the points on a scale, and then make the same trial with the back of the hand. I have just tried this, and find that the back of the hand, in order to distinguish the points as separate, requires them to be distant more than fourteen times as far as is requisite in the case of the finger-tip. There are parts of the skin (on the back, for instance) which are less sensitive than any part of the hand.

The finger-tip has a special structure, which is known to be closely connected with the sense of touch. The old naturalist and anatomist, Malpighi, made this discovery, and he tells us how he was led to it. Examination of the tongue of the ox showed him that the upper surface, which comes in contact with the food, is beset with numerous papillæ. Some of these (for he was able to distinguish three kinds) had a special nervous supply, and these, he thought, were particularly concerned with the sense of taste. The lips, being employed by the ox to investigate its food, might be expected to show papillæ too. Malpighi stripped off the epiderm of the lip, and found the deep layer of the skin crowded with them. The human hand next suggested itself for inquiry. Examining the tip of the finger with a lens, he made out the ridges, and what he rightly took to be the sweat-pores on them. Here again he satisfied himself by microscopic examination that the deep layer abounded in minute papillæ, and now he felt convinced that the sense of touch resides in the papillæ of the skin. You can form a fair notion of these papillæ, if you can persuade some companion to allow you to look at the surface of his tongue with a magnifying glass. On the tongue the papillæ are covered with a very delicate skin, which does not conceal their shape, but on the finger-tip the epiderm is comparatively thick, and fills up the depressions between the papillæ, which nevertheless retain both their form and their sensitive character.

Point out the chief differences between the skin of the palm and the skin of the back of the hand. The palm is covered with ridges, and crossed by conspicuous furrows ; it bears no hairs. The epiderm is thick, but rendered sensitive at the finger-tips by vast numbers of papillæ, projecting into it from the derm. The skin of the back of the hand is thinner, and the creases are close-set. The finger-nails are attached to this side. The veins show through the thin skin. The bones come nearer to the skin at the knuckles on the back of the hand than they do anywhere on the palm. These differences depend chiefly upon the circumstance that the palm is the grasping surface. When the fingers bend, the palm is contracted and the skin wrinkled, while the back of the hand is stretched. In a child's hand there is usually much fat, so that the wrinkles and creases do not show so plainly, and the veins on the back often cannot be seen at all.

On the back of each finger-tip is a nail, whose superficial position tells us that it is part of the skin. Does it belong to the epiderm or to the derm ? This may seem a difficult question, but you need only notice whether the nail bleeds and suffers pain when cut to find the right answer. Like every part of the epiderm, the nails are always growing, and always being worn away along their free edges. Some dervishes in eastern countries allow the thumb-nail of the right hand to grow very long. Then they point it and use it as a pen. I think they must find it awkward to put their right hands into their pockets, but very likely dervishes have no pockets.

Is there anything in the paw of the dog which answers to the nail of man—any epidermal structure which defends the tip of the finger ? You will see that the dog's claw is such a structure. The dog's claw can be used as a weapon ; the nail of the human finger is but a poor weapon; we might call it a claw, which has become so broad and thin as to be incapable of inflicting a serious wound.

How many bones are there in the human hand? There are first of all five long bones enclosed in the skin and flesh of the palm; the knuckles show where the upper ends of these long bones come. The long bone of the thumb is more moveable than the rest, and well clothed

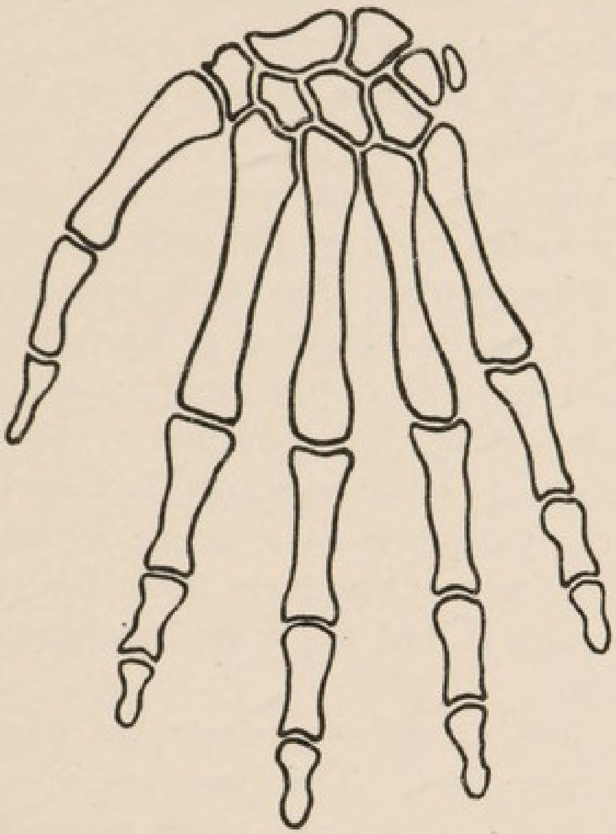

FIG. 9.—Bones of the human hand.

with flesh. These long bones are named *metacarpals*. Beyond them come the *phalanges*, and you will find that every finger has three phalanges except the first finger or thumb, which has only two. So we see that the bones of the hand are $5 \times 4 - 1$, that is 19. Make a plan of the bones of the hand by drawing strokes to represent the different bones, or better still, string pieces of tobacco-pipe, broken to the right lengths, along five wires, which can then be fastened together at one end.

The hand contains skin and bones—what else? You know that it bleeds freely if wounded, so it must contain blood-vessels, that is, veins and arteries. There is a pulsating artery which can be felt through the skin of the wrist; do you know how to find it? It not, you will be told by and by. We can see a few of the surface-veins through the thin skin of the back of the hand. Notice that they are irregular in arrangement, differing in different persons, and often differing in the two hands of the same person. They branch frequently, and run into one another, forming irregular circles or ovals. If you happen to have in the back of your hand a pretty long vein with very few connecting branches, you can show in which direction the blood of a vein flows. Let your hand hang down till the vein becomes gorged with blood. Then press it hard with a finger-tip. The vein becomes empty just *above* that point, while below it is as full as ever. The same thing can be still better seen in the veins of the arm. The observation that blood in a vein accumulates, not on the heart-side of an obstacle, but on the side away from the heart, had some little effect in convincing men that the blood in a vein regularly flows towards the heart, and not away from it, but there are much more convincing proofs than this.

The hand must contain innumerable nerves, for it is sensitive in every part. The presence of nerves is also shown by the fact that we can move separate fingers and even separate joints at pleasure. There are not only nerves which convey impressions to the brain or spinal cord (nerves of sensation), but nerves which convey impressions from the brain or spinal cord to the muscles, and so originate movements (nerves of motion).

Then we have in the hand a good deal of flesh, the same kind of substance which when cooked and set before us at table we call *meat*. Flesh or meat is stringy, being composed of long fibres, which are attached, usually at both ends, to the bones. When a fibre contracts or shortens, it pulls the bones, and that bone which is most free to move yields to the pull and changes its position. When you bend your finger or your arm, you do so by the help of masses of fleshy fibres, which contract in consequence of an impression received through a nerve, and probably starting from the brain. Nerves of sensation and nerves of motion are often both concerned in the movements of a limb. If, for instance, I happen to put my finger on a cinder which is so hot as to burn, I lift the finger as quickly as possible. What happens is this. A nerve of sensation conveys to the nerve-centres an impression of pain; the nerve-centres send an urgent message along another nerve (a nerve of motion) to a particular muscle, commanding it to contract. The muscle contracts and the finger is raised.

The fingers are capable of a number of distinct movements. They can be bent (flexed), stretched (extended), moved towards the middle line (adducted), or moved away from it (abducted). The thumb and in a less degree the fore finger can be moved in any of these ways independently, but the remaining fingers are inclined to move together, and do not easily move to any considerable extent one by one. The playing of musical instruments, especially the piano and violin, trains them to independent movement. You will remark that you can flex the fingers more powerfully than you can extend them, and the same is true of other parts of the body also. When we lie quite at our ease, as in bed, the limbs are a little bent, because the flexors are more powerful than the extensors. In many animals the inequality is much more marked than in man.

Look at the front or palm side of your wrist, and you will see two cords beneath the skin, which are evidently concerned in flexion, for they stand out more plainly when the hand is strongly bent. In a thin arm other cords can be made out besides the two just mentioned. All these are flexors of the wrist and hand. Deeper in the wrist and palm, so that they can only be seen by dissection, are the flexors of the fingers, long, slender tendons, popularly called "leaders" or "guiders," which lie close to the bones, being held down by cross-bands and sheaths. On the back of the hand, near the knuckles, you will see another set of tendons, which become most evident during extreme extension of the fingers. At the base of the thumb two extensor tendons are quite plain.

Since you are not able to dissect a hand, and trace the tendons which move the various parts, I would advise you to get a fowl's foot, strip off the skin, and look at the tendons of the toes. On that side of the leg and foot which joins the sole, you will find a large flexor tendon, which sends branches to the four toes. When it is pulled the toes become bent. On the other side of the leg and foot is a branched extensor tendon, which raises and spreads the toes. You can learn from this example what a tendon is—a smooth, very strong, white, shining, fibrous cord, which is firmly united to a bone. It often lies in a glistening sheath of the same fibrous substance, and may be prevented from slipping out of its place by cross-bands; the sheaths are plainly seen in the fowl's foot. A tendon is always attached to a muscular or fleshy mass; without muscular fibres there would be no contraction, no pull on the bones. The tendon itself cannot originate a pull; it can only transmit it. If you bare your forearm, grasp it near the elbow, and then flex the hand, you will feel the muscles swell; during contraction they become shorter and thicker. This will convince you that the flexion of the fingers is not caused by contraction of muscles in the fingers or in the wrist, but almost entirely by contraction of muscles in the thick part of the fore-arm, near the elbow. If the muscles which flex the hand and fingers were placed close to the bones on which they act, the hand would be a large, soft mass, and the fingers so clumsy as to be incapable of rapid, precise and combined movements. The sheaths and cross-bands hold the tendons close to the bones during flexion. How awkward it would be if wherever the wrist or a finger-joint was bent, a tendon stretched across the angle, taking the shortest course between its two points of attachment!

We have noticed the two flexor tendons which can be seen through the skin on the front of the wrist. One of these, that nearest to the thumb, is a convenient guide to the pulse. A good-sized artery, the radial artery, here runs just beneath the skin, on the thumb side of the tendon. By pressing the finger-ends upon the radial artery the pulse is felt.

The usefulness of the human hand is greatly promoted by the power of turning it round. Hold your hand palm upwards and thumb outwards. Then turn it over, so that the palm looks downwards, and the thumb turns inwards. There are few animals which can perform that simple action. Those which can do so are nearly all climbing animals, which use the hand, and perhaps the foot also, to grasp with, and may require to turn the hand in all sorts of positions in order to get hold of a bough in the most convenient way. Observe that you cannot turn your hand over except by swinging the thumb round the little finger. Lay your hand on the table and perform this action once or twice. Then try to swing the little finger round the thumb, keeping the thumb pressed against the table. The action can only be imperfectly executed, and then by bending both elbow and wrist into a very awkward position. This shows us that the hand is not merely rotated on a pivot or a pin; such an arrangement as that would be quite impossible.

There are two long bones in the human forearm, the radius and the ulna. It is the radius chiefly which carries the hand and forms the wrist-joint; it is the ulna chiefly which enters into the elbow-joint. You can make a model of the arrangement with two long pencils, a cork, and an indiarubber band. Lay the pencils side by side, with the cork lying between two of their ends, and bind pencils and cork together by the indiarubber band. Cut out a small paper hand, and attach it to one of the pencils at the end remote from the cork. This pencil will now represent the radius ; the thumb must of course be turned away from the ulna. Mark one side of that end of the radius which is farthest from the paper hand. The paper hand might now be brought round by making the radius simply revolve *on its own axis*, but there are many muscles, tendons and fibrous bands which pass from the radius to the ulna, and these effectually prevent any such motion. That end of the radius which carries the hand can however easily be made to revolve *about the ulna*, and this without disturbing seriously the fibres which connect the two bones. The hand can be turned over, the thumb swinging round from right to left, or from left to right, as the case may be. The radius will thereby be crossed upon the ulna, and by looking at the marked end you will see that it has revolved through 180°. It is still simpler to take a strip of paper, say 12 in. by 3 in., fashion a rude hand with a thumb at one end, and towards the other end cut the strip along its middle for half its length. Hold the ulnar strip down upon the table and throw the hand of the model over, when the elbow-end will be found to have revolved as before. The radius and ulna are not displaced so far as to strain the bands which pass from one bone to the other, the wrist-joint is undisturbed, and the elbow-joint, mainly formed by the humerus and the ulna, is very little affected. If you can get an actual human radius you will see that the revolution of its upper end is greatly facilitated by two features. There is a smooth, cupped end, which abuts upon a rounded prominence occupying nearly half of the end of the humerus ; there is also a smooth circular rim, which rotates within a groove upon the ulna.

The forearm and hand of man can be changed at pleasure from the *supine* position (radius and ulna parallel, palm upwards, thumb outwards) to the *prone* position (radius crossed upon ulna, palm downwards, thumb inwards). Tree-climbing quadrupeds can usually rotate the hand freely. Carnivorous quadrupeds, which strike their prey with the fore paws, have a limited power of rotation. Quadrupeds which use the fore limb solely for running have it fixed in the prone position, and the ulna is usually much reduced in size.

It is not difficult to procure the fore-feet of certain

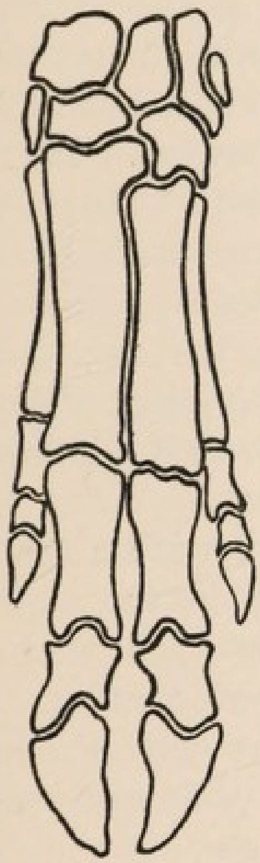

FIG. 10.—Bones of the hand of a Pig.

FIG. 11.—Bones of the hand of an Ox. There is a pair of stunted digits behind.

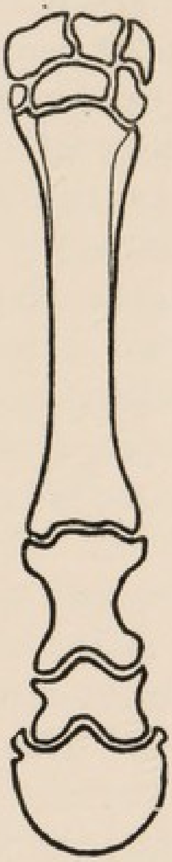

FIG. 12.—Bones of the hand of a Horse.

common animals, and to prepare skeletons of them. The dog, pig and sheep make an instructive series, which becomes much more interesting if the horse and bat can be added. From the actual skeletons of the fore-feet rough models are easily made with bits of tobacco-pipe and wires.

Dog. There are five fingers, all bearing claws. All the metacarpals are separate. The first finger (thumb) is short, and has only two phalanges; the rest have three each. The dog's hand is very like that of man, but the thumb is short, and not opposable to the fingers. Notice the strong claws and their firm insertion.

Pig. There are four fingers, all bearing hoofs; 3 and 4 are large, 2 and 5 much smaller, not reaching the ground; 1 (the thumb) is wanting altogether.

Sheep or *Ox*. Two fingers (3, 4) bear hoofs; there are vestiges of fingers 2 and 5 in the form of small hoofs without separate phalanges. The metacarpal (here called the cannon-bone) is long and apparently single, but really consists of the 3rd and 4th metacarpals united. In the young sheep the bone has a double cavity. There are splint-bones (vestiges of the 2nd and 5th metacarpals) on the sides of the upper end of the cannon-bone. The long fingers have each three sesamoid bones, that is, bony nodules formed in tendons, usually opposite a joint. There are two sesamoids behind the base of the first phalanx, and one behind the base of the last phalanx.

Horse. There is one finger only, the 3rd, with a metacarpal and three phalanges. Sesamoids as in the sheep. The splint-bones, one on either side of the upper end of the metacarpal, are the last vestiges of fingers 2 and 4.

Bat. There are five fingers, of which the first (thumb) is short and bears a claw; the rest are prolonged, and support the flying membrane.

A common plan can be discovered in the fore limbs of the man, dog, pig, sheep and horse. Even the wing of a bird, though extremely unlike the rest, exhibits most of the same parts; we can distinguish quite easily the humerus, radius, ulna, metacarpals and phalanges. No hand has more than five fingers; no hand has more than two phalanges in the first finger (thumb). But though a common plan may be traced in the hand of these different animals, the plan is liable to be changed according to special needs. The parts of the limb may be (1) enlarged, (2) diminished, (3) suppressed, (4) fused together, (5) altered in form, (6) altered in function ; lastly, (7) new parts may be added. Thus (1) the middle finger is enlarged in the horse ; (2) the side-toes are diminished in the pig ; (3) all the toes but one are suppressed in the horse ; (4) the radius and ulna are fused together in most hoofed animals ; (5) the phalanges of a bat's fingers are altered in form, becoming very long and slender ; (6) the hand of man has changed its function, and has ceased to be an organ of locomotion ; (7) the paddle of the whale contains many additional phalanges.

To everybody except anatomists the hand is an organ for grasping, and when the thumb ceases to be opposable, most of us would say that there is no longer a proper hand. In the same way everybody except anatomists, when the great toe as well as the thumb becomes opposable, as in the gorilla or orang, would say that the animal has got four hands instead of two. If there is no hand, the functions of a hand may be performed by other parts. Thus there are animals which grasp with the mouth (dogs, birds), with the tongue (giraffe), with a proboscis, formed of the enormously prolonged nose and upper lip (elephant), or with the tail (spider-monkey). I could even tell you of a fish (the sucking-fish), which holds on to floating objects by the top of its head and neck. There are animals which scratch or comb themselves with their teeth, with the claws of the hind limb (birds), or with spines on the tongue (lion, cat). While the same function may be discharged by different parts, the same part may discharge different functions. Thus the extremity of the fore limb may be used as a hand, or as a paddle (whale), or as a wing (bird), or as a fin (fish), or as a sucker (lump-fish) ; lastly it may disappear altogether (serpent).

IX. THE FRESHWATER AQUARIUM.

The bell-jar and other small forms of aquarium are not to be despised ; they serve to keep many aquatic animals and plants alive for a short time, and suffice permanently for a few hardy ones. But if you wish to make the most of the aquarium, you must construct it on a larger scale. I have kept one which measures 4 ft. long, 18 in. wide and 16 in. deep, for twenty years, and have found it so profitable that I strongly recommend such an one to others. The large space, abundant light and simple furnishing of the laboratory or schoolroom are taken for granted. The parlour aquarium must be on a comparatively small scale, and I doubt whether it will succeed anything like so well for general purposes.

First as to construction. My aquarium was strongly framed of deal, and stands on a stout table made for the purpose; no slate enters into it. The floor, ends and one of the long sides (that facing the window) were of wood, and only one side is of glass. Opposite the windows, I should explain, is a good roof-light. The ends of the aquarium were bolted together by four strong iron rods, two at the top and two at the bottom, which were passed through thick battens, and well secured by nuts. The rods run along the tops and bottoms of the long sides, and the ends project sideways two inches beyond them. All wood that had to resist wetting was covered half an inch thick with a mixture of sand, mastic and red lead, laid on with great care and thoroughly hardened before exposure to water; no leak has ever showed itself. A water supply-tap and a waste-pipe were provided, but the water is hardly ever changed. At the bottom a thick layer of fine mud, mixed with a little powdered chalk and calcium phosphate, was laid down. The side next to the window was darkened to prevent too abundant growth of green algæ; if this side has been made of glass, it should be covered with paint, but there should be an ample supply of diffused light. A loose cover of perforated zinc is used to keep out dust, but is often dispensed with to favour surface-growths.

In this aquarium I have grown a variety of plants. Isoetes, the water Lobelia, Frog-bit, Myriophyllum, pondweeds, Utricularia and Nitella have often thriven for years together. Duckweed and Riccia float at the surface. Mollusks have been introduced intentionally, and small animals of various kinds casually, together with water-weeds. The egg-laying and development of the mollusks has been a favourite study. Dragon-fly larvæ, larvæ of more than one species of Chironomus, Triclads, Hydra, Nais and a variety of infusorians are among the things that have appeared as it were spontaneously. No fishes have been kept in this aquarium, lest they should devour things of greater interest.

It is worth while to keep a freshwater aquarium, if only to see how the different water-weeds behave during winter. Many of them form special winter-buds, bright green and closely wrapped, which lie at the bottom during all the hard weather, but float to the surface in spring, being then buoyed up by the formation of air-bubbles in their cavities, and set free by the decay of the old stems. Nothing is then required except a free flow of water to disperse them widely.

The student of live nature will often require small tanks for special purposes. Things that he wants to keep his eye upon would perhaps be devoured or lost in the big aquarium. Rectangular vessels, narrow and deep, with a broad surface exposed to the light, are very convenient for the study of isolated organisms, and happily they are not at all expensive.

It is almost as easy to manage a marine aquarium as a freshwater one. We keep in our laboratory at Leeds a good-sized marine aquarium, as well as a bell-jar filled with sea-water. Into one or other minute animals and plants received from the Marine Biological Laboratory at Plymouth are put when they have served their immediate purpose, and abundant material for study is thus kept ready to hand. Both tanks have kept perfectly wholesome for several years without ever being emptied.

X. THE SUMMER DROOP OF BOUGHS.

From my study window I look out upon a lime-tree, and have abundant opportunity of observing how it changes its aspect according to the time of year. In summer its leafy boughs form gently drooping sheets, which rise and fall in the breeze, swaying gracefully as if loaded with no more weight than they can easily carry. In winter the branches rise again; being now bare of leaves, they form an open network which gives little hold to the wind. The buds, arranged first on one side and then on the other, show that future extensions will all lie in the same plane. Evidently the slender boughs of the lime droop in summer because they are weighted with foliage. A single lime-leaf weighs about half a gram, and on one good-sized bough I counted more than two thousand leaves distant fifteen feet or more from the main trunk; that is to say, two kilograms (over four pounds) of leaves were borne on the narrow end of a bough upwards of fifteen feet long. No wonder that the bough droops. In a friend's house there is a window which is darkened in summer by the leafy boughs of a sycamore; in winter not a twig of the sycamore can be seen from that window. Boughs have been known to break by the mere weight of the leaves in places not exposed to wind. Mr. Miller Christy[1] remarks that a horse-chestnut in his garden causes no obstruction to a path beneath in winter, when the boughs are bare, but that in summer a certain bough interferes very inconveniently with free passage along the path. This led him to note the height of the branch above the path during three years. The tree was forty feet high, and the branch in question measured 28 ft. 6 in. in length, and had a circumference of 26 in. where it left the bole. The annual droop of this bough amounts to about ten inches, attaining its maximum in

[1] *Journ. Linn. Soc.*, Botany, 1898, pp. 501–7.

September, when the fruits are of the full size. In the following winter the old position is not quite recovered, for there is a permanent droop, increasing at the rate of about two inches per annum.

All boughs of deciduous trees do not bend beneath the weight of their summer leaves. On examining by superposition winter and summer photographs of large boughs of oak and beech taken from the same spot, I can discover no deflection at all. The strength of the wood, and particularly of oak wood, may be one reason why the boughs of these trees yield so much less than those of the lime and sycamore; the comparative lightness of oak-foliage may be another.

XI. THE GLOWWORM.

Many of us dwell with peculiar pleasure on our recollections of the glowworm. Like the song of the nightingale, it is not only a delight in itself, but has the magical power of bringing back the time when we were young and the whole earth was gay. The mere mention of the glowworm recalls some refulgent summer, 1887 or even 1868, when the evening skies were obscured by no clouds for many weeks together. We remember the soft greenish lights among the mowing grass, or on sandy banks beneath pine-trees. A few of us know the pleasure of tracing the lights to their source, and of discovering the luminous insect mounted on a tall grass-haulm or a leafy spray. Those of us who dwell in cities, where glowworms are rare, find no doubt more pleasure and excitement in the spectacle than those who see them summer after summer, but we are ill-placed for inquiring into the causes and circumstances of the glow. If I were a leisured man and lived in the country, I would make this a very special hobby, and associate myself with the naturalists who are endeavouring to elucidate interesting questions about the glowworm by another light than its own—I mean the lamp of science.[1]

Let me now put and answer as well as present knowledge permits, three questions about the glowworm.

QUESTION 1. *What is the worm that glows?*

It is a female beetle, about half an inch long, and peculiar in having the wings and wing-covers totally deficient, so that it resembles a larva; the body is long, narrow, and flattened; the legs are short; the head is retractile, being withdrawn upon occasion into the fore part of the thorax; the eyes are small; and the jaws are those of a predatory insect. It is probable that the adult insect feeds little; indeed there is reason to believe that the adult male does not feed at all. Some naturalists have found the female feeding on plants, but fuller evidence is still to be desired. The larva on the other hand is carnivorous, and devours small mollusks, either dead or alive. The glowworm keeps close by day, but shows herself by night, often climbing up stalks or the branches of shrubs in order that her light may be as little obstructed as possible.

QUESTION 2. *How is the light of the glowworm produced?*

It is emitted from the under side of the abdomen, especially from the sixth and seventh segments, and can be traced to a yellowish substance, which is freely supplied with branching air-tubes, and shines through the transparent skin. Though the light looks so steady, it is really intermittent, consisting of flashes in close succession, eighty or a hundred in the minute. It has been much debated whether the glowworm can extinguish her light at pleasure or not. When alarmed, she certainly causes the light to disappear, and late in the evening she ceases to shine. But on close examination it will be found that

[1] One of the most important of recent researches on the glowworm by Bongardt will be found in *Zeits. f. wiss. Zool.*, 1903.

the light is not really quenched ; the female merely turns the luminous surface towards the ground. Even when the abdomen is cut off, the light continues to be emitted for a long time—under favourable conditions for some days. The luminous matter becomes brighter in oxygen, but is quenched by carbonic acid, hydrogen, sulphurous acid or a vacuum. The light is not accompanied by dark heat-rays; its photographic action is weak; all the rays belong to the part of the spectrum which is visible to the human eye; besides the light-rays Röntgen rays are given off. Not only the abdomen of the adult female, but the larva, the pupa, the adult male, and the eggs are luminous at times.

Microscopic examination shows that the luminous organ of a glowworm consists of innumerable cells, arranged in a dorsal layer, which is rendered opaque by organic concretions, and a ventral layer, which is clear. The cells are supplied both with air-tubes, branching repeatedly so as to reach every cell, and with nerves.

There is reason to believe that the light is not directly emitted by the cells of the luminous organ, but by a substance which these cells secrete. Bongardt found that this substance, after being dried and kept in a vacuum for twelve months, gave out light again when moistened and placed in air. Fresh luminous organs can be made to glow more intensely by irritation, *e.g.* with the point of a needle, but the effect does not instantly follow the stimulus. A glowworm when crushed emits no light. Water, as well as oxygen or air, is necessary to the emission of light. It is probable that the light is due to an oxidation-process, like that which makes phosphorus glow in the dark, but the luminous matter of the glowworm contains no phosphorus.

We have only a single species of glowworm in Britain ; two others occur in central Europe. The fire-fly of southern Europe is a beetle belonging to the same family as the glowworms, and several other luminous insects are known in different parts of the world. Some centipedes, one of which is common in Britain, have the same property. Many inhabitants of the sea are luminous, among the rest, deep-sea fishes, mollusks, crustaceans, worms, echinoderms and zoophytes. A protozoan not more than one-fiftieth of an inch long causes what we describe as the phosphorescence of the sea.

There are also light-emitting plants. The threads of certain fungi which subsist upon decaying wood shine in the dark; so do the bacteria which set up putrefaction in the bodies of dead marine-fishes. Observant persons are familiar with both kinds of luminosity. In fish-cleaning yards, especially such as are regularly overflowed by the tide, luminosity can often be remarked. I have seen hastily cleaned fishes' skulls shine every night for weeks. If they are washed with water, the water may become luminous; when filtered, the water loses its power of emitting light, but the filter begins to shine.

Flowers have occasionally been seen to emit flashes of light, but these are due to causes of another kind.

QUESTION 3. *What benefit do the glowworms derive from their power of emitting light?*

Gilbert White's explanation that the light of the glowworm is attractive to the male insect seems to be a little too ancient for some biologists, who are restless until they can replace it by a theory more worthy, as they think, of the twentieth century. But the old view makes intelligible several facts that must never be lost sight of. Bongardt has recently placed on record the important observation that a female glowworm when exposed in a bottle brings around a number of faintly illuminated males, and at their approach her light becomes more vivid. In our common English glowworm the female, which is pre-eminently luminous, has no wings, and the winged male has particularly large eyes. The same cannot be said of all glowworms, and hence a doubt has arisen.

Some naturalists seem to think that an explanation which suits only one species cannot be the true one. It seems to me that we complicate the problem unnecessarily by seeking for an explanation which will apply to all luminous insects, or even to all the Lampyridæ, some fifty in number. Why not consider the species one by one, and so eliminate the perplexing differences in habits and environment which always exist among a number of different species? We have no ground for supposing that the explanation which suits one case will suit all. The sounds and colours of animals admit of no universal explanation, and the same is likely to be true of luminosity. I would therefore prefer to consider the English glowworm by itself, not of course neglecting any pertinent suggestions which might be drawn from other species, but not waiting till they come to hand.

One speculation which has found eminent adherents is this. The glowworm has been thought to have a disagreeable taste which repels night-feeding animals, such as bats, and it is quite true that when a number of glowworms are imprisoned in a small vessel an unpleasant odour can be detected. The light, it is said, may be a warning light, giving notice that the insect is one which is notoriously ill-tasted. Belt put forth this view, and Darwin [1] supported it. Bongardt has pointed out that the taste and smell of the glowworm do not repel spiders, which prey upon it freely, but this argument is of course not decisive. Belt's explanation seems to me to fail in dealing with such material facts as the great eyes of the winged male, the ostentatious self-exposure of the wingless female, and the recently acquired knowledge that when the males gather about the female she emits a brighter light. Besides, if the female were luminous for self-protection only, if would suffice if she were luminous in a low degree, so as to prevent mistakes on the part of insectivorous animals within striking distance; self-pro-

[1] *Descent of Man*, chap. x.

tection does not account for a light which is visible from afar, a light so intense as to arouse the curiosity of dangerous enemies. Belt's explanation is not, properly speaking, an alternative to the attraction-theory. Both may be held together, if both should be adequately supported by facts. The light of the glowworm may guide the male to the resting-place of his mate, and also prevent insectivorous birds, drawn to the spot by the unusual glow, from devouring her by mistake.

Others have imagined that the light attracts the prey of the glowworm, just as a luminous fish, or an electric lamp lowered into the sea attracts crowds of small crustacea and other animals. There is, I believe, no proof that the mollusks, on which the glowworm is believed to feed, are sufficiently curious to draw near to a light, nor that the glowworm can fascinate more susceptible victims.

Until further enlightened, therefore, I shall continue to hold with Gilbert White that the light of our English glowworm is the lamp of Hero.

Glowworms are most abundant in the neighbourhood of woods. Bongardt tells us that after mating the females creep into the woods, at the rate of about a yard a day. At this time they are hard to find, for the luminous surface is turned towards the ground. It is only when expecting the visit of the male that the glowworm fully exposes her light-organs, either by climbing on a stalk, or by turning up the end of the abdomen.

XII. INVISIBLE DOMESTIC SERVANTS.

When we have counted up all the men and women, quadrupeds, birds, insects, spiders and mites that can be found under our roofs, besides the green plants that are grown in the windows, we have not come to the end of the living things of the house. There are still the microscopic organisms to be considered, and these are both more numerous and more important than we are accustomed to suppose. Wherever there is a perceptible current of air, microscopic organisms are wafted with the dust; wherever the motes dance in the sunbeam, some of them are living motes. A curious variety of minute objects is revealed when the dust of a living-room is spread out on a glass slip. Some little thought must be given in order to discover the neatest way of doing this. It will not do to tease out a visible pellet of dust; the particles will be found heaped together in utter confusion, and the smallest will escape notice altogether. But if a glass slip, smeared with glycerine, is left undisturbed on a shelf for a day or two, the particles will settle on it one by one, and will be conveniently spaced. Among them an experienced eye will soon detect wood-fibres, hairs of man and sheep, pollen-grains, fern-spores, and still more minute rounded bodies, which are the spores of the common moulds. Closer examination and higher powers are required for the identification of the smallest of all the particles, which are microbes, objects as much smaller than the grains of toothpowder as these are smaller than cherries. Though the microbes are so incredibly minute as to tax severely the resources of the microscopical observer, they are generally still alive when they float in the air of the room, and when they get into a place that suits them, they often show their powers of multiplication in a very surprising way.

When the common moulds establish themselves on a substance that supplies them with food, they often grow so big as to become visible to the eye, and then a pocket-lens will suffice to reveal many interesting details. The moulds spread through the food-substance as branching threads, and only in a comparatively late stage of their life-history send up columns into the air, which form the velvety masses seen on jam, decayed oranges, and old boots. These columns may support capsules, or branching chains, or rays standing out on all sides from a central globe, but in one way or another they produce and set free spores, which are the ordinary means of dispersal of the moulds. The green threads that run through certain kinds of cheese are moulds of a very common species, and since they are thought to improve the flavour of the cheese, these may be classed as useful moulds, but moulds in general do far more harm than good to the owners of the house.

An undeniably useful mould, however, is yeast, which has been used for thousands of years for making bread and beer. Yeast may be said to be a mould reduced to its lowest terms; it has lost all definite arrangement, sends out no branching fibres, and raises no columns into the air, but consists merely of loose granules, which sometimes stick together in twos and threes. It is immersed in its food, when the food is plentiful, and at other times clings as fine dust to whatever objects it has happened to alight on. In places where yeast has now and then a good chance of feeding and multiplying, yeast-dust is often widely disseminated. It is so in the house; it is so in the vineyard. Long before beer and bread were thought of, the yeast-mould had adapted itself to one particular mode of subsistence; it had come to depend upon the sugary juice of the ripe grape. When the sour grapes appear, yeast-cells, dry and apparently dead, are lodged by wind upon the grape-skin. During the whole time of ripening they remain torpid; they cannot penetrate the tough grape-skin, and as yet there is no sweet juice in the grape, such as they require. But after long waiting, the opportunity comes at last; the grape ripens, turns soft, and falls to the ground, bursting as it falls. A quantity of sweet juice, enough to nourish millions of yeast-cells, is suddenly put within their reach; they drink it in, and multiply with such speed that in a few hours all the sugar of the grape is consumed and turned to alcohol. A few hours more, and the grape is either shrivelled by drought, or washed clean by rain. The yeast-cells have come to the end of their annual feast; they dry up, and are dispersed as dust. The great multitude perish; only one here and there, perhaps after many vicissitudes, succeeds in getting lodged on an unripe grape of the following season.

When men began to press out the sweet juice of the grape to make themselves a refreshing drink, yeast-cells would often get from the grape-skins into the liquor, and ferment it. Then the juice would froth with the gas evolved, and it would soon be remarked that a little of the fermenting juice would start fermentation in a second vessel. It would be enough to keep a fermenting vat unwashed till the following grape-harvest to start the fermentation again with certainty. How yeast-cells came to be employed in turning the sugar of malted barley to alcohol nobody can tell; but we know that the Egyptians of old had found out the trick.

It was a further step to employ these same yeast-cells in making bread rise; this time it was not the alcohol but the gas (carbonic acid) which yeast gives off which was useful. Flour contains starch and diastase, a ferment which can under suitable conditions change starch into sugar. The diastase is not a living thing, as yeast is; but it is formed within living plants and animals, and turns starch into sugar for them. When the starch of a root or a seed is to be circulated for the benefit of the growing tissues, it is first turned into sugar by diastase. Fresh green leaves contain diastase; so do many seeds; so do the salivary glands of man and other animals. When we mix flour with water, the diastase which the flour contains soon gets to work, and much of the starch is changed to sugar. If now a little yeast is introduced, and the bread kept at the summer-temperature at which yeast is most active, the yeast consumes the sugar, setting free alcohol (which is allowed to escape in the baking) and plenty of carbonic acid, which forms bubbles in the sticky dough, and makes it spongy.

Yeast-cells are very small, only the hundredth of a millimetre in diameter. Suppose a man were to shrink until he had only the height of this letter (I), then a threepenny-piece in his pocket, if reduced in the same proportion, would be rather too big to represent the diameter of a yeast-grain.

In my household we now and then make a brew of vinegar, using this old-fashioned recipe. We take half a pound of coarse sugar, a quarter of a pound of treacle, half a pint of vinegar, and three pints of water, pour these together into a wide-mouthed stone jar, loosely closed to exclude the dust without excluding the air, and keep it as near as may be at summer heat (28° C., about 82° F.) for three months. Then we find in our jar near half a gallon of serviceable vinegar. Some add fresh currants or gooseberries to the mixture before brewing; others put in a toast dipped in yeast, but these things make no appreciable difference to the result.

There is one other ingredient which I have not yet mentioned. Old housekeepers often left it out, but it makes the yield of vinegar more certain, and we never omit it. This is a piece of a "vinegar-plant," or "mother of vinegar," as some call it; the Yorkshire name is "mothers." I will next try to explain what a vinegar-plant is.

When the three months are up, we find a jelly-like cake floating on the vinegar; it will probably be about a quarter of an inch thick. This cake begins to form as an extremely thin membrane, and grows rapidly until it has attained something like its ultimate thickness. If disturbed, it becomes covered with the liquid, and a new membrane forms above it. Its form is adapted to that of the enclosing vessel. When lifted out by the hand, it is found to be soft, brownish, almost transparent and tough, resisting any attempt to tear it across, but easily splitting into layers. This membrane is the vinegar-plant or mother of vinegar.

High powers of the microscope show that the membrane consists of innumerable rod-like bacteria, cohering into threads, and imbedded in a structureless jelly. The vinegar-plant is a mass of bacteria, glued together by their own exudation. Besides the bacteria which are entangled in the membrane, scattered rods and still smaller spores are found in the liquid beneath, and these too can produce a new film if placed in a suitable liquid.

With a little management we can see the growth of a vinegar-plant for ourselves; we can see the single rods adding length to length until they form threads, and the threads branching to form new threads. They grow like the simplest kinds of plants, and it is not incorrect to call the membrane a vinegar-plant, though it is rather a collection of plants than a single one.

Vinegar-bacteria are much smaller even than the minute yeast-cells. A globular yeast-cell has a diameter of about $\frac{1}{100}$ mm., but a rod of the vinegar-bacterium is usually only $\frac{1}{500}$ mm. long.

The rod-like cells of the vinegar-plant cannot maintain themselves in full activity without air, and thrive best at the surface of the nutritive liquid. The jelly which they exude is really a contrivance for keeping vast numbers of cells floating in contact with the air.

When vinegar is formed from sugar by any natural process, alcohol-formation is usually an intermediate step. First the sugar is made to yield alcohol, and then the alcohol is made to yield vinegar. In the manufacture of beer or wine the sugar of the malt or grape is first changed to alcohol by the action of yeast-cells. When the alcohol has once been formed, it may be changed to vinegar by the action of another kind of minute cells, the vinegar-bacteria. This often happens against the will of the brewer or wine-merchant; his liquor turns sour, and is spoilt thereby. It is the same or a very similar vinegar-plant which does the acidifying of the alcohol both here and in the domestic manufacture of vinegar. Knowledge of the fact that the formation of alcohol is a preliminary step to the formation of vinegar led to search for yeast-cells in the membrane of the vinegar-plant, and it was discovered that they are regularly present. Since the film which is now put into every domestic brew of vinegar contains entangled in it a number of yeast-cells, we can understand that it should make no difference whether a teaspoonful of yeast is added or not.

I have said that in former days housekeepers were not particular to add a piece of vinegar-plant to every fresh batch. Usually the vinegar formed all the same, and when the process was at an end a membrane was found covering the vinegar. They took very little notice of it, and it is hardly mentioned in the old books. Perhaps our forefathers regarded it as a disagreeable impurity; certainly they did not discover that this was the thing that made vinegar for them. Where does the new vinegar-plant come from, if no vinegar-cells have been put into the solution?

The contamination, long unsuspected, of the vinegar-bacteria with yeast-cells suggests the answer to the question. When nutritive liquids are exposed to the air without scrupulous precautions, a mixture of organisms of different kinds and different powers is sure to result. The old-fashioned housekeepers did not know exactly what they were doing. Their yeast contained vinegar-bacteria; their vinegar-plants contained yeast-cells. All the vessels which they used in making vinegar, in brewing, and in bread-making, contained both of them, as also did the dust and the very air of their houses. Now we see why it made little difference whether they introduced a bit of a film into their sugary mixture or not. They introduced yeast, and their yeast contained vinegar-bacteria. All the beer that they brewed no doubt contained vinegar-bacteria too, but when the beer was tightly corked up in a cask or bottle, carbonic acid being the only included gas, the bacteria perished for lack of air; had it not been for this, all the beer would have turned sour.

The constant liability of nutritive liquids to the attacks of predatory microbes renders it a useful precaution to add vinegar whenever we start a fresh brew of vinegar. Vinegar itself is not prone to undergo change, and the domestic microbes cannot harm it. If you treat a bottle of vinegar carelessly, leave the cork out, and keep it in a dusty place, it does not soon spoil. But the sugary solution falls an easy prey. Microbes of many kinds find nourishment in it, each one forming a characteristic and usually an unpleasant product. It is in the first stage of acetous fermentation that the risk is greatest, for the stronger the vinegar, the less the destructive microbes like it. Half a pint of strong vinegar added beforehand to every half-gallon of sugar-solution makes it reasonably sure that no microbes will harm it.

The invisible domestic servants, two of which I have attempted to describe, enabled our remote forefathers to make bread, beer, wine, and vinegar. A number of other microbes are concerned in the manufacture of cheese, in the separation of vegetable fibres, in the dissipation of dead organic matter, and in the perpetually renewed fertility of the soil. But the utility of the microbes as servants of man has been impaired by the progress of science. It is now possible to make artificially vinegar and alcohol, for which mankind were once entirely dependent upon microscopic organisms. Machinery devised by man is rendering the invisible domestic servants, like servants of some other kinds, less indispensable than they once were.

XIII. OLD ENGLISH GARDENS.

I have not the antiquarian knowledge necessary to treat of old English gardens fully. What I have done is to turn over some well-known books,[1] and collect a few

[1] Amherst's *History of Gardening in England;* Seddon's *Garden Craft*, &c.

particulars likely to be interesting to unlearned persons who are fond of gardens. I should like to show as well as I can in a small space how English gardens before 1485, which in many ways marks the advent of a new age, differed from the gardens of our own time.

We know very little of English gardens before the thirteenth century, but the names which have been handed down to us from that remote time tell us this at least, that a number of useful plants of foreign origin had been already introduced, and were popularly known by their Latin names, altered more or less to suit the taste of people who understood no Latin. The following are specimens of a much longer list given by Earle. *Febrifuga* becomes *Febrifuge*, and finally *Feverfew; Lactuca, Lactuce* and *Lettuce; Napus, Naep* and *[Tur-]nip; Petroselinum, Petersilie* and *Parsley*. It seems fair to conclude that they who preserved the Latin names of many useful plants knew Latin themselves, and had much to do with gardens. Many of them were, no doubt, monks, who during the dark ages were not only the gardeners, but the physicians, architects, scribes and schoolmasters of the time.

Here and there a plan of some old abbey-grounds has come down to us, on which is marked a herbary in the midst of the cloister, an orchard or a vineyard. *Herbary* has been driven out by the vernacular *yard*, which also takes the form of *gard* and *garth*, and survives in *garden, orchard* (wort-yard), *vineyard*, &c.

Account-books of the fourteenth century and later tell us some little, for instance of the use of pease in pottage, or of beans and butter, of the grafting of hawthorn-hedges, of the threshing-out of mustard-seed, of garlands of roses and woodruff, of spades, rakes, hoes and garden-rollers.

Illuminated manuscripts now and then depict a walled garden, divided into rectangular beds by narrow gravel walks; in them holy men are meditating, or children working. Such pictures show us the arbours and fountains, the pleached walks and clipt trees, the turf-banks and turf-seats of the later middle ages.

Favourite flowers. The English garden of the fourteenth or fifteenth century yielded many exotic flowers, besides English wild flowers, such as cowslips, foxglove, &c. We find the following named, among many others :—lilies, roses, gilliflowers (clove-pinks), peonies, periwinkles, golds (marigolds), blue and yellow flags (Iris), hollyhocks, columbines, lavender.

Vegetables. Garlic, leek and onions were grown plentifully, as well as beans and pease, cabbages, beet, lettuce, cress, radishes, turnips and carrots, parsneps, spinach, orach, pumpkins and cucumbers, mustard, &c.

Kitchen-herbs. Parsley, borage, avens, betony, patience (a Rumex), fennel, mint, saffron, sage, clary, coriander, anise, dill, hyssop, rue, dittany, smallage (wild celery), tansy and thyme seem to have been frequent. Saffron was a favourite ingredient of a number of dishes.

Drugs. Marigold, rosemary, henbane, horehound and valerian were much used in domestic medicine, besides many wild plants, most of which were quite inactive.

Fruit-trees. Several varieties of apples (costards, pearmains, &c.), pears (warden, Regul or St. Rule, sorrel, Martin, perjenet, &c.), plums ("bulleys," "dampsons," &c.), cherries, medlars, quinces ("coynes"), mulberries, peaches, chestnuts, hazel-nuts, great nuts (walnuts) and vines were usual. The vine was expected to yield eatable grapes and even wine in the southern and western counties, besides verjuice, expressed from the unripe grapes. Strawberries were a favourite ground-fruit; gooseberries and raspberries seem to have been brought in from the wild country, and cultivated in gardens as early as the time of Edward I., a great lover of gardens.

The old English garden before the time of the Tudors lacked many of our most valued trees, roots and flowers. The borders showed no lilacs, laburnums, larkspurs, Christmas roses, dahlias or fuchsias; the kitchen-garden no potatoes, rhubarb, or currants. No botanical gardens existed anywhere, for the first were founded in Pisa and Padua in the sixteenth century (1545), while England did not possess one till near a century later (Oxford, 1632).

Under the Tudors all the useful arts made steady progress. Gardens became frequent, and some of them attained lordly proportions, as we see from Bacon's well-known Essay. In the Netherlands the development of horticulture was both more scientific and more rapid than in England. It was from Holland and Flanders that our forefathers learned how to raise better varieties of vegetables, fruit-trees and flowers, as well as bigger and more profitable breeds of oxen, sheep and horses, how to keep sheep alive on roots instead of slaying them at Martinmas, or starving them through the winter. Holland taught us the value of the so-called artificial grasses, and the possibility of a continual succession of crops. Nor did the improvements which we got from Holland concern agriculture and horticulture alone. Holland taught our forefathers navigation, banking, book-keeping and the use of machinery. Englishmen have shown that they too can do great things. Our railways and electric telegraphs, our colonies and our parliaments are the products of an energetic and thoughtful race. But we do not follow up our discoveries with that minute attention to detail which certain other nations have shown. If we had been more docile, we might have learned yet more from Holland. Holland, by nature the poorest country in the world, where according to the old jest, men live aboard, a country drowned with water, and much of it below sea-level, a country without rocks, hills, forests or mines, teaches very distinctly that all the advantages of soil, climate and mineral wealth are of small importance in comparison with knowledge, industry and method.

The long succession of descriptive books which have done so much for English horticulture begins with the Great Herbal (1516).

Among the single benefactors who have enriched the gardens of Western Europe with flowers and trees unknown to mediæval times, few deserve our gratitude more richly than Busbecq, if it is true that we owe to him the lilac, the tulip, the seringa, the horse-chestnut and the sweet flag. It is hard to get conclusive proof of facts so remote, but besides the statement of Busbecq himself that he sent the sweet flag and many other plants to his botanical correspondents, we have the acknowledgments of Mattioli and de l'Ecluse. Mattioli, in his Commentaries, figures the horse-chestnut and the lilac from branches sent by Busbecq. De l'Ecluse is the authority for the packets of tulips received from Busbecq, then living in Vienna, but still keeping up communications with Constantinople. The word *tulip*, as the dictionaries tell us, is Turkish or Persian, and means a turban. Busbecq (1522–1592) was a Fleming, and served long as ambassador from the emperor to the Turk. He is familiar in history as the describer from first-hand knowledge of the sultan Suleyman and his Turks at the height of their power, when they made Hungary into an Ottoman province and swept round the walls of Vienna. He has his place in literature too as a graphic and unaffected writer. "On ne trouve point ailleurs tant de faits historiques en si peu de discours." A well-known jingling sentence in Bacon's Essays has made his name familiar to many an English schoolboy. Busbecq was an unwearied collector. During his fatiguing and sometimes dangerous travels it was his practice on reaching his lodging to inquire for old inscriptions or coins, and failing these, for rare plants. Bernardin de Saint Pierre proposed to call the lilac Busbecquia ; let us at least give a thought now and then to old Busbecq when the lilacs make our shrubberies gay with their blooms.

XIV. THE ROCK-BARNACLE.

The life of a rock-strewn sea-beach is a world in itself, and I would no more attempt to describe it in one short chapter than I would attempt to describe the land animals of an English country side. But a single visit to the sea-shore, like a single excursion through the fields, may be profitable if we resist the temptation to examine everything that we come across, and fix our attention upon some few objects. What can we reasonably attempt in a single morning's ramble and a single afternoon's boating party, which are all that we can now command?

The rocky beach before us, with its countless boulders and pools, abounds in living things to a degree that only the experienced shore-collector can appreciate. Though many of the free-swimming animals went down with the receding tide, and are now seeking their food in the groves of sea-tangle below low-water mark, a multitude of others have stayed behind to wait for the return of the tide. Some of them, like the sea-anemones, the limpets, and the barnacles, lie exposed on the bare rocks or on the tufts of brown seaweed. Some trust to the protection of a few inches of sea-water; many have squeezed themselves up, or sunk into the sand, or crept into a narrow cleft, or closed some protective shell which they possess, and the untrained eye fails to discover them among the blotches of colour due to rock-weathering, or the tufts of marine vegetation. One of the few creatures that move about freely is the shore-crab, and at a little distance he too becomes invisible, so nearly does his olive-green shell resemble the dark seaweeds. It is with some surprise that the young naturalist hears his elders remark that of all tracts on the habitable globe none so swarms with life as the beach a little above and a little below low water.

Our time will be frittered away if we glance perpetually from one thing to another. We will not load our memories with names, nor with brief descriptions hardly more profitable than mere names; let us pitch upon some one thing and consider it attentively. If local abundance may decide our choice, we can hardly find anything better than the little barnacles which stud the rocks with their dirty-white shells in such numbers that they often form a grey or yellowish band which can be seen a mile or two away.

The common rock-barnacle of the north of England is a rather small species, less than half an inch in diameter at the base, which is the widest part. On our southern coasts this species is replaced by others of the same general appearance, but differing slightly in details. There are much larger species than these, and many of us have seen a pink or purple barnacle as big as a walnut, which is often found in large quantities on the bottoms of ships arriving from tropical ports. Rock-barnacles commonly adhere so firmly to their support that they can hardly be removed without fracture. They are glued fast by a calcareous substance almost as hard as the shell itself. In our northern rock-barnacle the sides of the conical shell are divided into six ridges by narrow sunk spaces, and every ridge is marked by several radiating ribs, but the surface-pattern is often obscured by wear or corrosion. At the summit of the cone is a hole closed by two pairs of close-fitting valves, which can be raised or lowered a little, or parted to allow of the entrance of water and the protrusion of parts of the body. If live rock-barnacles are placed in sea-water and watched with a lens, the valves

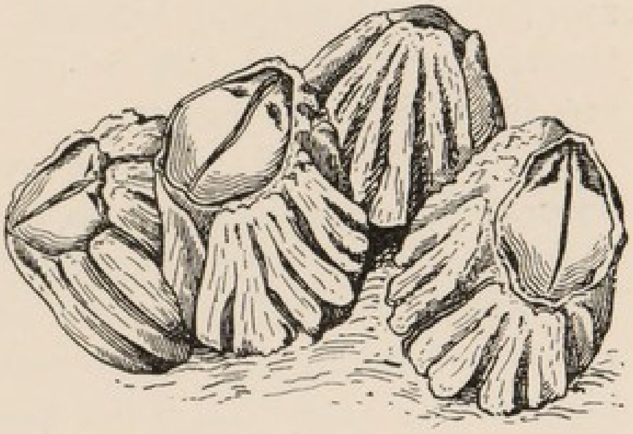

FIG. 13.—Group of rock-barnacles, slightly enlarged.

will be seen to gape at very frequent intervals; the slit between them enlarges to an oval; and then a kind of hand, with six fingers on each side, is protruded for a moment. The "hand" is really the middle part of the body, that part which in a crayfish bears the walking legs, and the "fingers" are legs, which get longer and longer backwards; each leg ends in a pair of slender, jointed, curled, bristle-bearing filaments. At the moment when the valves are parted, the "hand" is extended and the filaments uncurl; then they bend all together towards the mouth, and disappear beneath the valves. By the continual repetition of this action minute floating particles are drawn into the gullet.

The conical shell, with its six outer plates and its four valves, is firmly attached to the body of the barnacle as well as cemented to the rock. It is at first very small, and enlarges steadily as the animal within grows. The growth of its rigid shell presents no great difficulty to a mollusk, for there is always a free margin to which additions can be made; nor is the difficulty insuperable to any free crustacean which can change its shell periodically. But how does the barnacle manage? The only free margin to the outer shell is at the apex of the cone, and addition of new substance here, while not materially increasing the cavity, would quickly close the aperture on which both nutrition and respiration depend. The shell is never cast. A soft-bodied barnacle deprived of its external armour might dry up, or be dislodged by breakers, or devoured by other animals. Somewhat similar difficulties beset an Echinus within its globular calcareous shell. The box must grow and retain its original shape without being parted with for a moment. An Echinus-shell is composed of a mosaic of small pieces, which, tightly as they are compacted together, have free borders. By additions to these borders the shell increases steadily, preserving all the time its original shape. The shell of the rock-barnacle is fixed beneath, which complicates the problem still more, and it has in most cases no visible sutures, but sutures there are, however concealed. Darwin found that many rock-barnacle shells fall to pieces when boiled in caustic potash, separating along the sunk lines which are externally visible. Each of the strong ridges grows by the continual addition of fine laminæ to its base. Since the shell remains fixed all the time, this mode of growth would probably be impossible if the shell were a

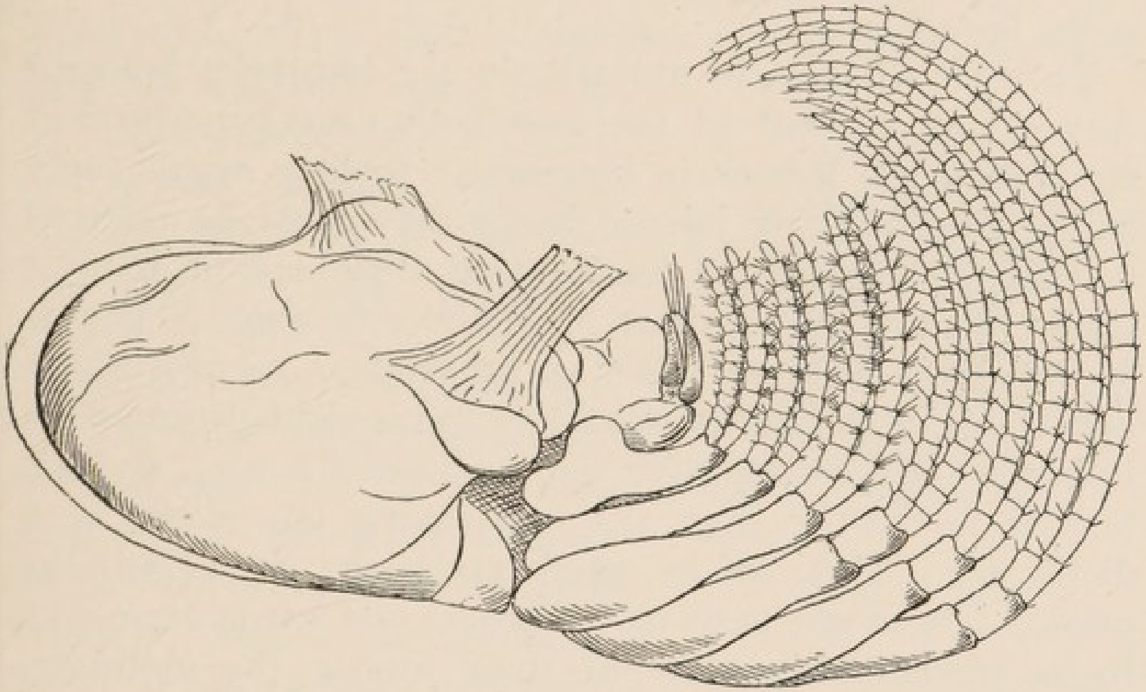

FIG. 14.—Rock-barnacle removed from its shell, in side-view. The six legs with their fringed joints, the muscles for attachment to the shell, &c., are shown.

dead, structureless deposit. It is not really such, for its substance is traversed by innumerable cavities, which lodge living tissue, and its growth is similar to that of tooth or bone, growth and replacement going on together.

Another kind of barnacle is often found attached to objects which have long floated in the sea, such as the timbers of a wreck, or corks torn off from a fisherman's net. This second kind of barnacle has a stalk, and at the end of the stalk is what we should at first sight call a head (though it is nothing of the sort), which is defended by five calcareous plates. If a stalked barnacle is broken open, we find inside the shell a headless animal with six pairs of legs, each ending in two lashes, which are jointed and fringed like those of a rock-barnacle. Unlike as they are on superficial examination, the two kinds of barnacle are evidently closely allied, and we do well to give them a common name. But they must be distinguished from one another, and the names of stalked and sessile barnacles are in common use. The sessile barnacle is what we have hitherto called the rock-barnacle; it is also called the acorn barnacle.

To what division of animals do the barnacles belong? Any young student of the twentieth century, who had received a few lessons in systematic zoology, would reply at once that having jointed limbs they must be referred to the Arthropods, and further that their aquatic habitat places them in that division of Arthropods which is known as the class Crustacea. Our young student, relying on the definitions of the books, would be quite right, little credit to him! Other naturalists have cleared the way, and his task is no harder than that of looking out words in a dictionary. But before good textbooks or definitions existed it was not easy to say where the barnacles ought to be placed. Linnæus put them among the mollusks, and many years later the great Cuvier, who by his own labours had greatly extended the knowledge of mollusks as of many other groups of animals, made the same mistake. Barnacles, he said, have external calcareous shells, like bivalve mollusks, and the body is not segmented as in crustaceans. It is true, he goes on to say, that the barnacles have jointed limbs, very like those of crustaceans, a mouth provided with lateral jaws, and a chain of nervous ganglia, but the Teredo or shipworm, which is certainly a bivalve mollusk, has jointed limbs too (this is a strange mistake of Cuvier's). On the whole he decided to leave the barnacles among the mollusks, acknowledging at the same time that they lead up to the crustaceans, and not at all blaming those who rank them as such. Cuvier's authority was decisive in his own day, and until 1830 the barnacles were regarded without hesitation as a very peculiar and aberrant sort of mollusks. In that year, shortly before the death of the great naturalist, Cuvier's interpretation of the zoological position of the barnacles was upset by the publication of quite unexpected facts.

An army-surgeon named Vaughan Thompson, who was stationed at Cork, had long seized every opportunity of studying the natural objects which came in his way. On April 28th, 1823, after a fruitless expedition to the sea-shore in search of new forms of life, he chanced to throw out a small muslin net while crossing the ferry at Passage, and made a haul of many curious crustaceans. Among these was one which he described as a small translucent animal, one tenth of an inch long, of a somewhat elliptic form, very slightly compressed laterally, and of a brownish tint. When at rest, it resembled a very small mussel, and lay on its side at the bottom of a vessel of sea-water, with all its limbs withdrawn. Its shell consisted of two valves hinged together along the back, and capable of opening for the protrusion of the legs. At the fore end of the body was a large and stout pair of limbs, provided with cup-like suckers for attachment. At the hinder end were six pairs of legs furnished with long bristles, which moved all together, and by their sudden strokes impelled the animal forward in a succession of jerks like a water-flea. The tail was short and bent under the body. Through the shell a pair of black eyes could be distinctly seen. It was not till 1826 that Thompson discovered what this new animal really was. On May 1st of that year he collected

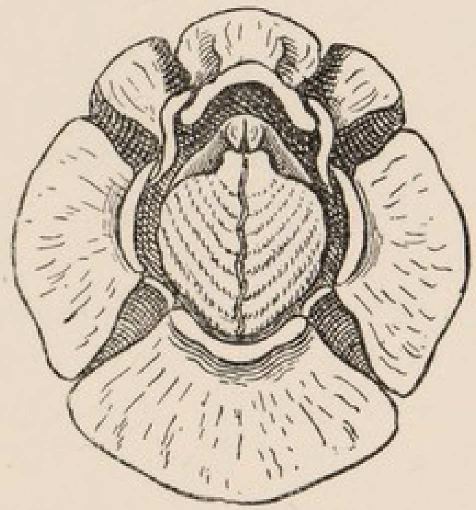

FIG. 15.—Young rock-barnacle, seen from above.

specimens, and put them into a shallow vessel of sea-water. A week later he found that two of them had cast their skin and were now firmly adhering to the bottom of the vessel. Great was his surprise to find that these adhering forms were young barnacles with conical shells of six ridges, four valves and protruded legs. Other individuals were seen in the act of casting their bivalve shells and attaching themselves to the bottom. The earlier stage, which by a rapid transformation passes into a barnacle, bears all the marks of an ordinary crustacean, and even its bivalve shell is very like that of a water-flea (see p. 170). Thompson had now no difficulty in drawing two conclusions; the barnacles are true crustaceans, and they undergo an extraordinary transformation.

Some further account of the naturalist who first unravelled the life-history of the rock-barnacle will, I think, be of interest to my readers, especially as his name is still unknown except to professed zoologists. One proof of this is that he was not included in the first list of Englishmen deemed worthy of mention in the Dictionary of National Biography. Happily for the credit of the dictionary, and we may even say for the credit of Englishmen, the omission was repaired in time, and an excellent notice by Dr. F. W. Gamble tells the story of a naturalist who will be remembered when a thousand celebrities of his own day are forgotten.

John Vaughan Thompson (1779–1847) was an army-surgeon, who served his country during the great French war, being stationed by turns in the West Indies, Madagascar and the Mauritius. After the peace he was transferred to Cork, where his most notable zoological work was done and published. His last years, occupied chiefly with medical duties, were spent in Sydney, where he died. Thompson has written his name indelibly in the history of zoology by the following capital discoveries :—(1) The development of the land-crab of the West Indies, and the proof that the spawning and early development take place in the sea; (2) the Pentacrinus-stage of the feather-star (Antedon); (3) the life-history of the shore-crab, and the proof that this, like others of the higher crustacea, undergoes a remarkable transformation; (4) the life-history of the stalked and sessile barnacles; (5) the recognition of the animals which he called Polyzoa, and which are now regarded as one of the primary divisions of the animal kingdom. These discoveries were made known by a little collection of pamphlets entitled "Zoological Researches," and two short papers in the Philosophical Transactions. Other of Thompson's writings on the natural history of various animals and plants appeared in scientific journals, and some of his papers were translated into French. But hardly any contemporary naturalist realised that these unpretending publications included some of the best and most anticipatory zoological work of that generation, or that Vaughan Thompson would afterwards take a foremost place among the zoologists who intervene between Cuvier and Darwin. To this under-estimate of his work a number of deficiencies, sometimes provoking but rarely important, contributed. Thompson's Zoological Researches, apparently printed at his own expense, were issued from a remote provincial press. The exposition is brief and hurried; the writing has no grace of expression; small slips abound, which betray the unpractised author; the plates (engraved by the naturalist's own hand), though careful, are wanting in style. In fact the Researches are just what we might expect from an army-surgeon, living far from libraries and museums, and bent solely on communicating, without any parade, what he believes to be solid and important additions to knowledge. Few indeed were those who could overlook the superficial defects of these memoirs, and recognise the soundness and lasting value of the discoveries which they revealed.

It is one proof of the scanty recognition which Thompson's work met with in his own lifetime that he was never elected into the Royal Society, and that his memorable contributions to the Philosophical Transactions had to be communicated by Sir Somebody Somebody. In those days admission to the Royal Society was easily got by men of wealth, distinguished by that "landed manner," which Adam Sedgwick remarked among the early fellows of the Geological Society. It could be got by scientific attainments also, if they were acknowledged by the world; but Thompson's merits found no judges at once competent and influential. The year of his death, 1847, was the very year in which admission to the Royal Society was regulated by a new system, which gave for the first time due weight to scientific merit.

Neither in 1826, when Thompson's observations on the transformation of the rock-barnacle were made, nor in 1830, when they were first published, was any other zoologist aware of the singular transformation of the rock-barnacle, or of the proof which it afforded that Cuvier's views as to the nature of barnacles were demonstrably unsound. In 1834 Burmeister published observations which placed it beyond doubt that stalked barnacles also hatch out as free-swimming larvæ, which after a time settle down and become enclosed in a fixed shell. Burmeister added the interesting fact that the stalked barnacle has two larval stages, only the second of which is provided with a bivalve shell. Thompson continued to prosecute his own researches, and in 1835, a year after Burmeister, he published his own account of the transformation of the stalked barnacle. Two ships coming into Cork Harbour, one from the Mediterranean, the other from North America, brought on their bottoms innumerable stalked barnacles. Thompson got a large supply, and kept them alive in sea-water till they emitted prodigious numbers of larvæ, not at all the same as those which had been seen to change into rock-barnacles, and easily distinguished by the total absence of the bivalve shell. Thompson published his observations in complete ignorance of Burmeister's discoveries.

It was necessary to put the results of the two naturalists together in order to attain the complete life-history, and this can now be readily done. Thompson had described the last larval stage of the rock-barnacle and the first larval stage of the stalked barnacle. Burmeister had described both stages of the stalked barnacle. Has the rock-barnacle as well as the stalked barnacle a first larval stage, differing from that which undergoes the transformation ? Thompson never put or answered this question, but it was not long before Harry Goodsir (at Edinburgh in 1843) discovered that the rock-barnacle has an earlier stage quite distinct from the late larva with bivalve shell.

I have not yet finished the story of barnacle-development, but we will break off here, and wait for an opportunity of examining fresh larvæ of the barnacles.

. . . .

This bright April afternoon is capital for tow-netting. There is so little wind that we have often to put out the oars in order to keep the net extended. Sometimes we are content to lie motionless for half an hour together, and then all is still except for the chuckling of little waves, which leap up against the sides of the boat. The water is absolutely clear, such water as we only get on our western shores; and looking over the side I can see groves of sea-weed and corallines, with here and there a sea-urchin, a star-fish, or a sea-slug. A large fish sculls himself gently in and out of the weedy recesses, and crabs clamber over the rocks. Now and then I pull in the tow-net, turn its long cone of muslin inside out, and wash it in a beaker of sea-water.[1] There are many small crea-

[1] The tow-net has a long cone of muslin attached to its hoop, and this is held by a cord. After being towed for some time by a slow-moving boat, the net is hauled in, and its contents examined.

It is a good plan now and then to send to the Marine Laboratory at Plymouth for a supply of what is called "Plankton," an assemblage of minute life from the surface of the sea. A bottle will be received, containing nauplii, crab-larvæ, medusæ of Obelia, the worm Sagitta, and many more pelagic animals. Early summer is a good season for these things.

tures which move slowly by the gentle contraction of glassy bells, others which travel slowly through the water without any means of propulsion that the naked eye or a hand-lens can reveal. Again we are warned not to run the risk of distraction. Even to name all the living objects that the eye can recognise in one of these beakers would be a waste, not so much of time, for time is cheap on an idle afternoon, but of attention, which is soon exhausted

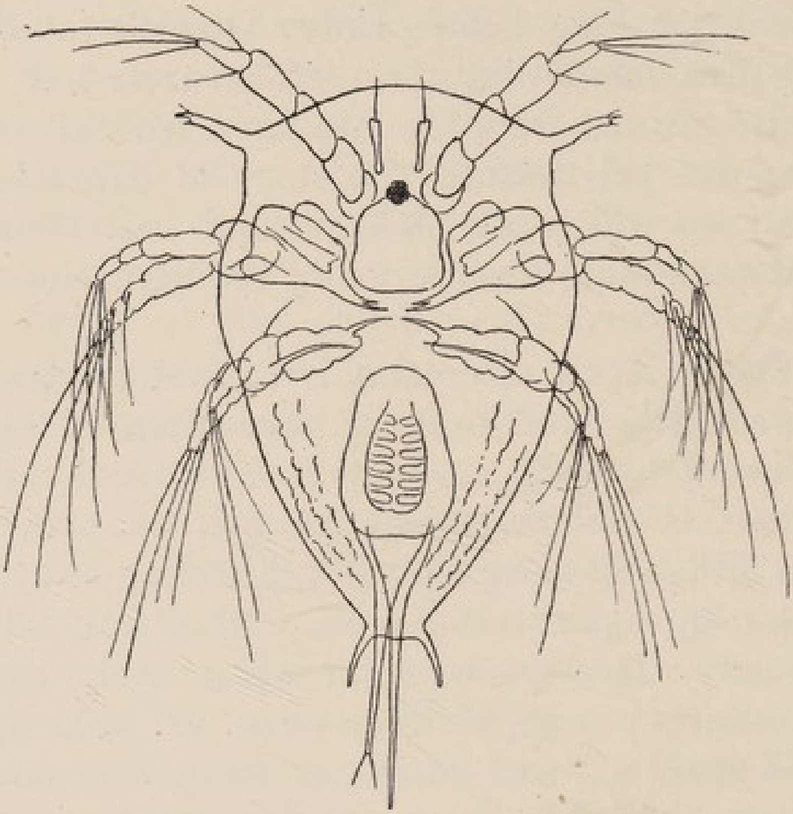

FIG. 16.—Nauplius of rock-barnacle, magnified.

and not easily repaired. We will remark one thing only, and I have my reasons for choosing these little white specks, just visible to the naked eye, which make short jerky leaps in rapid succession. With a dipping-tube it is easy to pick up a few, and transfer them to a watch-glass set on a strip of black paper. Then a good pocket-lens will show us what they are. We can make out an oval body, narrowing behind to a point, and three rather long pairs of limbs fringed with bristles. A microscope is needed to make out the details shown in the accompanying figure. Remark the horns which project from the sides of the head-region, the eye, apparently single, but really consisting of two eyes set close together, and the jointed limbs, the two hinder being forked. Even a beginner in zoology, if he should happen to know his crayfish, will recognise this as a crustacean; the forked and jointed limbs are proof enough of that. A zoologist of somewhat wider knowledge will say at once that it is

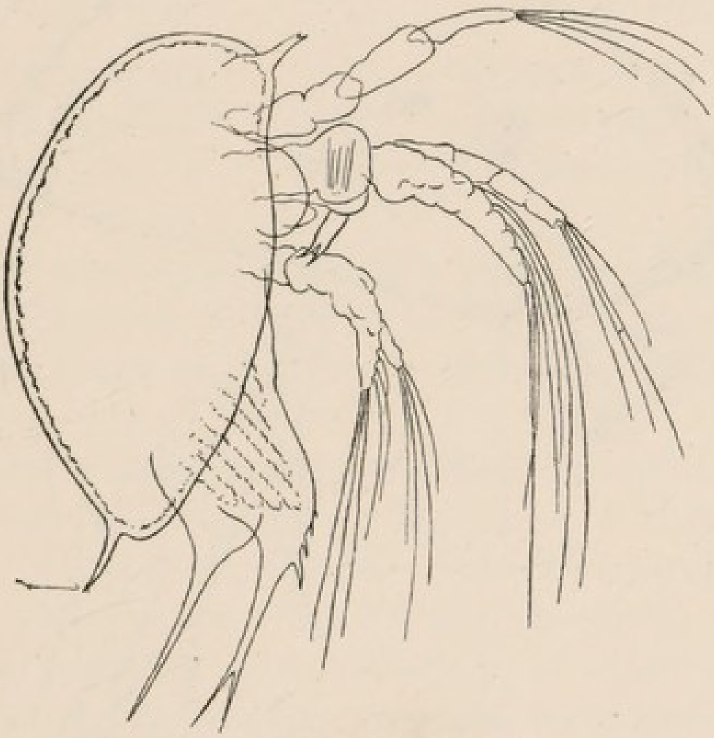

FIG. 17.—Nauplius of rock-barnacle in side-view, magnified.

a crustacean in its first or Nauplius stage.[1] Zoologists who happen to have attended to the crustacea will go further, and pronounce that this is the nauplius of a rock-barnacle. It is an early locomotive larva, destined, if lucky enough to escape the thousand risks that await it, to settle down on a tidal shore and change into a rock-barnacle, such as any one of the multitude that we glanced at this morning.

[1] Nauplius is an old name given to a Cyclops-larva by O. F. Müller, and now retained to denote, not a particular sort of animal, but a stage of crustacean development.

All through the winter and spring the nauplius of the rock-barnacle abounds in the surface-waters of the sea, and some kinds may be found at any time of the year. If a boat and tow-net cannot be had, nauplii may be procured by placing in a bowl of water a stone well-covered with living barnacles. After a few hours nauplii will be emitted, though in no great numbers. This method

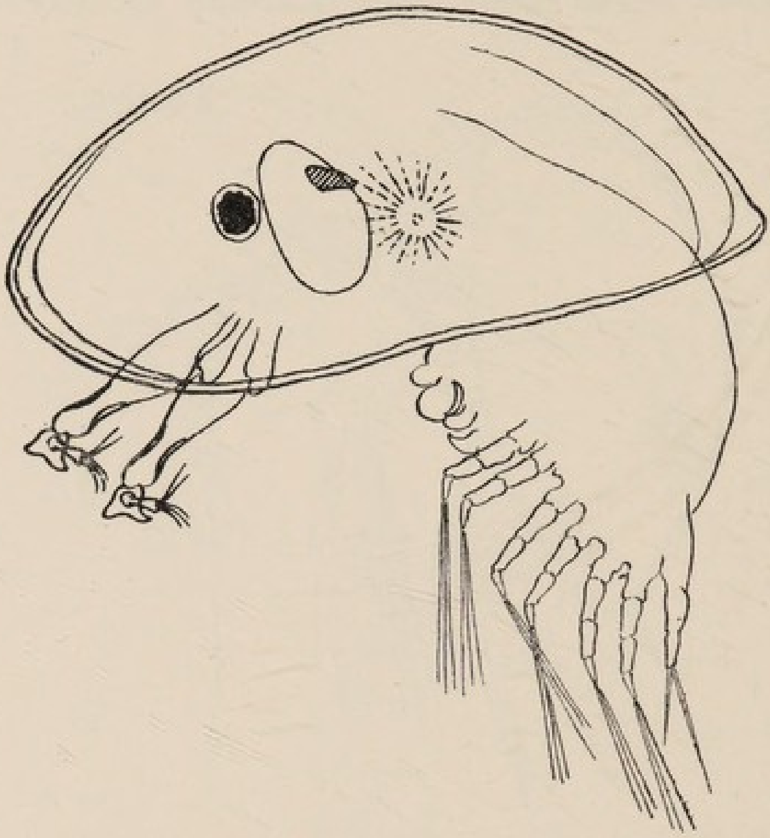

FIG. 18.—Cypris of rock-barnacle in side-view. To the left (head-end) are seen the adhesive feelers; to the right the six fringed legs and the forked tail. The bivalve shell, the large, dark, paired eye, &c., are also shown.

succeeds best in spring. The second larval stage, which was seen by Thompson changing to a rock-barnacle, is most plentiful in May. This is called the Cypris-stage, from its resemblance to Cypris, a well-known small crustacean with bivalve shell.

Barnacle-larvæ do not depend for transport entirely upon their own swimming power. The currents which are set up by wind and tide carry them along far more rapidly than their feeble exertions could possibly do. It would take a nauplius days to travel a single mile, even if it never ceased to propel itself in a straight line. But it need only keep itself near the surface of the sea, to be drifted along a hundred or a thousand times as fast.

It will now be convenient to recapitulate the life-history of the barnacles, and see how far Thompson and Burmeister had got. Balanus and Lepas are the technical names of the rock-barnacle and the stalked barnacle.

BALANUS.	LEPAS.
Larva 1. Nauplius.	Nauplius (B.T).
Larva 2. Cypris (T).	Cypris (B).
Rock-barnacle.	Stalked barnacle.

Thompson was acquainted only with the stages marked T, Burmeister with those marked B; neither knew of the Nauplius stage of Balanus, which was first recognised by Goodsir (p. 71).

The Nauplius-stage of the stalked barnacle had been found and figured long before the time of Burmeister or Thompson, by Martin Slabber, whose Naturkundige Verlustigingen (Recreations in Natural History), published at Haarlem in 1778, is a collection of short illustrated monographs of nondescript animals, executed after the manner of Rösel von Rosenhof's Insecten-Belustigung, (Nürnberg, 1746–55). Slabber relates that in November, 1767, two countrymen brought him the bottom of a cask and an empty corked bottle, both of which had been cast up on the seashore the night before, and which were covered with stalked barnacles. When some of these were placed in sea-water, they emitted clouds which rendered the water turbid. A magnifying glass showed that the clouds were composed of minute living bodies, one of which Slabber figures as he saw it by the help of Cuff's microscope, and his representation is quite recognisable. Slabber had thus, without knowing it, discovered the very singular larva of the stalked barnacle. He calls it a "sea-louse," and thinks it may have been the food of the barnacle.

We have not yet sufficiently described the Cypris-larva of the barnacle, and we must by no means pass over the transformation by which it is converted into a fixed barnacle. The Cypris-larva is furnished with a pair of new antennæ, which shortly before, that is, in the late Nauplius, were to be seen telescoped into the fore part of the body, like the growing antennæ in an insect-larva shortly before pupation. It has three more pairs of legs than the Nauplius, bringing the number up to six. The bivalve shell is large enough to enclose the whole body, including the antennæ, and can be closed by an adductor muscle, except at the ends, which always gape a little. The Cypris-larva swims rapidly, or creeps by the help of its prehensile antennæ. The lowest joint but one of the antenna is furnished with a sucker, which adheres even to so smooth a surface as that of glass. The mouth of the Cypris is closed, and no food can be taken in during this stage.

When the Cypris, swimming or creeping through the water, and guided by its eyes and antennæ, has discovered a spot convenient for its settlement, it applies its suckers and immediately adheres. A sticky fluid is poured out from the suckers at this moment or even earlier, for free larvæ have been found with their suckers already charged with cement. The body is now parallel to the surface of attachment, in the position of a shrimp resting on the ground. The skin splits along the mid-dorsal line, and the bivalve shell, together with the compound eyes and other parts which will henceforth be superfluous, are shed. Then the young barnacle bends its body into the position which it will hereafter retain. When it first became attached, the limbs rested upon the ground, but the body now erects itself until the animal stands upon its head. Just after erection the young rock-barnacle is very like a stalked barnacle in the same stage, and consists of an attached base formed by the head and antennæ, a stalk, which for a short time is flexible, and an enlarged free end, which bears the jointed legs, and is defended by valves and plates. Provision is now made for the protection of the body by an outer case. A fold of skin is pushed out, which grows rapidly until it envelops the body on all sides. Hard plates, answering in a general way to the dorsal and ventral plates of a free-swimming crustacean, form upon this fold. They soon lose all traces of a serial arrangement, and become disposed in an outer and an inner circle. The inner circle sinks within the outer one, and constitutes the valves described above, whose free edges gape to allow the protrusion of the limbs.

It is easy to see that the barnacles, whether stalked or sessile, derive important advantages from the possession of early free-swimming stages. We might go further, and say that they could not continue to exist without motile stages of some kind, for a ready mode of dispersal is indispensable to the due spacing of all animals which as adults are stationary. We learn from observation of the course of development of various animals that three conditions favour the production of special motile stages. These are (1) a sedentary life in the adult stage; (2) heavy armour; (3) a marine, and especially a littoral habitat. All three conditions are associated more or less intimately, and often co-operate to produce the same result. Sedentary life in the adult favours mobility in the larva, for if the adult cannot migrate, the young must do so. Heavy armour makes the adult more sedentary. Habitat, little as it seems to be related to modes of dispersal, is really closely connected therewith, for the waters of the sea, which are continuous over vast areas, and kept in circulation by wind-currents, offer great facilities for early migration. Rivers are much less favourable. They are relatively small and isolated, and they end in the sea, which destroys at once nearly all kinds of freshwater animals which enter it. The crowded state of the shallow seas, which abound in animal life beyond any other part of the earth's surface, favours early dispersal. Crowding brings competition and multiplies enemies, so that the risks to be faced by any species are intensified. Hence a greater number of embryos have to be produced in order to keep up the number of the species. These numerous embryos cannot be subsisted directly or indirectly by the parent, and must therefore be turned out at once to shift for themselves. Their first necessity is dispersal, and hence the embryos of littoral animals are almost of necessity minute, provided with temporary locomotive organs, and quite unlike their parents in form as well as in size. Barnacles, like the majority of shore-animals, are obliged to produce vast numbers of eggs on account of the risks which are to be run. The eggs are minute and ill-furnished with yolk. The issuing embryos are altogether unlike their parents, and adapted to a life of free movement.

The rock-barnacle is a good example of development with transformation of the kind most usual among animals. The frog and the insect, though often chosen as examples, because they are familiar to dwellers in inland places, are examples of an unusual kind. They do not migrate first, and then settle down to feed, but acquire by a late transformation the power of migrating. In insects the transformation is often nearly the last event in the life-history.

XV. RATS AND MICE.

If you were suddenly called upon to define a rat or a mouse, you would come off pretty well if you were to say that it was a small quadruped with short hair, clawed feet and a long tail. The zoologist would not consent, however, to put into one family, nor even into one order, all the animals which exhibit these characters. He would point out that some of them are sharply distinguished from the rest as rodent or gnawing animals, by the structure and arrangement of their teeth. In a rodent the incisors or front teeth are long and chisel-edged, grow perpetually at the base, and are separated by a wide interval from the teeth next behind, which are always grinders, the canines or eye-teeth being undeveloped. Rats and mice are rodents, but the shrew, though popularly called a field-mouse, is not a mouse, nor even a rodent. The shrew has incisors, which are not greatly prolonged, and do not continue to grow at the base; canine teeth are present, and there is no conspicuous gap between the incisors and the grinders. Rats, mice, voles, squirrels, rabbits, and guinea-pigs are familiar examples of the rodent order. Rats and mice, differing in this from all other common European rodents, have long bare tails, with rings of overlapping scales. The voles, which are often called by such names as field-mouse or water-rat, have short hairy tails.

It is only in comparatively modern times that mankind has dwelt in houses constructed so as to give facilities for the parasitic life of rats and mice. During the middle ages an Englishman's house was one-storied, and had no floor but hard-trodden earth. There were no ceilings with floors above, no wainscots, no holes for water-pipes, no drains; and it is easy to understand that there were then no house-rats, while mice were chiefly found in barns. As houses became more elaborate, and trade between distant countries frequent, three sorts of rats and mice came to abound in our houses, and all three have now spread to distant parts of the earth. They came to us from the far east, India or China. The domestic mouse came first, though little is known as to the time and manner of its coming. Even so late as the twelfth century we had no rats, and it is said that there is no ancient name for a rat in any European language. The first rat to enter Western Europe was the black rat, a species of small size, only 7 or 7½ inches long, of iron-grey colour, paler beneath, with a tail longer than the body, and ears half as long as the head. This was the rat or ratton of Old England, the rat of the witches in Macbeth, and of Piers Plowman. It was of gentler disposition than the rats which are now so familiar. Some of my readers can testify to this, for the pied or white rats kept as pets are usually varieties of the old black rat.

In 1727 another rat new to Europe settled in vast numbers upon the Volga, as we learn from the Russian naturalist Pallas. This species is generally quoted as the brown rat, but it has several aliases, such as the grey rat, the Norway rat, and the Hanover rat. Its native country has been pretty clearly made out to be Western China. It is lighter in colour than the black rat; the ears and tail are relatively shorter, and it measures 9 or 10 inches in length instead of 7 or 7½. The brown rat is a bold and enterprising animal of great versatility, feeding upon grain, fish, flesh, or carrion. It takes readily to the water and swims well, not uncommonly haunting ditches and streams, and sometimes burrowing in the bank like a water-vole; in the Hebrides it is said to live upon shell-fish and crustacea. It defends itself against cats and dogs, bites sleeping animals, and is particularly destructive to young water-fowl. No lurking-place is too cheerless for it to settle in, and no rival has hitherto been able to stand against it. From the extreme east of Russia the brown rat spread rapidly over Europe. By the middle of the eighteenth century it had become a familiar pest along the Baltic and the Mediterranean, as well as in every part of England; by the beginning of the American war it had made its way across the Atlantic. There is now no important country in any part of the world which does not harbour the brown rat. Everywhere the black rat has given way before it, and a chance specimen is now a zoological curiosity, to be kept alive in a cage or set up in a museum.

Our domestic rats and mice are remarkably prolific, bringing forth several litters in the year. The young are blind and hairless, and are reared in concealed nests, lined by shreds of any soft material which the mother is able to procure.

Can any one tell us what is the special use of the long scaly tail of the true rats and mice? Several explanations have been offered, but we want some kind of proof that they are founded on fact.

The long-tailed field-mouse and the harvest-mouse are both real mice, and quite different from either voles or shrews. They never enter houses, though the long-tailed field-mouse is common in barns during the winter.

XVI. NATURAL HISTORY CLUBS.

I have belonged to many natural history clubs, but have found hardly any of them profitable. This must be my excuse for proposing changes which I know beforehand will be unwelcome to many brother naturalists.

My first piece of advice to anybody who was thinking of founding a new club would be :—Let no papers be read to the club. The zealous young naturalist's first notion is to turn over textbooks and encyclopædias until he has compiled what will take an hour to read. There may be profit in this to the reader, not very much, I fear, but upon the listeners the effect is melancholy beyond the power of words to describe. No assembly of free agents can be kept together on such terms. I will go a step further, and add :—Let there be no lectures, as a rule. Now and then, I admit, it may be stimulating to hear some naturalist of experience discourse, but even he is generally tedious. A third prohibition, if I can be listened to after what I have already made bold to say, would be :—Let no local lists be prepared, read, or printed. They are hardly ever worth the paper they are printed on.

We have maintained a useful and agreeable college natural history club for several years without papers, lectures, or local lists. The members are simply invited to bring natural objects to show. They shortly explain them, draw illustrative pictures, and answer questions. Conversation is started, and goes on till the president thinks a change of subject desirable. Nobody rises to speak except the exhibitor, who usually stands at the blackboard. Three or four objects fill the hour, and an hour or a little more is found to be enough. The discussion is preceded by a cup of tea and half an hour's chat. It is not thought good form to bring bought preparations. Living things, especially living plants, furnish a great part of our exhibits. No collections are displayed. No special value is attached to an object merely because it is rare. The members of this particular club have all qualified for admission by attending a course of biological instruction for at least a year. Except in colleges, the standard would be lower, or there would be no standard at all. It is indispensable that at least one competent naturalist, skilled in the use of the microscope, should be there to direct and explain.

I will next mention a few natural objects, which may profitably occupy the attention of a club of amateurs.

(*a*) Preparations illustrative of the structure of a green leaf.

(*b*) Mouth-parts, antennæ, compound eyes, tracheæ, gizzards, feet, &c., of the commonest insects.

(*c*) The details of a feather.

(*d*) The mechanism of a bird's wing.

(*e*) Live tadpoles.

(*f*) Stages of the life-histories of common insects (dragonfly, blue bottle, tiger moth, &c.).

(*g*) Pollen-grains and pollen-tubes.

(*h*) The "flowers" and capsules of a moss.

(*i*) The spores, spore-cases and prothalli of a fern.

Diatoms, desmids, polycystina, &c., are generally tiresome and unprofitable, because they are not treated as living things, but as mere named patterns. I need hardly say that they become truly profitable when they are studied in the best way.

Biological research will in general be found too hard for such a club. Natural history recreations, of an instructive but by no means profound kind, are all that most amateur clubs can wisely attempt. Those which succeed to this point thoroughly justify their existence.

It is nearly always a mistake for an amateur club to print anything, even an annual report. Our college club asks only for a shilling subscription, which is entirely spent on refreshments. We have no constitution, we have only two officers, and we never print a line.

XVII. THE PURPLE SAXIFRAGE.

There are two or three vigorous plants of purple saxifrage on my rockery, and one of these has flourished for years, delighting us every April with its purple flowers, which are large and numerous for so small a plant. The stem is prostrate, and the leaves make little rosettes.

Why do this and certain other plants thrive better among stones than in common soil? Gardeners have a notion that big stones keep the soil warm; I do not accept this belief until it is confirmed by thermometer-readings. Stone has less capacity for heat than water, and wet soil might be expected to keep its heat better than rock. Stones promote drainage, especially when they are porous, fissured or liable to occasional slipping, and this is, I believe, a more important consideration. A stony soil limits the number of competitors, and gives an advantage to such plants as the saxifrages, which can thrive almost without earth, or to those which are able to send their roots into long winding crevices. Another thing that must not be overlooked is that big stones screen plants from the wind.

When you make a rockery do not set awkwardly shaped stones on end in a steep pile. Such stones look like broken teeth, and cast shadows which hinder the growth of the plants which are set in the interspaces. Lay the stones nearly flat, and keep the slopes so gentle that they neither intercept all the sunlight nor create torrents in heavy rain. It is often advantageous to tilt the stones a little in such a direction that they drain into the rockery and not away from it. A rockery that starts abruptly out of level ground is as flagrantly artificial as one that is stuck over with spar or bits of grotesque limestone. Let the surface continue the natural curves of the ground, if there are such, or rise imperceptibly if there are none. Let the stones be large, earth-fast, and all of that kind, whatever it is, which comes most plentifully to hand. Let your alpines creep among them at their own pleasure, except where over-luxuriance calls for pruning. The reward of judicious laying-out will be found in a modest array of healthy and varied plants, set where we can enjoy them every day. Of course we cannot hope for the charm of the untouched natural experiment, the nook among the hills where a little collection of wild flowers have found the shelter, the moisture, and the light that suit them best. We must be content with some one pleasant effect, the rich colour of autumn cranesbill in a sunlit fissure, mossy saxifrage carpeting a broad, damp stone, a dwarf mountain ash rooted in a safe crevice, potentillas in their summer glory of yellow and green, or cotoneasters with leaves that redden at the approach of winter. Our enjoyment of the flowers will often be heightened by the recollection of some remote spot where we have seen them flourish in perfection, an Alpine pass, it may be, or a stony hillside in the fjæld, or a rocky cleft in our own familiar Lake-country.

I wonder whether any botanist would have been sagacious enough to infer from the structure of the purple saxifrage that it is the most ubiquitous of arctic plants, showing itself wherever a patch of rock breaks the ice and snow of the far north. I think not, but the range of plants is generally known long before their structure has been investigated, and it was so in this case.

Considering how peculiar are the conditions of life in polar regions, that the surface of the ground is seldom free from ice and snow, that the subsoil is often permanently frozen, that for months together in winter the sun never rises, while for as many months in summer he never sets, one would have expected to find the arctic plants, or many of them, strikingly different from all others in appearance and internal structure; having become adapted to polar conditions, we might suppose that they would thereby become unfit for all others. Our purple saxifrage shows how mistaken any such expectation would be. It has its special adaptations to arctic life, as we shall shortly see, but these adaptations do not catch the eye at a glance. And I think that no one without direct observation would have ever suspected that among the plants which venture nearest to the north pole are dandelion and lady's smock, which we consider very ordinary plants indeed.

The conditions of arctic life are not so trying to plants as to animals. When frost sets in and the ground is buried deep in snow, very nearly all plant-life ceases to be active; on the other hand, when the sun shines throughout the twenty-four hours almost any plant would thrive. The only general physical condition that is rigorously imposed upon arctic plants is the not very stringent one that they must be able to endure intense cold during the dormant season. The success or failure of the many competing species is probably determined by other conditions, such as whether the flowers are attractive to the insects which buzz about the flowers in the arctic summer, or whether the seeds are capable of transport by any natural agent over great expanses of snow. In all climates we find that the qualities which ensure the predominance of certain species are hardly to be appreciated by human intelligence. We cannot tell why among our British Composite weeds particular kinds enjoy a special dominance, each in a site of its own selection (dandelion and daisy in short grass, hawkweeds on railway cuttings, thistles in ill-drained pastures, groundsel on road-sides, and so on). There are scores of other Composites which to the obtuse perceptions of man would have seemed just as likely to prevail in these very spots.

The adaptations of plants to cold conditions are commonly such as these :—(1) the stature is low (arctic willows and birches, for example, are only a few inches high); (2) the shoots dare not expose themselves to the bitter wind, and branching freely without elongating, form dense, almost solid bushes, especially in wind-swept places; (3) the leaves are small, very numerous, clustered, sometimes hairy, often leathery, with dense cuticle, sometimes succulent, often evergreen; (4) the stomates may be protected by being depressed beneath the general surface, by a waxy bloom, or by the rolling of the whole leaf into a hollow sheath; (5) the tissues are often particularly dry, and growth is slow; (6) the flowers are often large and bright-coloured.

Many of these adaptations are found in the purple saxifrage, which is prostrate, with small, tufted, succulent leaves, hidden stomates, relatively large and bright flowers. Close examination brings to light some interesting details.[1] The leaf is of small size, rarely exceeding 5 mm. in length ($\frac{1}{5}$ in.); it is elongate, widening towards the tip, and fringed by fine teeth. The leaves are grouped into 4-ranked rosettes, which open imperfectly, and are thus partially screened from light and air. The upper part of each leaf, which is more exposed than the rest, is covered by a dense cuticle; the stomates are restricted to the lower part, which is often sheltered by other leaves. Near the tip of the leaf is a large water-pore, by which any excess

[1] The leaves of the purple saxifrage have been minutely described by Lazniewski in *Flora*, 1896.

of water in the vessels can be promptly exuded. In a sudden access of cold, abundance of water is so dangerous to the tissues that many plants besides the purple saxifrage have special means of discharging it. The cellular substance of the leaf of the purple saxifrage is succulent, but not very copious, and it is laden with unfreezable contents. In early spring, as soon as the snow is gone, large rose-coloured flowers hide the stem and leaves. The flowers are solitary, erect, short-stalked, and about half an inch in diameter, very large therefore in comparison with the size of the leaves. The honey is more deeply placed than in other saxifrages. These peculiarities are probably connected with the observed fact that whereas most saxifrages are pollinated by flies, this one species is diligently and persistently visited by butterflies, whose favourite colour, like that of moths, is purple, and which, unlike some other butterflies, have long tongues, able to penetrate the recesses of flowers.

Seeing how completely the purple saxifrage is enabled to endure extreme cold, the wonder is, not so much that it ranges far north, as that it should be able to make itself comfortable in an English rockery, where both cold and heat are moderated by winds blowing off the sea and bringing with them almost incessant rain. This is not an isolated case; many of our very common plants, while able to thrive under British conditions, are equally fit to withstand the sharpest cold ever felt on this planet.

I hope it will not discourage the reader too much if I set down the distribution of the purple saxifrage. That kind of information is as a rule very depressing, because it is poured out in unrelenting doses, and put to no use whatever. If we treat one plant only, and exert ourselves to interpret the facts of its distribution, we may possibly attain some small result; at any rate the sacrifice of time and space will not be very great.

The purple saxifrage overspreads all suitable places, and especially clefts and crannies of the rocks, throughout the arctic regions of the three continents, which border on the north pole. It forms large carpets on the tundras. In Europe it travels southwards along the Scandinavian mountains, becoming more scattered the farther it goes. It is found high up on the mountains of Scotland and Wales, on some of the lake-mountains (it is profuse for instance in Dungeon Gill), and a few of the Yorkshire hills. It reappears in the Alps (descending as low as the Lake of Constance), the Jura, and the Pyrenees. In America it occurs in parts of Canada and the Rocky Mountains, getting as far south as Mexico, but the eastern states do not seem to suit it, and it is only found, completely isolated, on Willoughby Mountain in Vermont. In Asia it is found at great heights on the Himalayas and other southern ranges.

One can fancy the purple saxifrage laying down the conditions under which it could engage to be happy, and saying :—

"The far north for me! What I like best of all is a little rocky knoll, open to the sun, but sheltered from the wind. Let us fix the latitude at something between 70° and 80° N. I want a place where the snow melts early, and where the snow-water can run off at once through chinks and clefts. I don't in the least object to a short summer of three months, for the sun will be shining all the time, so that I can get my flowering and fruiting over before the nine-months winter sets in. Give me such a place as that, and I promise to make things gay. Such a burst of purple bloom as you shall see!

"If I can't get exactly what I ask for, I don't mind living farther south, provided that I find a sheltered nook among the rocks. Let there be plenty of sun, good shelter from the wind, and the higher the better. If I am to be set down in western Europe, I prefer that slope of the mountains which is turned away from the damp S.W. wind. There must be no peat or clay to hinder the water from running off. Above all, I want the place, whatever it is, to myself, and can put up with a site which is not all I could wish, if it suits my rivals worse than it suits me. Some plants which take up little room I don't strongly object to as neighbours. Sedums and pinks and the modest little Drabas are unobjectionable. Polemoniums are too aggressive, and cover too much ground with their odious blue flowers. How any one can dress in blue I can't understand! Cryptogamic riff-raff, such as lichens and that sort of thing, need not be taken into account. But whatever you do, keep me off the places where there are a lot of heaths. I am quite sure that the heaths and I can never be happy together."

Some naturalists, whose opinion carries the greatest weight, have invoked the Glacial Period to explain the distribution of such plants as the purple saxifrage. Charles Darwin and Edward Forbes put forth a glacial explanation of the present range of arctic and alpine plants, which was afterwards adopted by Sir Joseph Hooker in his "Outlines of the distribution of Arctic plants."[1] The leading features of the explanation are these:—In glacial times the ancient flora of Europe, whatever it was, became supplanted by an arctic flora. When the climate grew milder again, the arctic flora either retreated northwards, or else climbed the alps and other mountain ranges. In this way it came about that the same plants occur on distant mountain summits and also in the arctic regions.

Analysing the argument, it seems to rest upon these four propositions:—

1. The arctic regions have a characteristic flora.

2. The alpine regions of Europe have a characteristic flora.

3. These two floras are so nearly the same that they may be supposed to have had a common origin in comparatively recent times.

4. The arctic-alpine flora in central Europe is now restricted to high ground.

I believe on the contrary that known facts and even

[1] Phil. Trans., 1860.

the tables of Hooker's memoir justify the following very different propositions :—

(1) There is no extensive and characteristic arctic flora. There is indeed a scanty assemblage of peculiar arctic species, but most arctic plants, especially such as are widespread and frequent, are, like the purple saxifrage, found also in temperate Europe, temperate Asia, or temperate North America.

(2) There is an extensive and characteristic European alpine flora, which comprises so many peculiar species that it is probably much older than the Glacial Period.

(3) The arctic and alpine floras are by no means identical. Such characteristic alpine genera as Gentiana, Primula and Soldanella hardly occur within the arctic circle. Though the so-called arctic flora has many species in common with the alpine flora, these common species are in by far the greater number of cases characteristic of neither ; they are generally frequent and wide-spread in the interjacent lands at all elevations. Among these may be named the buttercups (several species), lady's smock, shepherd's purse, dog-violet, campion, wood-sorrel, the commonest clovers and vetches, silver-weed, coltsfoot, milfoil, dandelion, harebell, ling, thyme, speedwell, the plantains, sorrel, crowberry, and the nettles, besides most of the rushes, sedges and grasses. The reputed arctic-alpine species are often far more plentiful outside the arctic and alpine regions than within them.

(4) The arctic-alpine species are by no means restricted in temperate countries to heights, but often thrive at moderate elevations, if not pressed too hard by man or by competing species.

Cold, wind, and other severe climatic conditions have brought about in not a few plants special adaptations to arctic and alpine conditions. The experiments of Bonnier show how directly and rapidly transplantation from small to great elevations may act upon certain plants, inducing reduction in size of parts exposed to air, crowding of leaves and shoots, enlargement of roots, and the like. The fact that they are capable of rapid adaptation has made it possible for certain plants to maintain themselves on high, bleak, wind-swept mountains and on arctic shores, as well as in the sheltered lowlands of temperate regions. The absence of visible adaptation to extremely hard climatic conditions is, however, equally remarkable. Take the list just given (p. 90) and see how few of the plants named could have been set down as arctic-alpine by mere consideration of their structure.

Insufficient attention has, I think, been paid to the acts of man in draining and reclaiming wastes. There can be no doubt that many European plants, now restricted to high or northern tracts, could perfectly well endure a mild climate, if they were left undisturbed by draining, mowing, grazing, and the competition of introduced species. A cause so apparently slight as the application year by year of a particular chemical manure has been found to affect visibly the proportions of particular species in the herbage. Thus it has been found at Rothamsted that the product of a tract of unmanured permanent grass-land included nearly 50 species, viz. about 17 grasses, 4 leguminous plants, and 27 species of other families. By vigorous manuring for many years continuously, the number of species was reduced to 15, the leguminous herbage becoming excluded altogether, and the miscellaneous herbage nearly so. Purely mineral manures reduce the percentage by weight of grasses, and increase the percentage by weight of leguminous plants in the hay, while they reduce both the number of the species and the proportion by weight in the hay of the miscellaneous herbage. In the same way where a farm immediately adjoins a moor there is often a striking contrast between the vegetation which has been grazed and manured and that which has been left in a state of nature. A wall may thus come to separate two plots which are occupied by two quite different assemblages of plants.

By the discouragement of many species which are either unprofitable to man, or unable to withstand under artificial conditions the competition of the introduced and selected species which thrive by cultivation, the flora of the wastes has come to appear more alpine and arctic than it really is. Even now, if cultivation were to cease; if the streams were again to become choked with swamps; if the imported species were no longer favoured by manuring and cropping; we should probably see many species of plants descend from the barren hill-tops, to establish themselves in the plains or on the lower hills. The process, by which during the period of scientific observation these denizens of the wilderness have been ousted from many spots where they used to thrive, would be reversed, and such reversal, if carried far, would give such an extension to the flora which we call alpine or arctic, as we should expect to result from a great fall in mean annual temperature.

I do not believe that we need call in the glacial period to explain the present distribution of European plants. With or without a glacial period we should have had, under present conditions of climate and tillage, a great contrast between the cultivated land and the wastes; the wastes would, as now, occupy the far north and the highest ground of central Europe; there would be species common to both areas which no longer occur in the interjacent lands. To explain the identity of the arctic and alpine floras by means of the glacial period is to explain by a well-ascertained fact a coincidence which is not yet established. Before we ask what is the cause of the identity of the arctic and alpine floras, let us ask whether they are truly identical.

XVIII. WATER-LILIES.

Whenever I wish to refresh my recollection of the common water-lilies, I can do so by means of a very pleasant little excursion. A few miles from the busy city where I live is a great park, with ornamental lakes, in which water-lilies and other aquatics are grown. The walk across the park is charming. Undulating ground gives incessant variety to the landscape; avenues of overarching trees temper the summer heat; now and then we catch sight of a wide plain with scattered villages and church-towers; and beyond the plain a range of noble hills shows its dim outline. The hall is of Queen Anne's time, stately and formal. Seventy years ago it was devastated by fire, and it has never been restored. The walls are still standing, but the roof and floors are gone. Though the hall is desolate, the gardens with their clipped hedges, and terraces, and fountains are still kept in good order. The natural beauty of the place is enhanced by its loneliness. Ancient magnificence has been first humbled, and then invested with simple natural sweetness. The solid masonry with its time-worn classical ornaments has lost all its stateliness, and hop, wistaria, clematis and roses now trail over walls which were once rigid and imposing. At the meeting-place of three avenues have been formed a terrace, an artificial lake and smaller basins. Here the water-lilies can not only be admired, but studied closely, for even their great root-stocks can be reached in the shallower pools.

We have only two common native species of water-lily, the yellow and the white. There is another native plant which looks very like the true water-lilies, and would be easily taken for such on a hasty inspection. This is the Villarsia, which is really a water-gentian, but has the form of leaf and the habit of a true water-lily. It shows in a striking way the power of external conditions to produce similarity of structure in plants quite distinct from one another. The flowers and fruits of Villarsia are totally unlike those of any true water-lily.

The leaves of the white water-lily (Nymphæa) float at the surface, and take a shape not uncommon with floating leaves, that is, oval, with the margin slightly raised and crimped. The leaf-stalk is attached near the centre, and behind this point the leaf is split. The special reasons which bring about so great a variety of form in the leaves of land-plants do not apply to floating leaves, which are usually of very simple shape. They need no protection from wind; down-pointing cusps, such as drain off the rain from many hanging leaves, would here be quite useless; all the leaves lie in one plane and are well exposed to light. The chief accident to which they are exposed is the sliding of one leaf over another, which hinders the

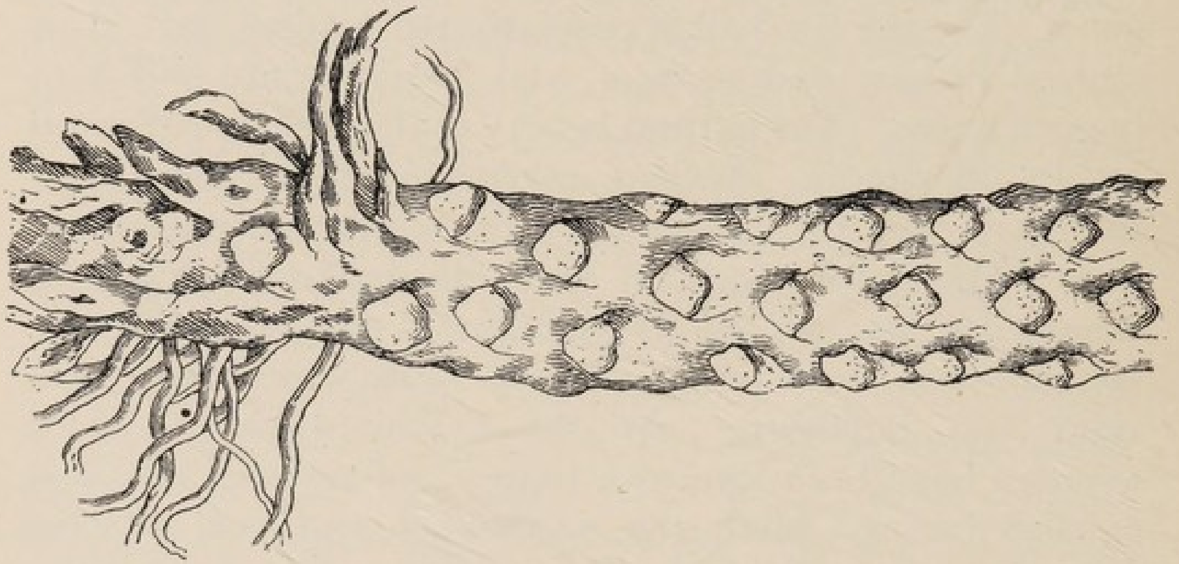

FIG. 19.—Yellow water-lily. Upper surface of rootstock. $\times \frac{3}{8}$.

access of air and light to the lower leaf, and often causes premature decay. Under natural conditions this accident does not occur. Nymphæa is partial to deep waters, and I have found it rooted at the bottom of a Highland loch, in a depth of forty feet. Then the long, curved and flexible leaf-stalks, like slack cables, allow so much play to the leaves, that they can adjust their distances and avoid mutual pressure. But when the plant is grown in shallow water, it cannot avoid overcrowding. There is not enough length of stalk for the leaves to adjust their distances, and they sometimes push one another into the air, or are pushed up by the undue elongation of the leaf-stalk.

Like all floating leaves, those of Nymphæa bear cuticle, stomates and palisade-cells on the upper surface only, for the under surface, being turned away from the light and air, takes no direct part in the work of assimilation, and does not require protection from evaporation or intense sunlight.

If the leaf or flower-stalk of a Nymphæa is cut across, numerous air-canals are seen to traverse it. They lead into the leaf or flower, and give buoyancy, besides carrying air to the submerged organs. Into the air-spaces peculiar

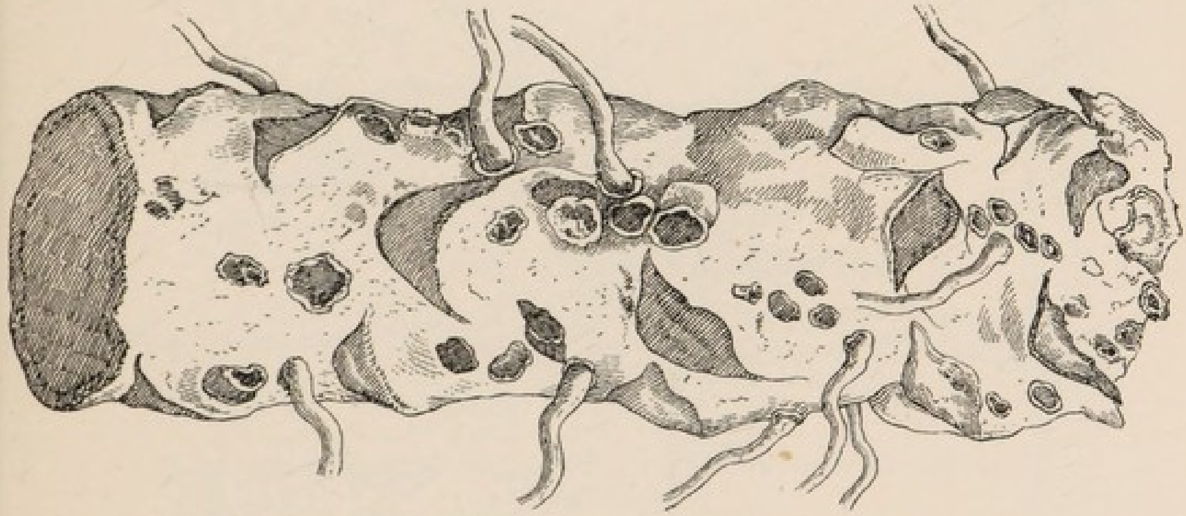

FIG. 20.—Yellow water-lily. Lower surface of rootstock. $\times \frac{3}{8}$.

stellate hairs project, which are stiffened by a deposit of calcium oxalate. Their function has not been ascertained with certainty; perhaps (as Stahl believes) they discourage the attacks of snails and other animals which feed on submerged vegetation. Of course the stalks need special defences; for if they are much damaged, the entire leaf or flower will be destroyed; the attacks of caterpillars or snails which gnaw the *blades* of the leaves are less serious.

When the leaf-bud begins to expand, its margins are folded inwards, and the future upper surface is nowhere exposed. At this time the leaf is completely submerged, and completely wetted. Shortly after it has gained the surface and expanded into a flat oval plate, its surface becomes glossy, and is covered with a waxy secretion, which throws off the water.

The textbooks of botany which I have examined give no adequate description of the stem (rootstock) of our water-lilies, and I shall therefore describe them more fully than would otherwise be necessary. The rootstocks of the white and yellow water-lily (Figs. 19, 20, 22) are alike in their general appearance, and resemble the human arm in size and form, except that they are a little flattened from above downwards along their whole length. They are prostrate, and lie on or in the mud. The larger end

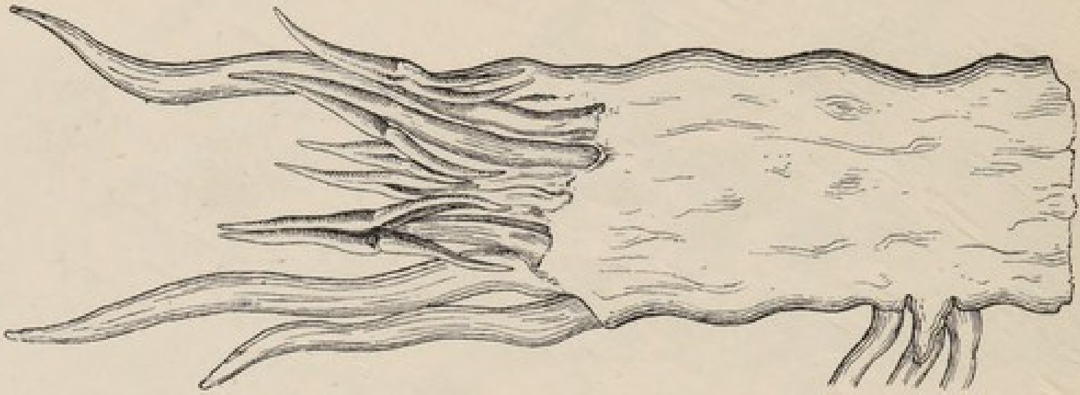

FIG. 21.—Yellow water-lily. Section through growing end of rootstock. × $\frac{3}{8}$.

is the older, and is more or less decayed. The leaves of the year are given off towards the smaller end, and beyond these, during most of the year, is found a bunch of undeveloped leaves, rolled up tightly and forming pointed stalk-like projections, which stand out horizontally for perhaps a foot beyond the growing point of the rhizome and in line with it. The growing end is a little turned up, and buried among the bases of the leaves of the current year. A few inches farther back the leaves have disappeared, but their scars mark the rootstock, especially its top and sides, with a conspicuous pattern. Towards the growing end, from the sides and lower surface, many rootlets, of about the diameter of a goose-quill and often a foot long, project downwards into the mud. A rootlet is generally shaggy with root-hairs, except for an inch or two at its base and an inch or two at its tip. Branched rootstocks are often found. The rootstock contains so much air that it floats in water when the roots are severed. So far the description applies both to Nymphæa and to Nuphar.

The rootstock of Nymphæa (white water-lily) is black externally, and roughened by the very numerous leaf-scars, which are prominent, smaller than in Nuphar, and set much more closely. The arrangement is quincuncial $(^{*}{}_{*}{}^{*}{}_{*}{}^{*})$. When preserved in a watery fluid, both the rootstock and the water in which it is immersed turn to an inky black, which is due to tannin present in large quantity in the tissues. When cut across, the rootstock of Nymphæa shows a central zone of harder tissue; the vessels are few and scattered.

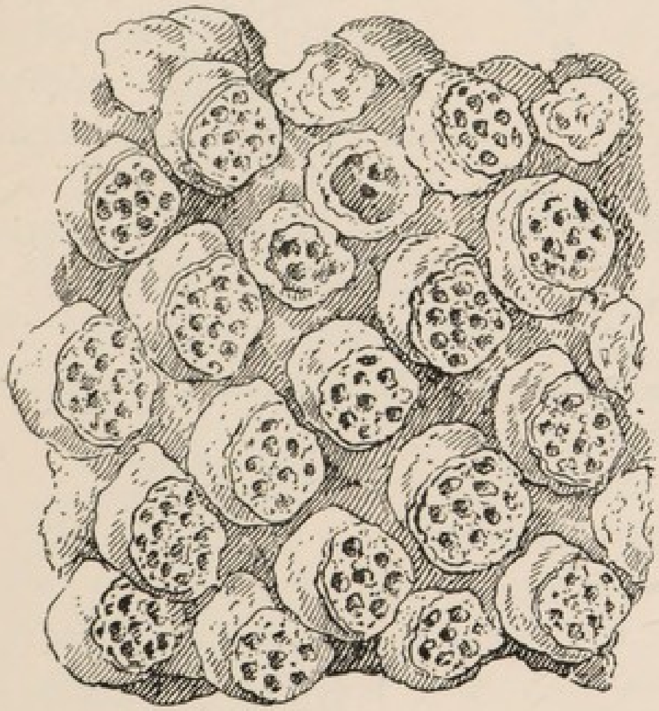

FIG. 22.—White water-lily. Part of upper surface of rootstock (natural size), showing the bases of old leaves, with air-canals.

FIG. 23.—Root of yellow water-lily.

The rootstock of Nuphar is not so dark as that of Nymphæa, but of a stone-colour blended with green. The leaf-scars are larger and more distant from one another; each has a sloping buttress (Fig. 19). The underside (Fig. 20) is flattened, and bears fewer leaf-scars than the top or sides. The rootlets spring as a rule from the base of a leaf-scar, three to six in a longitudinal series; when they wither and fall off, they leave pits (Fig. 20). No ring of harder tissue is seen on the cut end. The rootstock does not contain so much tannin as that of Nymphæa.

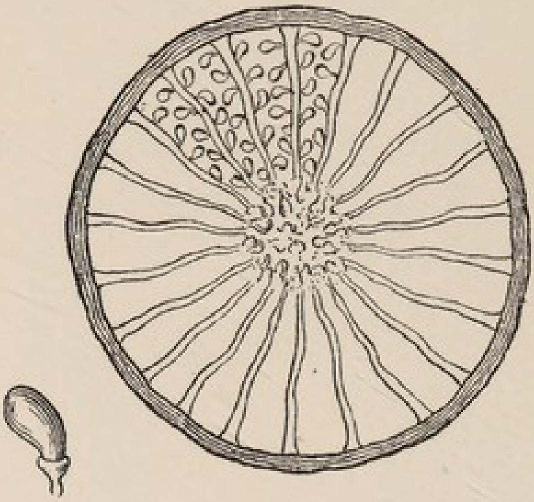

FIG. 24.—White water-lily. Section of fruit, slightly reduced. An enlarged seed is shown at the side.

The flowers of Nymphæa are formed beneath the surface of the water, and only float when expanded. Even when they have once expanded, they close every evening, beginning as early as 4 o'clock in the afternoon, and sink. There are four green sepals (or outer floral leaves) and probably only eight true petals, but the number is greatly increased by secondary petals (four groups of four each) which form within and between the four primary petals of the inner whorl. The secondary petals pass gradually into the stamens, and a narrow white petal often bears one or two anther-lobes. Very likely all the secondary petals were once stamens; if so, the flower is a double one, like a cabbage rose. The unaltered stamens are very numerous. The pistil consists of many united carpels, each many-seeded, and

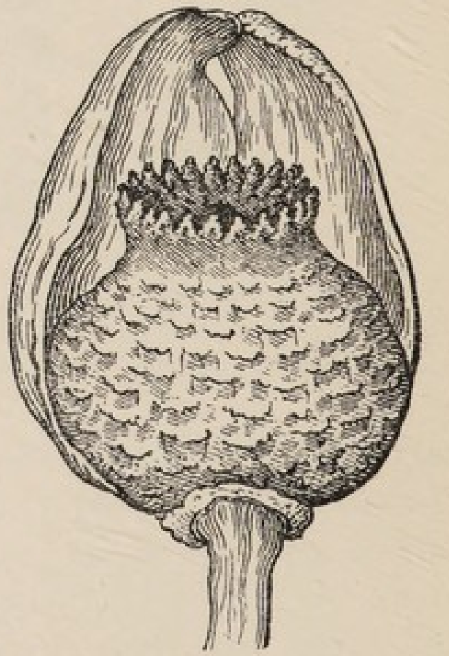

FIG. 25.—White water-lily. Ovary, with two sepals. Slightly reduced.

the whole mass is half-sunk is a flower-cushion or receptacle, formed out of the end of the flower-stalk. The numerous stigmas have a radiating arrangement, as in a poppy, to which the water-lilies are believed to be allied. Nymphæa is pollinated by flying beetles, such as rose-chafers, which are sometimes caught in the closing flowers and drowned.

After flowering is over the pistil slowly enlarges, and

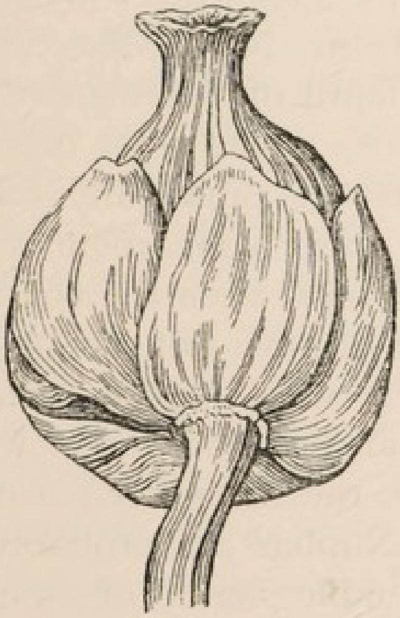

FIG. 26.—Yellow water-lily. Entire fruit with calyx. Slightly reduced.

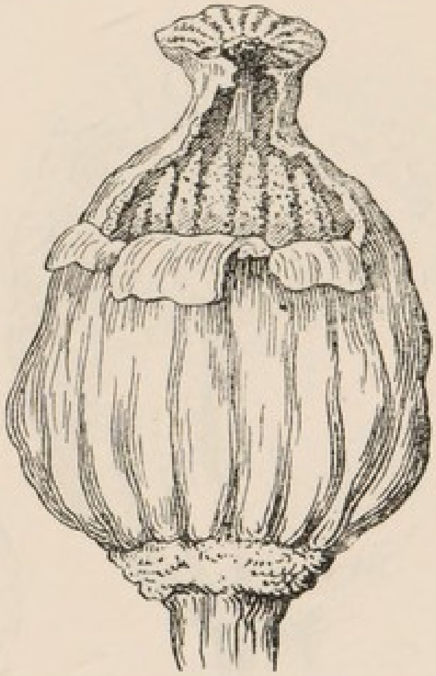

FIG. 27.—Yellow water-lily. Fruit beginning to burst. Slightly reduced.

before long is set free by the rotting of part of the flower-stalk. It sinks to the bottom until the seeds are ripe. Then the envelope bursts, and a rounded mass of slimy seeds is disclosed, which floats up to the surface, and forms patches not unlike fish- or frog-spawn. During ripening each seed becomes invested by a spongy membrane or aril, and air is secreted and lodged in this. The floating seeds are soon dispersed by currents or wind, possibly by birds also. After a few hours the air escapes from the arils, the seeds become waterlogged, and being, like nearly all seeds, heavier than water, they sink to the bottom, where they are destined to germinate.

Nuphar, the yellow water-lily, in addition to its floating leaves, which nearly resemble those of Nymphæa, has submerged leaves, which are thin, like many other submerged leaves, and wavy. Their large size and abundant chlorophyll shows that they are functional, and their presence in Nuphar as well as their absence in Nymphæa is easily explained by the situations in which each kind of water-lily is most at home. Nuphar flourishes best in shallow pools, where the sun's rays can reach the bottom; Nymphæa prefers a depth of twenty feet or more, where the bottom must be practically dark. In the colder months of the year, when the floating leaves have not yet made their way to the surface or are turning yellow with age, the submerged leaves of Nuphar are probably a valuable source of assimilated carbon.

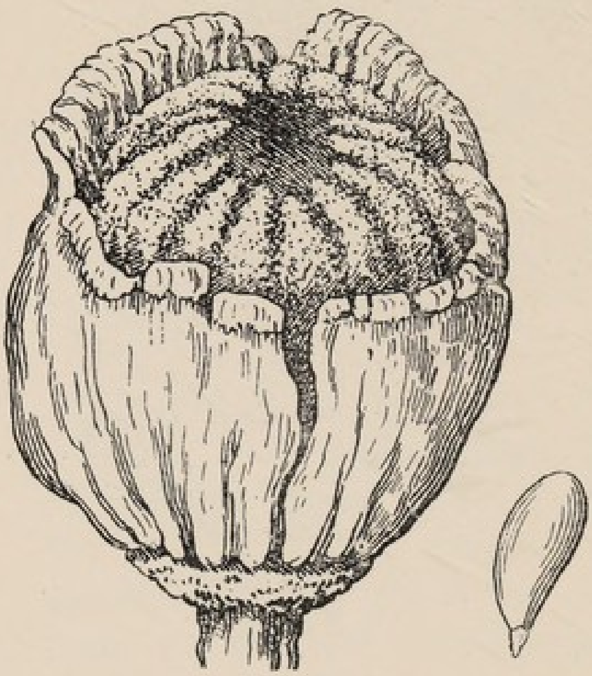

FIG. 28. — Yellow water-lily. Fruit burst open and exposing the carpels. Slightly reduced. An enlarged seed is shown at the side.

The flowers of Nuphar differ materially from those of Nymphæa. They do not float, but stick out of the water, and expand in the air, not sinking by night. There are more outer leaves than in Nymphæa, the petals are smaller, the carpels not sunk in the flower-stalk. The flowers exhale a peculiar alcoholic odour, which is perhaps attractive to the beetles, flies and bees which visit them. The fruits do not sink like those of Nymphæa, but float. After a time the green rind absorbs water until it swells and bursts, exposing the white carpels, which have the arrangement and appearance of the segments of an orange (Figs. 27, 28). The carpels soon break loose and float on the surface, by reason of the air which is lodged in their spongy substance. After a day or two the air is dislodged, and the heavy seeds sink to the bottom; sometimes the seeds fall from a carpel which is still buoyant.

Any one who watches the germination of water-lily seeds will find that the young plants pass through a series of changes which perhaps preserve a record of ancient stages of evolution (Figs. 29, 30). The seedling has at first long strap-shaped leaves, like those of Vallisneria and other submerged plants. This form of leaf, though not peculiar to aquatic plants, is well suited to life in a slow current of water. The ribbon- or strap-shaped leaf is succeeded by an ovate leaf, with narrowed base, which reminds us of the aerial leaves of water-plantain (Alisma) or the floating leaves of some common Potamogetons. The next stage is a sagittate leaf like that of arrowhead. Lastly the backward-directed lobes curve inwards till they meet, the long sides become uniformly convex, and the floating leaves of Nymphæa or Nuphar are attained. Such a succession of leaves appears to be normal in water-lilies, and is also exemplified by the Alisma-family, which includes arrowhead and water-plaintain. Its occurrence in two distant families indicates that the succession was

FIG. 29.—Seedling of white water-lily, with primary root, secondary root, strap-shaped leaf and ovate leaf.

strongly adaptive in its origin, but it appears to be so ancient in both cases as to have become *ancestral*, that is, perpetuated rather by long-continued inheritance than by the exigencies of present conditions.

FIG. 30.—Seedling of yellow water-lily, magnified. To the left are seen the seed, still enclosing the seed-leaves, the radicle, and a small lid, which opens to allow the escape of the radicle; in the centre of this lid is the micropyle. To the right is a bud, from which are given off two leaves, one long and strap-shaped, the other folded, besides an adventitious root.

In spite of their aquatic situation the water-lilies are much beset with caterpillars, the larvæ of a moth known as the Brown China Marks. The larva is found in early summer on pondweed, and afterwards devours the leaves of water-lilies and some other aquatic plants. It makes a flattish sheath out of two pieces of leaf, and thus completely conceals its own body. The sheath, even if submerged, is kept full of air, for the larva has no gills, and breathes solely by spiracles. The pupal stage is passed within the same sheath, but is never submerged. Other insects attack the water-lilies in ways of their own. A Dipterous larva mines the leaves, and excavates long winding galleries in their thickness. The rootstocks harbour a beetle-larva (Donacia), which, though it lives at the bottom of a pond or river, is an air-breather. It procures the air which it requires by tapping the air-filled cavities of the rootstock, and filling its respiratory tubes through spiracles constructed for this very purpose.

It interested me greatly, when visiting the lakes of the

Algonquin reservation in Canada, to remark how similar was their vegetation to that of our own ponds. There were water-lilies just like ours to superficial observation, and these water-lilies were gnawed by insects, which came very near to our China Marks. Of all faunas and floras those of freshwater basins might have been expected to be most narrowly limited in space, because of the great apparent difficulties of transport over land and sea. Yet there is, I believe, no fauna or flora so wide-spread and so constant. Is this due to the long-continued survival of ancient forms in small and disconnected areas, where they are subject only to feeble competition ? Or can it be explained (as Darwin thought) by supposing that fresh-water plants and animals, instead of being at a disadvantage, enjoy unusual facilities for dispersal ?

XIX. HOUSE-FLIES.

The passage which follows gives all the information respecting house-flies that a well-informed and observant man, who had never occupied himself with insects, was able to furnish. I think it may be taken as representing the average amount of knowledge possessed by intelligent people who are not naturalists.

" The house-fly is a small insect which buzzes about our rooms in summer. It is often found on the window-pane. Sometimes there are found with it many smaller flies—young ones, I suppose. The bluebottle is quite different from the house-fly, much larger and of a blue colour, while the house-fly is black. Some people say that the house-fly stings, but it has never stung me that I can recollect. I do not know where house-flies come from, but bluebottles are bred from maggots, such as anglers use for bait."

My friend's remarks suggest several comments, and first of all this, that he mixes up under the name of " house-fly " a number of quite different insects. In our houses the following flies are commonly met with, and any one of them would be called a house-fly by the man in the street.

1. *The Common House-fly* (Musca domestica). During later summer and early autumn this is the most abundant fly found in rooms of city-houses. It is not nearly so plentiful in country-houses, where other species often replace it. Dr. L. O. Howard of Washington made collections of the flies of kitchens, pantries and dining-rooms in various parts of the United States. Upwards of 20,000 were collected on sticky fly-paper and examined. Nearly 99 per cent. belonged to the common house-fly.[1] No census of this kind has been taken in England, but my own observations lead me to believe that none of our house-flies preponderate to such a degree over the rest, though in restaurants and taverns, where food, shelter and warmth can always be had, and where neighbouring stables furnish convenient breeding-places, the common house-fly may multiply prodigiously. In private houses, even in great cities, but still more in country-houses, there is a variety of sorts, though one or another may decidedly prevail at a particular season. Six out of the eight house-flies recorded as present occasionally in American houses are importations from Europe, and several of them are much more plentiful in our houses than Howard's census shows them to be across the Atlantic. Our common house-fly has now been transported to every quarter of the globe.

In September we find in our houses some very provoking flies, which settle time after time on the face or wrist, and press the skin with much determination, as if trying to draw blood. These flies are hard to catch, being uncommonly wary, and much on the wing; they do not often settle on the window-pane, where a fly is most easily taken at a disadvantage, but often rest on the floor or in a dark corner. Such examples as I have captured have all

[1] Flies and Typhoid Fever, *Popular Science Monthly*, 1901.

proved to be common house-flies (M. domestica), and I suspect that they have become so artful by haunting horses; at all events this species does annoy horses a great deal.

How do we tell the common house-fly from other flies of much the same general appearance? One distinctive mark is found in the colour of the abdomen, which in the common house-fly is always yellowish at the base, and often over a great part of the under surface. If we separate the very peculiar antenna from the front of the head, and examine it with a lens, we shall see that the long bristle, which forms its proper termination, is feathered, whereas in some other house-flies it is naked. The upper surface of the thorax shows dark longitudinal streaks in many flies, due to absence of the hairs which elsewhere hide the dark skin. In the common house-fly four regular and distinct streaks run lengthwise along the back of the thorax, but are not continued upon the grey semicircular shield (scutellum) at the hind end of the thorax; another dark streak, broader in the female than in the male, runs along the middle line of the back of the abdomen. All this particularity is necessary in order to distinguish with certainty the common house-fly from other flies which are often met with in houses.

The common house-fly often hibernates in cellars and attics. In a mild winter some of these semi-torpid flies make their way from time to time into the living rooms, and I think I have seen them in nearly every month of the year.

The larva is bred in horse-dung; or, as some naturalists tell us, in decaying vegetables. It is like the maggot of the blow-fly, though much smaller. It pupates within the larval skin after one week of larval existence, and the fly appears at the end of the second week.

The common house-fly is often infested with mites, or with false-scorpions (Chelifers), one species of which (Chernes nodosus) has often been found on the legs of flies.

Sometimes all the flies in a particular shop (a provision-shop) are found to harbour Chelifers.

2. *The Black Fly* (Musca corvina) is very like the common house-fly, and like it is marked with four dark streaks on the thorax ; in the black fly, however, the streaks are continued upon the scutellum. The abdomen of the male is yellowish, that of the female dark grey. This fly is decidedly larger than the common house-fly. It is frequent on walls around stables, and occasionally enters houses, as if by mistake, or else to hibernate there.

3. *The Stable-fly* (Cyrtoneura stabulans) is larger than the common house-fly, and about as big as the black fly. It is of a grey colour, with a reddish tinge on the scutellum and legs. The four dark streaks on the thorax and the dark streak on the abdomen, which are conspicuous in the common house-fly, seem pale and almost washed out in the stable-fly. This species is common in outhouses and stables in the north of England, as well as out of doors, but is not often seen in houses ; it is comparatively rare in the southern counties. The larva has often been found feeding on radishes or other vegetables in a kitchen-garden ; it is said also to prey upon other larvæ.

4. *The Little House-fly* (Homalomyia canicularis) is a regular inmate of our houses. It is rather smaller and rather paler in colour than the common house-fly ; the abdomen is of conical shape behind ; the bristle of the antenna is not feathered, and the wing-pattern is slightly different. The males, which are far commoner than the females, have yellowish translucent patches on either side of the base of the abdomen, which may be very conspicuous, when the fly is seen against the light shining through the window-pane. The mode of flight also is peculiar. Sometimes we remark only a slow movement to and fro, just beneath the ceiling, but at other times, in hot summer weather, the flies execute a peculiar evolution, which enables us to identify them. One darts at another, and after a sort of hasty kiss the two fly off in different direc-

tions. Any one who lies down on a sultry July or August afternoon, and casts his eyes to the ceiling, is very likely to see this manœuvre repeated time after time. The flies which I have captured dancing in this way have all been males. When the little house-fly comes to rest on a vertical surface, such as a hanging cord, its head is nearly always turned downwards.

5. *The Staircase-fly* (Homalomyia scalaris) is, like the last, a little smaller than the common house-fly. It not only abounds in houses, but also in streets and gardens. This species is most certainly recognised by a large tubercle on the inner side of the tibia of the middle leg. A number of Homalomyia-flies may sometimes be seen out of doors, dancing merrily in the sun, and an experienced eye will sometimes detect two or even three different species in the throng. The larvæ of the Homalomyias are very peculiar, and quite unlike those of any species of Musca. Every segment bears a pair of plumed appendages, many of them relatively large, which give a distinctive appearance, not to be mistaken by any one who has ever examined it.

6. *The Grey House-fly* (Stomoxys calcitrans). This is the fly that bites. It is very nearly of the same size as the common house-fly, but its wings are more widely parted in the resting attitude ; the body is more thickly clothed with grey hairs ; and the eyes are not so red. When the head is closely examined, a slightly curved proboscis is seen to project forwards from it ; this encloses a sharp lancet, which inflicts the wound. The larva is reared in dungheaps, and hence this is a common fly in farm-houses ; it is much less frequent in cities.

7. *The Yellow House-fly* (Pollenia rudis). This is often found on the windows of country-houses. It is larger than the common house-fly, and its thorax is clothed with soft yellow hairs. The fly often hibernates in the house, and is generally seen in spring, long before the common house-fly appears.

It is quite unnecessary to remind any naturalist that no insect which has once expanded its wings grows afterwards, to pass over such occasional anomalies as the queen of the white ants. Therefore when we see little flies running among the house-flies on the pane, the mere fact that they are much smaller tells us that they do not belong to the same species. Among the most active of these little flies are those named Phora, which may often be distinguished by the nimble way in which they run about, as well as by their hardiness, for they may be found at all seasons of the year. Another very common little fly is the fruit-fly, which lays its eggs in over-ripe or decaying fruit. This is a Drosophila, and though few of us remark it, it is so common in houses that we have only to leave a soft, pulpy fruit, like a tomato, exposed to the air for a few days to get a plentiful supply of Drosophila-larvæ.

I do not venture to describe here the structure of any house-fly. The student who has some knowledge of insect-structure and command of technical methods would find occupation for a few weeks or months in examining any one of the following fly-structures:—the antenna, the eye, the proboscis, the haltere, the spiracle, the foot.

XX. SOLAR IMAGES ON THE PAVEMENT.

In my garden there is a large concrete pavement, overshadowed by a cherry-tree. This bright summer morning, as I saunter past the tree, my attention is arrested by the dappled shadow of the foliage, which looks like a dull-purple sheet riddled with holes, some large and some small, but all more or less circular, and with ill-defined edges. Why should they be of that shape rather than of any other? What I have called *holes* in the shadow are places where the sun shines through chance openings in the foliage, and as the openings are of all imaginable shapes, one would expect to find endless variety in the shape of the luminous patches. But it is not so; the circular shape greatly preponderates. The explanation is far from difficult. Has the reader ever made for himself a camera obscura? If not, it is worth while to do it for once. You only want a box of any convenient dimensions, say a foot every way. In the middle of one end pierce a very small hole as accurately circular as possible. It is best to cut a big hole in the wood, cover this with a card, and pierce a small hole in the card with a needle. The opposite end of the box may be taken out and replaced by tracing paper, or it may be papered inside with white paper, so as to form a reflection screen, and a peep-hole cut in one of the adjacent sides. Take the box into a dark room, light a candle, and set it opposite the hole about as far from it on one side as the papered side of the box on the other, that is one foot, if the dimensions given above have been kept. Looking through the tracing paper, or through the peep-hole, you will now see a distinct inverted image of the candle-flame. Why inverted? A simple diagram, which you can make in a few minutes, will tell you. Draw the box in section, and the candle in front of it. Suppose that the tip of the flame comes 2 in. above the level of the hole. Rays of light will pass off in every direction, but only those which enter the hole will take part in the formation of the image. These will all descend, because the hole is lower than the luminous point. Let us next suppose that the bottom of the candle-flame is 2 in. below the level of the hole. The rays reflected from this part of the candle will have to ascend in order to enter the box, and in so doing they will cross the rays emitted by the luminous tip just where both enter the hole. Other light-rays will behave in the same way, descending or ascending according as they issue from points above or below the level of the hole. Your diagram will make it clear that the image formed by the pin-hole must be inverted. Remark that the form of the image is not the same as that of the hole, which is circular, but the same as that of the illuminated object. Suppose next that the hole is appreciably enlarged, what will be the effect upon the image? The rays from any luminous point, such as the candle-tip, will now enter the box not as a mere line, but as a cone, and at the screen the cone will be just twice as broad as at the hole. The images of other points will spread out in like manner, and overlap; the general shape of the whole candle-image will remain the same as before, but it will be blurred. If we continue to enlarge the hole, the image will become very indistinct, and at length so much light will be reflected from every part of the inside of the box that there will be no visible image at all.

This simple experiment of the pin-hole camera explains the circular spots on the pavement. The chinks between the leaves replace the pin-hole; the sun replaces the candle; and the pavement is the screen. We get images, not of the chinks but of the sun, and as the chinks are often too large for good definition, the images are blurred.

Proof that this is the true explanation can be got by observing what takes place during a partial eclipse of the sun. When the bright disc becomes crescentic, the patches on the pavement become crescentic too. I have before me a photograph of a pavement overshadowed by trees, which was taken at Bombay during the partial eclipse of 1898, and all the bright patches are crescentic.

Photographers can get very fair pictures of the view from any window without using a lens. They employ a pin-hole to form the image, and you could hardly distinguish such a picture from an ordinary camera photograph, though you would not consider it highly successful. June 27

XXI. THE SONG OF THE SKYLARK.

When a lark leaves the ground, and rises with jerky flight into the sky, singing lustily all the while, we are astonished to hear him pour out his music while he is labouring so hard. A man would find it enough to run or climb, without attempting to sing as well. How does the soaring lark manage to keep up his song until he is lost in the blue sky? Even that is too little for him; he loves to rise and fall again and again, singing all the time.

Part of the explanation (the easiest part) lies in the structure of a bird's breathing organs. When a man breathes, he expands the chest, and so draws in a little fresh air to mix with the much larger quantity of vitiated air which the lungs already contain. By no effort can we change more than about half of the air in the lung at a single inspiration, and in ordinary breathing we do not replace more than about one-seventh of the air. There is no means of sweeping out the human lung with a through draught. But in the bird all the air in the lung can be changed at a single inspiration. The lungs are prolonged into capacious air-sacs, of which there is no trace in man, and these contain far more air than the lungs themselves. Thus, when the chest of the bird expands, a large volume of air is drawn through the comparatively small lung, and the air-sacs are filled with almost pure air, which ventilates the lungs, both as it enters and as it leaves the body.

It is a common thing in zoological laboratories to fill the air-sacs of a bird with some stiffening liquid. Paraffin-wax will do, or cocoa-butter, or plaster of Paris, or a fusible metal with very low melting-point. The injection runs far beyond the limits of the thorax, to the farther end of the abdomen, and into the neck; it even penetrates most of the bones. Of course the injection will not run unless a vent is made for the air to escape by. If the humerus, or principal wing-bone, is broken across, the air will escape that way. Such an injection gives convincing information as to the great volume of the air-sacs, which fill a large fraction of the body-space. These great air-receptacles seem to act like the wind-bag of some old-fashioned musical instruments, and can, without being refilled, keep a small pipe sounding for a long time. They may also enable the bird to aerate its blood comfortably, without taking frequent breaths. But at this point we become aware of a dreadful and irremediable gap in our knowledge of the flying bird. We do not know how frequently it inspires, and there is no ready way of finding out. A bird at rest inspires very frequently, more frequently than other Vertebrates. But the flying bird ?—the skylark ? If he could only tell us how he manages !

After the visible mechanism of the skylark's song has been allowed for, questions suggest themselves as to the supply of heart-power and nerve-power, which is implied in full song during hard exercise. Why cannot a man sing when running fast ? We answer, that running makes us "lose our wind." Active exertion quickens the inspirations, and before long even the quickened rate does not suffice. If the violent exercise is unduly prolonged, we may find ourselves hardly able to breathe at all. But this difficulty of breathing is only an external symptom ; it indicates a disturbance of the bodily functions, which would not be completely provided against by greatly increased lung-capacity. Sir Michael Foster has explained to us, in his Rede Lecture on Weariness, what this disturbance is. Muscular effort exhausts some part of the living matter of the muscles ; it sets up a greater demand on the blood for oxygen ; the blood draws more oxygen from the lungs, and pours more carbonic acid into them ; strain is put upon the nervous mechanism which regulates the blood-flow. But, whenever muscles contract, other things besides carbonic acid are poured into the blood—things which act like poisons upon muscle and nerve. The brain becomes stupefied, the heart distressed, and what we attribute to simple loss of wind is largely, perhaps chiefly, due to a temporary blood-poisoning. There are organs in the body, such as the skin, the kidney, and the liver, whose function it is to remove these poisons, and render them harmless. When the eliminating organs get vigorously to work, the distress abates, and the runner finds his "second wind." Sooner or later, if violent exertion is kept up, the poisons get the upper hand again; the muscles, brain and heart begin to fail, and now the failure is more lasting; the body has not only become fatigued, but poisoned by poisons of its own making. Training strengthens and enlarges the muscles; it also improves the adjustment, and, so to speak, educates the vascular, nervous and eliminating organs. There have been morris-dancers, who by long discipline have become capable of dancing, singing, and playing the fiddle at the same time, and this for long together. In the skylark the adjustment is so good that even great and prolonged exertion does not disturb the respiration.

The continuous prolongation of the song of the skylark would be hard to understand except on the supposition that it is maintained by the incoming as well as by the outgoing breath.

Poets call the skylark *him*, and the nightingale *her*, but all singing birds are males, with the not very important exception that the females of a very few species (canary, lark, bullfinch, &c.), especially when solitary, are able to produce a tolerable melody. Song is primarily the allurement of the male; with this he secures the affections o the female, and with this he encourages her to persevere in her toilsome duties of nest-building and hatching. But no one can observe the lark long without being persuaded that he often sings merely because it pleases him. His song may be heard at any time of the year except during the three or four months of deepest winter, and of course family affairs do not occupy his attention anything like so long as this, though two broods of young larks have to be reared in one season.

Why has the lark such long claws to his toes? Is it a provision for running more easily on grass—the tread being lengthened to suit the yielding grass for the same reason that snow-shoes are lengthened far beyond shoes intended for firm ground ? Animals still smaller than the lark, which have to run about on grass, sometimes have legs of amazing length in proportion to the size of the body. The weight of a harvestman or a daddy-long-legs is insufficient to press down a single blade, and if its legs were not very long and jointed in many places, it could only travel over a meadow by continually ascending and descending, or else grasping every bit of grass that came in its path.

XXII. THE CHEESE-HOPPER.

Last October, being interested at the time in mites, I sent to a cheesemonger for a pound of mitey cheese. In it were observed, besides the mites, a few small white worms, which were recognised as the grubs of the cheese-fly. They grew steadily all the winter through, and proved very useful in the laboratory, whenever we had occasion to study the structure of the headless, footless larvæ which are called maggots. The grubs are sluggish, and move slowly about the cheese by wriggling, and occasionally by grasping inequalities of the surface with their mouths. When they desire to change their quarters, they are able to leap several inches at a time, after a fashion which was described by Swammerdam more than two centuries ago. Bending its body into a semicircle, the larva grasps the last segment with a pair of strong hooks, which can be protruded from the mouth. All the muscles are strained in the effort to straighten the body, but the hooks keep their hold until the muscles are contracted to their uttermost. The circle narrows to an oval, and the oval closes up till its sides meet. Then the hooks relax, the larva suddenly reverses its curvature, and presses the ground with such force as to jerk the body into the air several inches. If possible, the body is arched in a vertical plane, the head and tail being turned downwards, but on a smooth, flat surface the circle is horizontal. The mechanics of the cheese-hopper's leap still await complete elucidation.

A very similar, if not identical fly devours the fat of salt hams, and is sometimes very destructive.

In April the grubs sought to leave the moist cheese, and to find dry hiding-places. It was surprising to see how they were able to flatten their bodies in their efforts to squeeze through narrow chinks. When they had gained suitable retreats, they ceased to move, and the skin, lately so flexible, turned hard, changed from white to red, and glistened like burnished copper. The shape of the body underwent a change, becoming more regularly cylindrical, though the narrowed head-end, and the thicker, tuberculate hinder-end could still be distinguished. The cheese-hopper was thus transformed into a hard, shining, motionless, seed-like pupa. Within the larval skin, which was not cast, but retained as an outer wall of defence, a new skin, the pupal skin, formed, and within this were developed the new organs of the fly, infinitely more complex than those which sufficed for the unadventurous larva.

In May the flies began to emerge; at the head-end the segments split open horizontally, and a singular object protruded, which was recognised as the head of the fly. From the forehead projected a great bladder, which fluctuated as the pressure within rose and sank. It is by means of this bladder that the fly forces open its prison-walls (see p. 19). Next the legs and wings were extricated, which adhered, not to the hard outer case, but to the flexible pupal skin within. When it first becomes free, the fly is soft, pale-coloured, and unable to use its wings, which look like crumpled white appendages of the thorax. They are slowly extended until they project considerably beyond the end of the abdomen, assuming gradually the gauzy texture and the iridescent colours of nearly all transparent insect-wings. Meanwhile the brownish-grey of the body changes to a shining, metallic black. The fully formed fly is only 5 mm. ($\frac{1}{5}$ in.) long, much smaller than a house-fly. It was not long before the fertile females were seen exploring the surface of the cheese for crevices in which to lay their eggs, and a new generation of the cheese-hoppers will soon appear.

Here is an excellent subject for home-study. The cheese-hopper is an animal of complex structure and singular mode of life, which can be obtained with very little trouble and in large quantities ; I hope that some of my readers may think of investigating it for themselves. A convenient receptacle is a box a foot deep, in which a bowl can be set to hold the cheese. The bowl should be covered with a glass plate, and the cheese must not be allowed to get dry ; it has little tendency to dry up if the larvæ are numerous. A larder, where the smell of cheese will give no offence, will do to hold the box. I kept mine in a private laboratory, and suffered no annoyance.

XXIII. BANANAS.

Look at a banana, and see what you can make out by your own observation. I think you ought to discover that it is a fruit, that it is a fruit of that particular kind which we call a berry, and that it proceeds from a flower with an inferior ovary.

It is certainly a fruit. You have seen the great green spikes hanging in the fruiterers' shops, and bearing hundreds of unripe bananas apiece. Soft, pulpy objects arranged on a stem in that candelabrum-fashion cannot be supposed to be leaves, nor branches, nor anything but fruits. If the banana is a fruit, where are the seeds ? You may eat the fruit, or slice it, or examine it in any other way that you can think of, but you will discover no seeds at all. The banana must be one of those plants whose fruits are devoid of seeds. Have you ever eaten an orange which had no pips ? Seedless pears, grapes, figs, pine-apples, dates, and pomegranates are well known.

Observe that all these are cultivated plants, and that seed-bearing varieties of the same species occur in each case. The seedless varieties appear, as it were accidentally, in cultivation, and are carefully saved and propagated; most people prefer fruits which have no seeds. How can a seedless plant be propagated?

The banana is properly a berry, because it has no regular bursting-lines, and because it is filled with a pulp, in which the seeds, if there are seeds at all, are imbedded. The seeds of berries, such as currants or grapes, can only escape by the digestion or rotting-away of the outer wall of the fruit.

The shape of the banana is peculiar; it is curved and four-sided (sometimes five-sided). Do the four sides (let us call them four) indicate that number of compartments in the fruit? You cannot make out any compartments by cutting the fruit across, but if you strip off the rind, you will find six strings, which are really bundles of vessels, running lengthwise along the outside of the pulp. The six strings answer to the midribs and united edges of *three* carpels, and show us that the four sides cannot really indicate as many compartments. How then did they come there? I will not tell you, but if you study the shape of the fruit carefully—if you remark that it has a convex and a concave side, and that the concave side is narrower than the convex side—you must be rather dull if you cannot see why the fruit is four-sided.

The great flower-spike which you know is at first inclosed in a sheath, which afterwards falls off and allows the fruits to expand.

How do we know that the banana-fruit proceeds from a flower with an inferior ovary? Here again a very little sagacity will suffice. An apple or orange is an inferior fruit, and has a scar at the top as well as at the bottom. A cherry or plum is a superior fruit, and has no scar at the top. Is the banana like the apple or the cherry in this respect?

A ripe banana contains much sugar; you know its sweet taste. An unripe banana contains little sugar but much starch. The unripe fruits are sun-dried and ground to meal, which in some tropical countries forms the chief food of the people. The meal is scalded and eaten as porridge, or made into cakes and baked. Bananas are probably native to the Malay Archipelago, but have long been grown in India, Africa, America, and the West Indies. They are very productive, and are said to yield forty times as much food for a given acreage as a crop of potatoes; no other tropical fruit is so important as an article of food. Vast quantities of the fruit are exported from the West Indies to the United States; bananas sold in our shops come chiefly from the Canary Islands and the British West Indies (1902). The leaf-stalk yields a valuable fibre, and the fibre of one variety of banana forms the celebrated Manila hemp.

I have before me a photograph of a clump of bananas growing in Ceylon.[1] A single leaf-blade is as tall as a man, and since the leaf-stalk is considerably longer than the blade, a banana rises high above the ground, and looks like a fair-sized tree. Its trunk is not however of solid wood, but merely consists of a number of leaf-stalks wrapped one round another. The great leaf-blade has a strong midrib, from which side-veins pass outwards to the margin; it looks, especially when fretted by the wind, like an enormous goose-quill. Banana-plants grow very fast, as well they may, considering that they are nearly all leaves; the ascending shoot of a plant thirty feet high only rises a few inches above the ground. No wonder that they have been compared to gigantic leeks. A banana will grow and ripen its fruit in twelve months.

The family (Scitamineæ) to which the banana belongs yields also arrowroot and ginger; it is therefore a family of great importance to mankind.

[1] Plate in Schimper's *Geography of Plants*.

XXIV. SILVER FISHES.

Some people have in their kitchens and pantries great numbers of silver fishes. They shelter by day in chinks and recesses, like cockroaches or crickets, but when all is dark and quiet they come out to feed. In factories and shops, especially where grain, crumbs, sugar or other vegetable food is to be procured, silver fishes sometimes abound, and when the shutters are opened of a morning hordes of these insects, large and small, may be seen fleeing from the light, or as I rather think, from the sound of footsteps; in a perfectly still place they may sometimes be seen to feed tranquilly in a pretty good light. The full grown silver fish is only one-third of an inch long, so that they must be reckoned among the smaller insects. The body resembles in shape half of a carrot which has been sliced from end to end along its middle line. The thick end is towards the head. The thorax, which bears six rather long legs, is of nearly uniform width, and the abdomen steadily tapers backwards. From the small head stand off two long many-jointed antennæ, and the hinder end bears three tails, each of many joints. Two black eye-clusters appear on the sides of the head when it is examined with a lens. The legs are flattened at the base like those of a cockroach, and are thus fitted for creeping into narrow spaces. On the under side of the abdomen are two pairs of minute jointed prominences, which spring from the last segment but one and the last but two. The shape of this little insect, its gleaming white colour, and the shining scales which it leaves on the fingers when captured, no doubt suggested the name of silver fish. Similar names are used both in France and Germany (*poisson d'argent ; Silberfischchen*).

The eggs are laid in crannies, and produce small larvæ very like the parent except in size. The tails of the larva are comparatively short, and the two pairs of prominences beneath the abdomen are as yet undeveloped. Until its first moult the larva has on the top of its head a tooth, which was used to break through the egg-shell. Earwigs, fleas and other insects, besides some centipedes, have a tooth or spine on the top of the head for breaking the egg-shell. A similar contrivance is found on the tip of the snout in reptiles, birds, and egg-laying mammals.

Silver fishes never acquire wings, nor pass through a resting stage, though they change the skin several times. From the first they are very like their parents, and after the first moult, which takes place seven days after hatching, they differ in no important respect.

Another small insect very like a silver fish may often be found in fields and gardens by a close observer. This is called Campodea. It is still smaller than the silver fish, never exceeding one quarter of an inch in length, and has a white skin. It is so delicate that it cannot be picked up without injury, and it dies as soon as it is placed in a tube or bottle. Campodea has only two tails, the middle one being absent. Like a silver fish it goes through no transformation. A third creature of the same order (Thysanura) lurks about bakers' ovens, while a fourth is sometimes very plentiful on rocks near the sea.

Many carnivorous beetle-larvæ are strikingly similar to a silver fish or a Campodea, having a slender body, long legs, long antennæ, and two or three tails. Such larvæ occur more or less frequently in all the lower orders of insects, and may be said to be the ordinary larvæ of these groups.

The silver fishes are believed by naturalists to resemble the most ancient of all insects, for there is reason to believe that the first insects which ever appeared on the earth had a simple life-history, and never possessed wings at all, resembling in these respects such Arthropods as centipedes and millipedes. When wings were first acquired by insects, they were probably developed rather late in life, and not all at once, but by degrees, growing larger and larger at each moult, as they still do in some insects. The acquisition of wings rendered activity in the early or larval stage less necessary, for the winged parent could now lay her eggs more easily in places where food of the right sort was plentiful. Then the larva in many cases became soft-bodied and short-legged, or even lost its legs altogether. The fly and the larva came in the more specialised insects to differ so greatly from one another that the body had to be completely recast when the larva changed to a fly. A resting-stage thus became necessary, especially where the fly had come to adopt a different mode of feeding (see p. 248). The resting or pupal stage is no doubt the last-acquired of the stages of an ordinary insect's life-history.

The events which I have related, and the steps by which insect-transformation was at length attained, may seem to you difficult of proof. Unfortunately I cannot lay before you the whole of the evidence, but I can mention one fact which will help to persuade you of the substantial truth of the explanation just given. Among existing insects all the steps by which complete transformation is supposed to have been attained can still be found.

It will make this more evident to set down in a table the life-histories of five different sorts of insects.

Silver Fishes, &c.	Cricket, May-Fly, &c.	Many Carnivorous Beetles.	Oil-Beetle.	Higher Insects.
Campodea-larva, the only stage in the life-history.	Campodea-larva.	Campodea-larva.	Campodea-larva.	
	Wings acquired gradually.	Resting-stage (pupa). Wings revealed suddenly.	Short-legged larva. Resting-stage (pupa). Wings revealed suddenly.	Short-legged larva. Resting-stage (pupa). Wings revealed suddenly.

It gives one matter for reflection to know, as we do, that the cockroach of our kitchens has existed with little change since the time when our coal-fields were laid down, and that the silver fishes are still more ancient and more primitive.

XXV. WHITE CLOVER.

On my close-shaven lawn the white clover spreads fast, and drives out the grasses. To grow freely in close turf, a plant must enjoy some special advantages, for it has to hold its own against a particularly severe competition. What is the secret of the success with which clover encounters its rivals? In summer-drought we see that the clover keeps green, while the close-cut grass turns brown. Nearly all round the year the clover continually pushes out new branches, which root themselves in the soil. Its runners insinuate themselves among the grass, grow strong, expand their leaves, and often end by occupying the site completely, leaving no room for any other plants. But though on the lawn clover generally gains on the grasses, in the paddock the grasses gain on the clover. It is hard to find a single plant of clover where the soil is rich and damp, for there it is completely overshadowed. By the side of a footpath the clover is always pushing out into the sandy walk, while the tall grasses establish themselves securely under the hedge. The advantage of the white clover is merely local; it prevails over the grasses where the ground is hard and dry, and also where upward growth is checked by the lawn-mower, browsing cattle, or the tread of foot. But in the paddock, still more in the meadow or the hedge, the grass-haulms, drawing out their jointed stems like perspective-glasses, overtop the clover, which is nowhere in the competition.

Each plant has advantages of its own. Clover has a trefoil leaf with a long leaf-stalk; a grass has long strap-like leaves with no leaf-stalks at all. Clover spreads out its leaf like an umbrella, the grass like a pennon. The umbrella-like leaves of clover cover the ground more completely, and catch a great part of the possible sunlight. Some adjustment of the leaves is necessary in most plants to keep them out of one another's way; in clover this is conveniently effected by the long leaf-stalk, and by an organ of movement at its base. A very slight change of figure at the base, acting upon the long lever of the leaf-stalk, causes a visible displacement of the leaf-blade. With most grasses, on the other hand, the great object is to gain a moderate height rapidly. They have telescopic haulms, and long narrow leaves springing at different heights, out of one another's way.

The base of a clover-leaf bears a pair of stipules, which

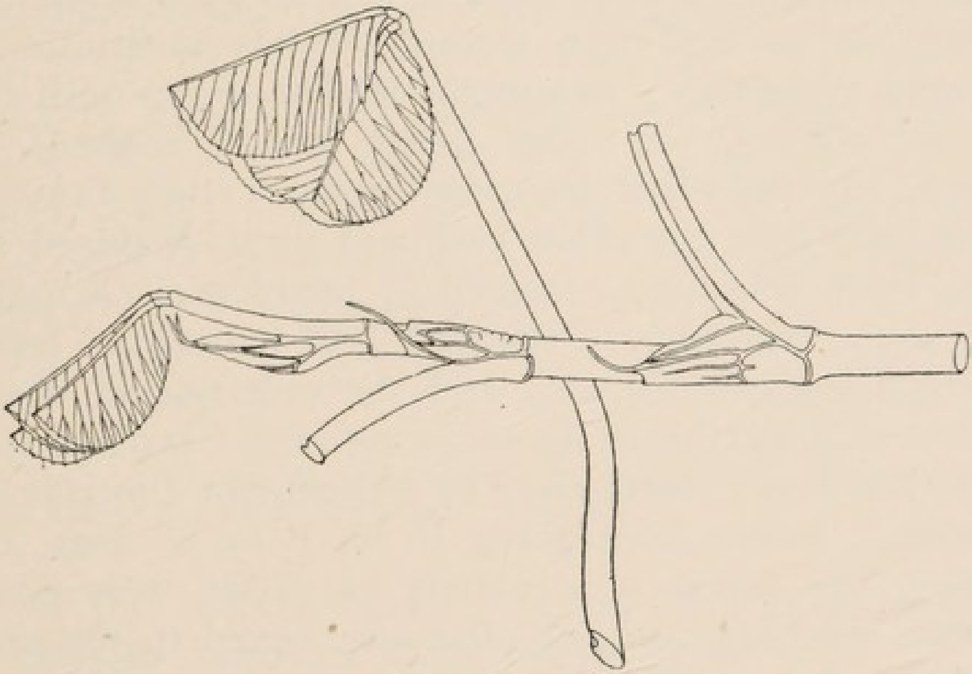

FIG. 31.—Prostrate stem of white clover, with leaf-bases, stipules and leaf-buds. A leaf in the sleep-position is introduced behind. Natural size.

form a protective sheath (Fig. 31), often enclosing the rudiments of a young branch or root, besides the organ of movement of the leaf-stalk. The delicate tissues are thus screened from intense light and heat, and in some measure protected from trampling by cattle. Towards the tip of a growing branch the leaves become crowded, and one sheath often encloses others, thus giving additional protection to the tender growing-point.

Each of the leaflets of the trefoil leaf bears a whitish patch near the middle of its upper surface. I wish I could tell you what is the use of this patch. All that I know is that the epidermis here becomes separated a little from the tissues beneath, and that the white colour is due to reflection of light from an extremely thin layer of air. Buttercup leaves and many others show white patches of the same kind. When the leaf is dipped into hot water, the air is expelled, and the white patch disappears.

Of what advantage is the trefoil leaf to the clover? Watch the leaves at sundown, and you will see that they fold up when there is no more sunlight to be absorbed, and when radiation of heat to the cold sky is to be feared. The division of the leaf into distinct leaflets facilitates the operation of folding; two of the leaflets droop until they become vertical, one edge being turned towards the ground, and the other towards the sky; then the third leaflet folds over the other two, and forms a ridged roof above them (Fig. 31). Instead of broad surfaces, only a single edge, answering to the midrib of the central leaflet, is turned towards the sky, and the radiation of heat is checked in proportion as the radiating surface is diminished.

The Darwins[1] ascertained by experiment the effect of preventing leaves from going to sleep on a clear, cold night. The leaves of a variety of plants were pinned open on sheets of cork, or otherwise forced to remain in the horizontal position. Many were hurt, and some killed, while others, whose movements were not impeded, either escaped, or at least suffered much less. Clover and wood sorrel leaves, when pinned open, condensed large drops of dew, a proof that they had become chilled, while those which were unconstrained remained perfectly dry.

How are the drooping and erection of the leaflets of clover effected? If we look carefully at the meeting-place of the three leaflets, we shall see a kind of cushion, and just beyond it three short cylindrical stalks (Fig. 32). Part of each cylindrical stalk is different in texture from the rest; it is glossy, semi-transparent, and transversely wrinkled. Here is the organ of movement for the leaflet.

[1] *Movements of Plants*, chap. vi.

What do we mean by an "organ of movement"? It can generally be recognised at a glance by its form and its position. At the base of a leaf-stalk, or some other moveable part, we often find an enlargement or cushion. A thin section at this point shows a crowd of minute, colourless cells. The bundle of vessels, where it traverses the cushion, becomes particularly flexible, owing to lack of woody thickening in the walls of the vessels. The covering epidermis is often wrinkled, sometimes only on one side. The small, crowded cells of the cushion are capable of absorbing water from the surrounding tissues, on either

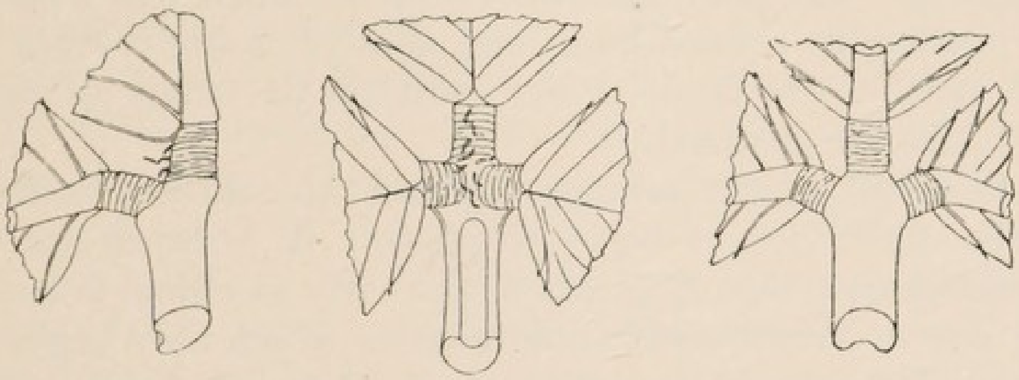

FIG. 32.—Three views of the organs of movement, at the bases of the leaflets of a white clover-leaf. Magnified.

side of the central strand. Then they swell, and the whole stalks leans over to the opposite side.

Proof that the organ of movement of the clover leaflets is situated just where they are attached to the leaf-stalk is not hard to find. We may destroy or injure other parts, such as the blade of the leaflet, or the midrib, without necessarily hindering the power of movement in what is left. If the leaflets are amputated just above the base, the stumps can still open and close. But if we destroy or injure the part which has been described as the organ of movement, the leaflets are unable to move any more. Cut away with a pair of fine scissors the green blades from all the leaflets of an expanded clover-leaf, and go with a lantern after dark to see how they are behaving. You will find that, notwithstanding the mutilation, the bare midribs have executed as usual the movement by which they are accustomed to protect the leaf from the cold of night.

A clover leaf generally erects itself before the leaflets close; the leaf and leaf-stalk are thus gathered beneath the radiating surface, which, as we have seen, is reduced to a minimum.

Clover as a rule opens by day and closes by night. Artificial darkness may cause it to fold up its leaves, but not always. Now and then we are surprised to find that clover which we had locked up in a cupboard overnight has its leaves wide open when we come to look at it next morning. The plant gets into what we must call a habit of opening at a fixed hour, and goes on doing it even in the dark. The habit is soon lost, if the hours of light and dark are changed.[1]

On a still, bright summer day note the earliest hour at which clover leaves begin to close. If it were not so troublesome to watch plants in the early morning, I would ask you to determine also the hour at which they begin to open. You would find that the leaflets are hardly ever stationary. When they are fully expanded, they will soon begin to close, and when they are completely closed, they will soon begin to open. This is not true of all plants whose leaves take a sleep-position.

In the next lesson clover is compared with wood sorrel.

XXVI. WOOD SORREL.

The leaves of wood sorrel have almost the same shape as those of clover, and they can open and close, but in a way of their own. In closing, the leaf-stalk generally erects itself; then each of the three leaflets droops until it hangs nearly vertical (Fig. 33); lastly, it bends inwards along its midrib until its under surface fits close against those of the other two. Why this difference? Why

[1] F. Darwin and D. F. M. Pertz, *Annals of Botany*, vol. vi. p. 245, and vol. xvii. p. 93.

should not wood sorrel adopt the method of closing of clover, or clover that of wood sorrel? I can only answer these questions doubtfully and imperfectly. Clover, when it goes to sleep, seems to be a little better screened from the cold than the wood sorrel. Clover exposes little more than one leaflet to the cold air; wood sorrel all three leaflets. Clover turns only one midrib towards the sky; wood sorrel the edges of all three leaflets, though in a sloping position. Clover inhabits perfectly open situations, while wood sorrel is overshadowed by trees. It would appear, therefore, that the leaf which, under ordinary summer conditions, is most severely tried is most completely protected.

Clover, in taking the sleep-position, turns its proper under-surface outwards; wood sorrel turns the upper surface outwards. This difference is perhaps connected with a difference in the position of the stomates. In clover the stomates are distributed over both surfaces of the leaf, being more numerous, though smaller, on the upper surface, while in wood sorrel they are restricted to the under-side, which is concealed when the leaflets droop. Hence wood sorrel, when it folds its leaves, screens all its stomates, clover only about half of them. All this accords with what we know in other ways, viz. that wood sorrel is particularly sensitive to drought, while clover endures drought very well.

There is a general rule as to the sleep-position of leaves, and clover observes this rule, while wood sorrel breaks it. Any common leaf, which has a flattened shape, and takes a more or less horizontal position by day, has its two faces adapted to different functions. The upper face is crowded with chlorophyll-corpuscles, and takes a darker shade of green in consequence; it is often protected from the weather by a glossy cuticle. This surface is specially adapted for the assimilation of carbonic acid; we may call it the *assimilating* surface. The under face of the leaf is often hairy, or in other ways rendered unwettable;

the chlorophyll-corpuscles are widely spaced, and the colour is rendered pale by the numerous air-spaces. Here are found most or all of the stomates and air-spaces, and it is by this under surface chiefly that water is exhaled and carbonic acid absorbed; let us call it the *pore-bearing* surface. When a two-sided leaf takes a special sleep-position, the rule is that the assimilating surface is screened as completely as possible. Clover, like most other plants, conceals its assimilating, and exposes its pore-bearing surface; wood sorrel conceals its pore-bearing, and exposes its assimilating surface.

The upper surface of a clover leaflet is unwettable, being protected by a waxy bloom; the lower surface is easily wetted; in wood sorrel both surfaces, but especially the under surface, wet with difficulty. In each case the surfaces which are pressed together are unwettable; it might be hard to separate surfaces which had been pressed together when wet, and they would not soon dry.

Make a model of a clover-leaf, cutting the leaflets out of card, and joining them by tapes. Paint the upper surface bright green, and the lower surface pale green. This model will enable you to represent to yourself the different sleep-positions of clover and wood sorrel.

Clover and wood sorrel are strongly contrasted in almost every way. Clover seeks the sun; it does not shrink from competition with close-growing grasses, and it can even endure trampling. So long as daylight lasts, it keeps its leaflets open, and then, when there is nothing more to be got, closes them tightly. Its most conspicuous defence against the weather is one which hinders excessive heat-radiation under a clear sky. Wood sorrel, on the contrary, loves shade and a damp, still air; a bank, sheltered from wind and sun, or the edge of a wood, are among its favourite sites. The light that it prefers is chequered light—the gleams that enter through waving boughs, or shine in horizontally when the sun is low. Strong sun-light, wind, and drought are all harmful to it. The very look of wood sorrel tells us how unfit it is to face rude extremes. It is pale and fragile, with tender green leaves, slight flower-stalks, and petals delicately veined with purple. In one particular only does wood sorrel show an unexpected hardiness. Provided that it can get adequate shelter, it will endure arctic cold. It does not die down in winter, and endures frost without even closing its leaflets. In April not a few wood sorrel leaves, which have lasted the winter through, are still green, and still open and close, while all the old clover leaves are dead.

Wood sorrel leaves close, not only by night, but whenever the sun shines full upon them, whenever they are beaten by rain, or much blown upon, or rudely touched by moving objects. This sensitiveness would almost hinder them from assimilating enough to keep the plant alive, if the assimilating surface were to be concealed whenever they drooped. As it is, the leaves, even when closed, can profit by a weak horizontal light, the kind of light which best suits a shade-loving plant.

The long leaf-stalk renders the mechanism of erection and depression more effective, and makes it easier to bring the leaflets into the most favourable light-position. Wood sorrel is most at home where the shade of the trees is broken by frequent patches of sunlight; in such situations the power of moving the leaf an inch this way or that may be of great value. The plane of the expanded leaf can be inclined, so as to catch the light better. Wood-ruff too, a plant subject to similar conditions, is enabled in a different, but not less effectual way, to set its leaf-planes as nearly as possible at right angles to the rays of light. An organ of movement is a necessary part of the equipment of the wood sorrel leaf. Look at the enlarged base of the leaf-stalk, and you will find a thin ring of tissue distinct to the eye, especially when, as is often the case, the stalk is reddish and the ring pale-green (Fig. 34 *b*). The chief use of the ring in effecting leaf-movements is best seen when wood sorrel growing in a garden is examined frequently. It is easy to alter the incidence of the light by cards, and to show that the leaf-stalk bends chiefly at the ring. Sometimes the ring is of different depth on different sides, showing that it has become permanently adapted to a particular attitude. Each leaflet has its own special organ of movement, which answers to the wrinkled stalk at the base of each clover leaflet (Fig. 34 *a*, *a'*). Just below the ring at the base of the leaf-stalk, is the place where the

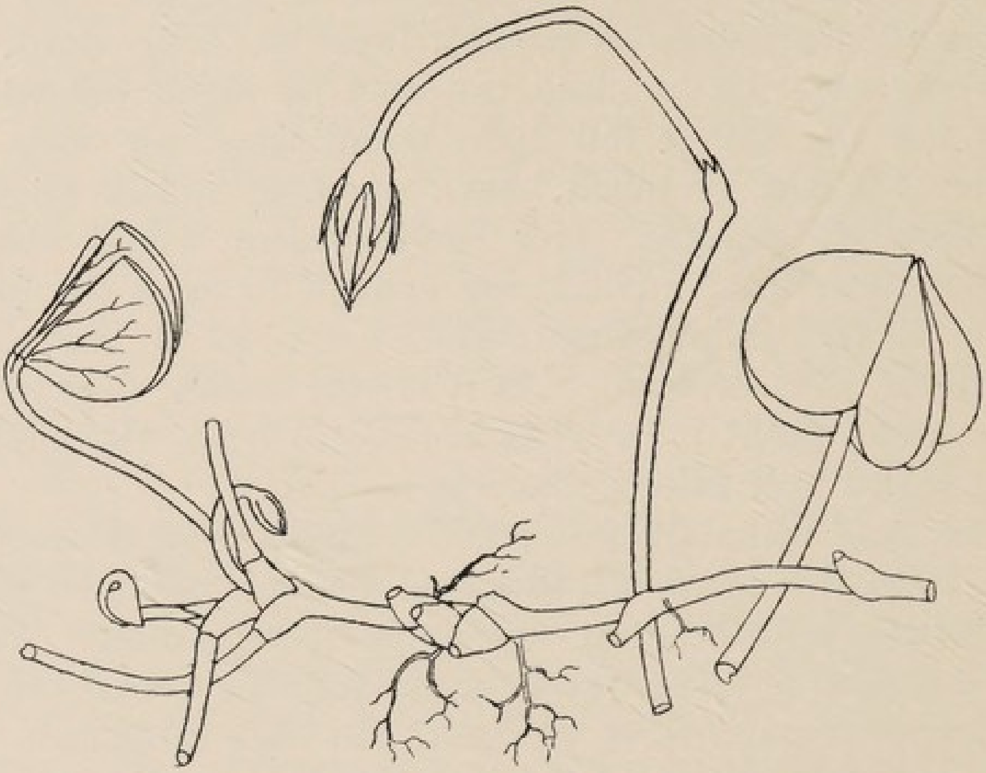

FIG. 33.—Stem of wood sorrel, with leaf-buds, flower-bud, bases of old leaves and roots; also a detached leaf in the sleep-position, and a fruit with its stalk. Slightly enlarged.

leaf breaks off at the approach of winter; the leaf-base will then be found to be packed with food-materials, which were formed in the leaflets, passed down the leaf-stalk, and stored up as a supply for the winter.

The leaf-stalks and flower-stalks of wood sorrel are moderately hairy. The edges of each leaflet are set with a regular row of hairs, and so are the short stalks of the leaflets. It looks as if these hairs would hinder the passage of air through the narrow space between the closed leaflets, and still further diminish the loss of water by evaporation.

If you examine a leaf-bud of wood sorrel, you will find that each leaflet is doubled in two, and all three are laid side by side (Fig. 33). This is exactly like the folding in a clover-bud. See how densely the buds are clothed with hairs ; I suppose for protection in the bleak spring weather.

The slender prostrate stem spreads over the leaf-mould, sending down its roots into the earth here and there. Wherever a number of leaves spring from the stem, it becomes enlarged, and every such enlargement is capable, if detached, of subsisting as an independent plant.

The leaves of wood sorrel are distinctly acid, and the acid is oxalic acid combined with potash. There is much in the leaflets, still more in the leaf-stalks, very little in the enlarged leaf-bases. Is the acid a mere waste-product, or has it a defensive function ? Wood sorrel is not often bitten by insects ; Stahl found that snails do not eat it, and that the leaves of favourite plants, when washed in a one per cent. solution of potash oxalate, are refused even by famishing snails.

Though the shape of the leaves of clover and wood sorrel is so similar, it is probable that they originated in different ways. This seems to be shown by the leaves which are borne by their nearest relations. Clover belongs to the great family of leguminous or pod-bearing plants ; wood sorrel is a peculiar sort of geranium. Now leguminous plants have often pinnate leaves, composed of several pairs of leaflets, with an odd one at the tip. If we suppose the numerous pairs of leaflets which we find in most vetches reduced to a single pair, these, together with the odd leaflet, would make a trefoil, such as that of clover ? How can we tell which is the original odd leaflet in the trefoil leaf of clover ? It is that one whose stalk, when extended, is in line with the main leaf-stalk, and which overarches the other two when the leaf goes to sleep.

Geraniums do not usually bear pinnate leaves, but their rounded leaves are often deeply cut, and in one English geranium (dissectum), each is cleft into three parts, not quite detached from one another, the lobes being subdivided by shallower notches. It is possible that in wood sorrel the same process of division has been carried a little further, and that each of the leaflets thus formed has acquired its own organ of movement.

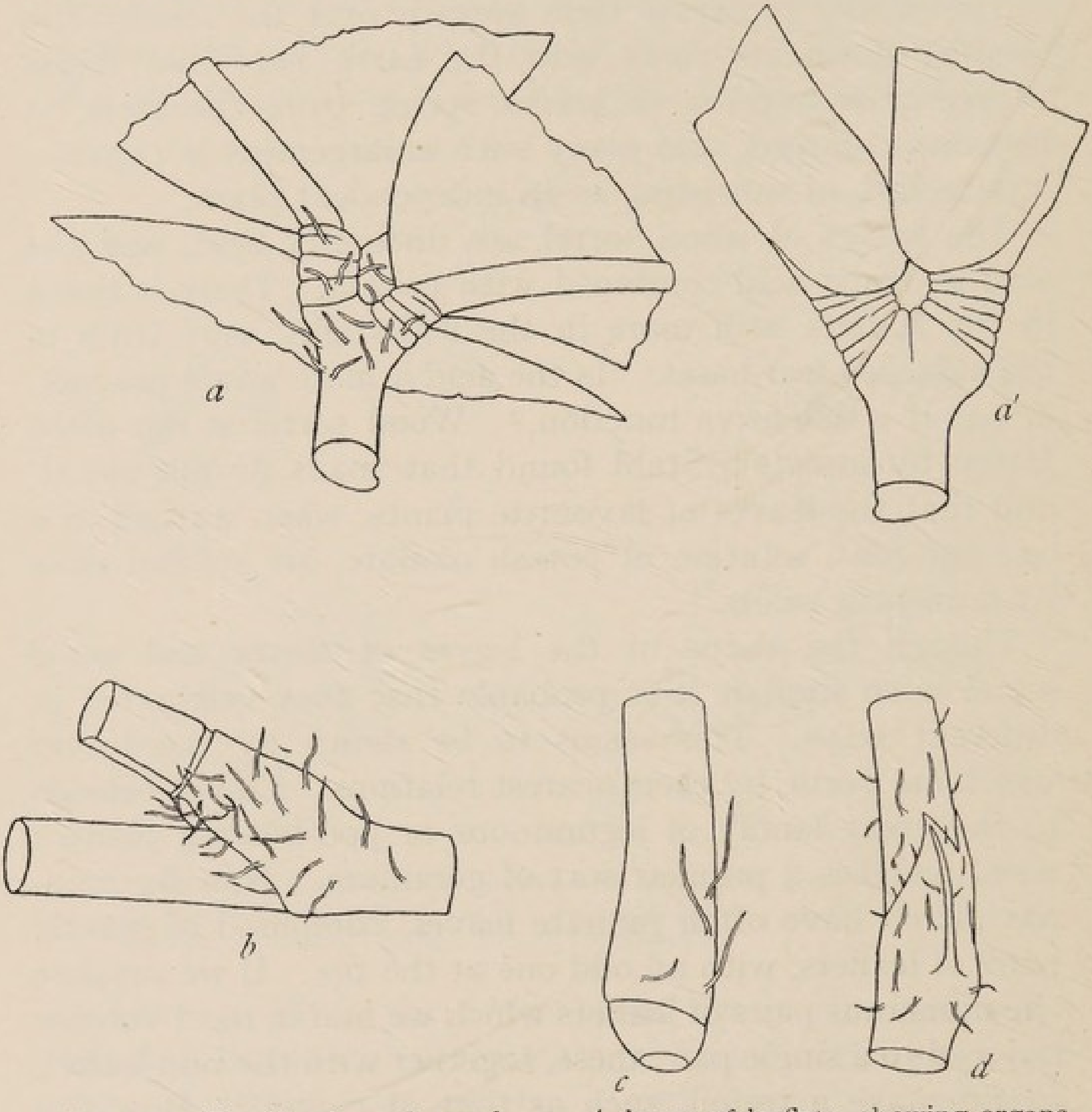

FIG. 34.—Details of wood sorrel. *a*, *a′*, bases of leaflets, showing organs of movement (in *a′* the hairs are left out); *b*, base of leaf-stalk, with organ of movement; *c*, base of flower-stalk, detached, with organ of movement; *d*, the two united bracts of the flower-stalk. Compare Fig. 32. Magnified.

The early botanists, judging by the trefoil leaves, looked upon wood sorrel as a particular kind of clover, and even Ray so treats it. Long study was necessary before the characters which indicate real affinity could be distinguished from those which are adaptive only.

Find a flower-stalk of wood sorrel, and look for the upper organ of movement, whose place is indicated by a small two-pointed bract (Fig. 33 *d*). Where the bract springs, some species of Oxalis send out several flower-stalks, and the minute bract of our common wood sorrel probably marks the place where the flower-stalk once broke up into several. There is also a ring-like organ of movement at the base of the flower-stalk (Fig. 34 *c*). Study of the movements of the flower-stalk will show you that it droops by night or when the flower is shaded, erects itself in the weather and light which encourage the petals to expand, droops after flowering, and erects itself once more for the ejection of the seeds.

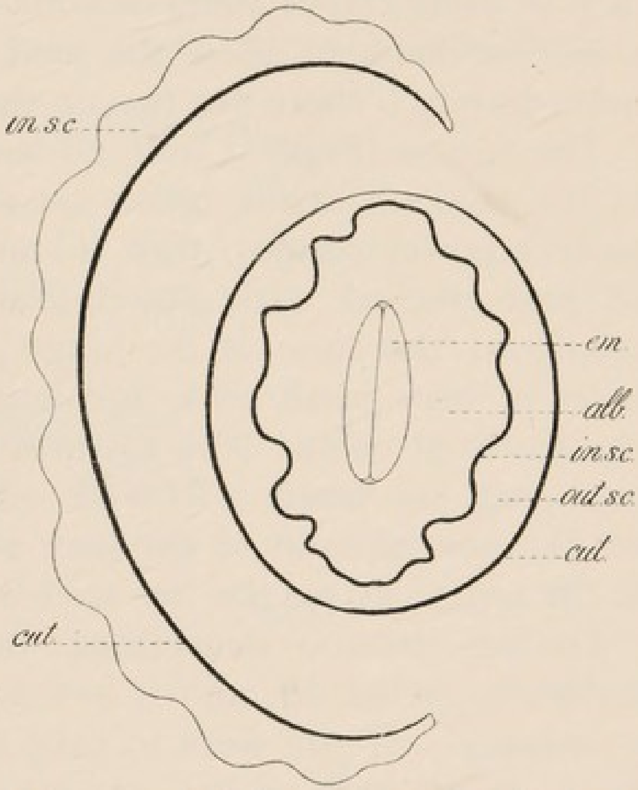

FIG. 35.—Wood sorrel seed, before and after discharge. To the right is seen the seed in section; *cut*, cuticle; *out. s.c.*, outer seed-coat; *in. s.c.*, inner seed-coat; *alb*, albumen or food-reserve of seed; *em*, embryo (cotyledons). To the left is seen the integument of the seed after discharge; the elastic cuticle has now become internal.

It is easy almost any time in summer to see the long-stalked fruits of wood sorrel pushing through the leaves. If you gather a few and lightly press them, they will perhaps go off with a faint pop, and a seed or two will shoot to a distance. After all the seeds are discharged, the fruit looks much the same as before, for the openings close up immediately.

There are many plants which throw out their seeds by the twisting of the seed-vessel, or by the squeezing together of its walls, or by the sudden release of the carpels, but wood sorrel is peculiar in this, that the propulsive mechanism is not contained in the wall of the fruit, but in the seed itself, which may be compared to a self-propelling bullet.

The fruit of the wood sorrel has the general arrangement found in a field-geranium. There are five carpels side by side, surrounding a central axis. The exposed face of each carpel splits into halves, and these open like a pair of doors to allow the seed to escape, closing again immediately; there are two or three seeds in each carpel.

The figures (Figs. 35 and 36) show the internal structure of the seed. Outside comes an elastic coat, in which the motive power resides, then a number of cells, which are at first packed with starch-grains, but become nearly empty at the time of discharge; then an inconspicuous layer of very small cells, and a strong protective layer of chestnut-red colour (the testa or seed-coat). Within the seed-coat are small cells with oily contents, which serve for the nourishment of the very young seedling, and lastly in the centre we see the two seed-leaves of the embryo.

During ejection everything outside the seed-coat is suddenly peeled off, and it is this which hurls the seed to a distance. If you were to take a golf-ball, and sew it up in a stout indiarubber covering, stretching the indiarubber to the utmost as you stitched it to its place, it is easy to understand what would happen if the stitches suddenly gave way. The indiarubber would recoil, first flattening out and then bending in the opposite direction, so that the concave surface would become convex, and the envelope would turn itself inside out. In doing so, it would strike the ball with the surface which lay in contact with it, hard enough perhaps to propel it along a table. In the wood sorrel seed the indiarubber layer is represented by the outer elastic coat, the starchy cells are mere padding, now that they have given up nearly all their contents, and the layer of small cells is that which suddenly gives way and releases the spring. It is generally taught, as for instance, by Kerner, in his Natural History of Plants, that the starchy layer impels the seed by its expansion, but there is reason to believe that this is not so. The elastic layer does really contract, and often breaks up in doing so. The supposed expansion of the starchy layer would imply turgidity or distention by water, but the seed goes off in alcohol, salt solution, and other liquids which strongly absorb water. Instead of the starchy layer swelling, while the elastic layer is passive, it is more likely

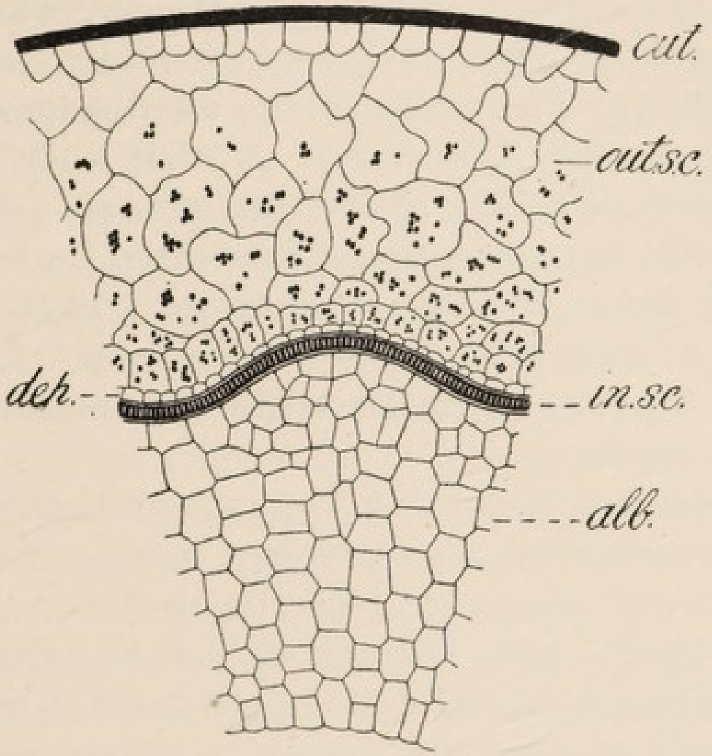

FIG. 36.—Section of outer tissues of wood sorrel seed. *deh*, dehiscing layer, along which the separation takes place; the other letters as in Fig. 35.

that the elastic layer contracts, while the starchy layer is passive.[1]

A yellow-flowered wood sorrel (Oxalis corniculata) is remarkable for its world-wide distribution; it is absent only from the coldest regions. Perhaps it owes its almost universal dissemination in some measure to its singular power of scattering its seeds. The yellow wood sorrel flourishes as a weed in many gardens and greenhouses,

[1] I have to thank Mr. T. H. Taylor for these observations on the elastic layer.

springing up in the most unexpected places. No doubt this species is often unconsciously introduced by man, the seeds having been shot into manure-heaps, or pots of earth, and then removed in the course of trade.

Wood sorrel produces, as is well known, two kinds of flowers, one of which is small, appears late in the season, and never opens, so that it is necessarily self-pollinated. In these small "cleistogamous" flowers the stamens are short, and the anthers lie close to the stigmas. Pollen-tubes are emitted from pollen-grains which have never left the anthers. The stalks of the cleistogamous flowers are short and bent downwards, so that they are often hidden in moss, or sunk a little in the ground. As in some violets, the cleistogamous flowers are often buried beneath fallen leaves and a sprinkling of loose soil; in the far north they must be regularly covered with snow. Long after the seeds of the aerial fruits have shot off, the subterranean fruits go on ripening.

The first printed account of the sudden discharge of the seeds of a wood sorrel is to be found in the description of the yellow wood sorrel by John Jacob Dillen, a learned German botanist, who, writing in Latin, called himself Dillenius. He was brought to Oxford in 1721 by our own botanist, William Sherard, formerly consul at Smyrna, and was by Sherard's will appointed the first professor of botany in Oxford. In 1732 Dillenius published a great work in two folio volumes, illustrated by many fine plates engraved by his own hand, and named the Hortus Elthamensis, because it described the exotic plants cultivated in Dr. James Sherard's gardens at Eltham. In this work Dillenius figures the yellow wood sorrel, for which, in those pre-Linnæan days, he had no more convenient name than "Oxys lutea, Americana, humilior et annua." He notes that the leaves fold up at evening or during rain. The flower-stalks, he goes on, at first droop, but erect themselves when the flowers expand; after flowering is over, they bend down again. The capsule is however erect, and resembles the beaked fruit of a geranium; each of the five carpels bears several seeds in a single row. When the seeds are ripe, the capsule bursts, and forcibly throws out the rounded, reddish-brown seeds, which, when examined by a lens, are seen to be transversely wrinkled. After the seeds have been expelled, the valves by which they escaped close up, and there is no sign that they have ever opened at all. This description, though not very full, is of interest as an early observation of a natural contrivance. In Dillenius' day botanists were almost exclusively engaged upon the definition and grouping of species. To find an equally interesting account of a natural contrivance, we should have to go back to the time of the ancients. The old Greek naturalists, besides a few writers of rather later date, were attentive to these things.

Let us end our lesson with a little talk about the names of the wood sorrel. What has *wood sorrel* to do with *sheep's sorrel*, or a *sorrel* horse? *Sorrel* means *sour;* indeed we may now and then find in old books the name of *wood sour*. Sheep's sorrel and wood sorrel are both of them *sour* or acid, but how a horse of a particular colour should come to be called *sorrel* I could not understand till I turned to a dictionary. There I found that *sorrel* may stand, not only for *sour*, but also for *sere*. A sorrel horse has the colour of a withered leaf. Our undistinguishing forefathers mixed up two words which had nothing to do with one another, except that they were somewhat alike in sound. *Alleluia* is given by Ray as an old English name of wood sorrel; no doubt it got this name because its trefoil leaf, like that of the shamrock, was regarded as a symbol of the Trinity.

XXVII. THE HERRING.

The mock-dissertation, which is aimed at all who discourse learnedly on very ordinary themes, hits the writers of object-lessons, nature-studies, &c., pretty hard. The best-known of all mock-dissertations is probably *Swift's Pious Meditations on a Broomstick*, intended to take off Boyle's *Occasional Reflections upon several subjects;* another, which happens to ridicule just such a chapter as the present one, is Nash's *Praise of the Red Herring*, to be found in his *Lenten Stuffe*, 1599. It was Nash's humour to write at tedious length on a whimsical topic without giving a particle of useful information. He discourses upon himself and his late adventures, upon Yarmouth, the trade of Yarmouth, and the ancient history of Yarmouth, gives extracts from learned authors, which go to prove that a red herring is wholesome of a frosty morning, and sets up a claim that the red herring is more than a match for all other English merchandise; wool, cloth, corn, lead, tin, iron, butter, cheese—none of them is the fellow to a red herring. He cries out in the middle of his discourse, "Let me see, hath anybody in Yarmouth heard of Leander and Hero?" and goes on to tell the story in his own way. He explains how the herring came to be king of the fishes, by what accident the smoking of herrings was hit upon, how the herring was honoured by the Pope of Rome, what is best to draw on hounds to the scent, and who first put herrings in casks. Once he begins to excuse himself, "There be of you, it may be, that will account me a palterer for hanging out the sign of the red herring in my title-page, and no such feast towards, for aught you can see." But the rigmarole goes on as before, and ends without one word to the purpose. Such was the new journalism in Shakespeare's days, when, as poor Nash complained, "the seven liberal sciences and a good leg would scarce get a scholar bread and cheese."

If this is what the mock-dissertation ends in, the triumph over the writer of grave discourses is brief and poor; it is the grasshopper mocking the ant. So let us not be ashamed to draw if we can a little instruction from the herrings which afforded Nash nothing but amusement.

Even a red herring is not a bad study, but a fresh herring is far better, and as fresh herrings are very easily procured in the season, I will suppose that we have one before us. We remark first the general shape of the body, the rounded back with its single dorsal fin, the forked tail-fin, in front of which, on the ventral side, comes the anal fin. Between this and the head the belly thins out to a sharp edge, and is serrated by a number of bony plates, each of which has its own keel. There are two paired fins, answering to the fore and hind legs of a quadruped, or to the arms and legs of man; the front pair (pectoral fins) are set just behind the head, while the hind pair (ventral fins) come beneath the fore part of the dorsal fin. The fins of a herring are supported by bony rays, which are soft and flexible, each being made up of a series of small joints; stiff spines, like those which support the dorsal fin of a perch, or stick out in front of the dorsal fin of a stickleback, are altogether wanting in the herring. All parts of the body except the top of the head are covered with thin, flexible, silvery scales, which are so easily rubbed off, if we pass the finger from the tail to the head of the fish, that we might suppose them to be quite loose. They are not really loose; a delicate transparent membrane overlies them all and forms a sheath to every one. This membrane is the proper epiderm or outer skin-layer, and the scales lie within it, being formed from the derm or deep skin-layer. The scales of fishes have therefore a different origin from the scales of a snake, or the scales on the feet of birds, which are truly epidermal, and not dermal. The large eyes cannot be closed, but are slightly protected by transparent folds, something like eyelids; the eyelids of the herring, however, are not upper and lower, but fore and hind; the opening between them is vertical, and cannot be enlarged or diminished.

If you force open the mouth of a fresh herring, you will find that the upper jaws are pulled downwards when the lower jaw is depressed, as if to prevent small objects escaping from the sides of the mouth. The gape is not wide, nor is it necessary that it should be, for the herring feeds upon minute crustacea which swim at the surface of the sea, and its mouth has very naturally quite different proportions from those of such a fish as the pike, which pursues large animals. The teeth of a herring are so small that they can hardly be seen without a magnifying glass ; there is a patch of them on the roof of the mouth, and another on the tongue, both of which are more easily felt than seen.

The herring has particularly open gills, and a large, smooth gill-cover. Raise the gill-cover, and look at the gills, row behind row of soft red filaments. The wide gill-clefts make it possible to capture herrings, pilchards and mackerel by the drift-net, which is a long net hung vertically at the surface of the sea. In trying to force their way through the net they get meshed, the gill-covers catch, and the fishes are held fast.

From a herring or any other fish which has been boiled you can easily extract the lens of the eye—a small hard globe, white in a boiled fish. Why is the lens, which is flattened in man, sheep and ox, globular in a fish ? Because of the high refractive power of water. There is little difference between the refractive power of water and that of the substance of the lens, so the curvature of the surface must be very great in any animal which has to see under water.

In the head of a herring you will find a pair of hard white otoliths. They belong to the inner ear, and in some way that we very little understand serve to increase the power either of hearing or of some other sense. They are more easily extracted from the head of a large fish, such as a cod or a haddock. The ear in the herring or any other fish has no passage by which the vibrations of the water can be directly transmitted, and of course there is no drum in such an ear. The powerful vibrations set up in water can pass even through bones and flesh. There is no doubt that herrings can hear. Huxley tells us, in his lecture on the herring, "that in a dark night, when the water is phosphorescent, or, as the fishermen say, there is plenty of 'merefire,' it is a curious spectacle to watch the effect of sharply tapping the side of the boat as it passes over a shoal. The herrings scatter in all directions, leaving streaks of light behind them, like shooting stars."[1]

A herring is notorious for the number of bones which it contains—long, slender, needle-like bones, which stand out in unexpected places, and occasionally stick in the throat of a hasty feeder. It is worth while to clear the flesh away from an inch or two of the backbone of a herring, towards the middle of the body, and thus expose the bones. There are various ways of doing this. I can often succeed in dissecting the herring on my plate with a table knife. An anatomist who is perfectly indifferent to bad smells, would prefer to macerate the fish, that is, put it in a dish of water, and set it on the roof until the flesh is so soft that it can be washed away with a gentle stream of water. Boil the herring, if you prefer that plan, but you will have to be extremely cautious in handling the boiled fish, for it will fall to pieces at a touch. It is better to souse it in boiling water, scrape, brush, or pick away as much flesh as will come off easily, souse it again, and go on until you have got a few vertebræ free of flesh and quite perfect. You will find them very different from the vertebræ of a rabbit or any quadruped. The bodies or centra of the herring's vertebræ are cupped at both ends, a weak form of articulation, but strong enough for an animal whose weight is supported by so dense a medium as water. But the most noteworthy point about the vertebral column of the herring is that it sends out two sets of ribs, an upper and a lower set, besides dorsal spines. Where the tail begins the arrangement is further complicated by the addition of more bones, many of which are very loosely connected with the back-bone. Some of these last are forked, so that the herring really deserves its reputation

[1] Huxley's Collected Works, vol. iv. pp. 473-492.

of being full of bones. I know of no fish to match it, though many fishes have both upper and lower ribs. These outgrowths give excellent support to the muscles of the trunk, but why they should be so very numerous is more than I can explain.

Just beneath the back-bone, and running almost from head to tail, is the silvery air-bladder. It is possible by careful search to find the air-duct which leads from the stomach to the bladder, pass a pipe into it, and blow out the bladder. The chief use of this air-receptacle is no doubt to make the fish just so buoyant that it can keep at the surface of the water without effort. Then it can hold itself upright by the slightest exercise of its paired fins, and propel itself by the sculling action of the tail. It is worth while to study the action in a live gold-fish. Many fishes have no duct to the air-bladder, and can only fill it with gases drawn from the blood, but the herring's air-bladder has not only a duct communicating with the stomach, but a fine passage passing backwards and opening on the surface of the body, as well as two slender tubes which enter the head, and lead up to the organ of hearing. The mode of action of these complicated passages is hardly at all understood. It is of interest to remark that the air-bladder of a fish is the beginning of the lung, by which quadrupeds, birds, and reptiles breathe. We have all the stages of development. First the bladder becomes cellular, that is, divided into compartments, then it becomes double, then it acquires special blood-vessels leading to and from the heart, and lastly, the simple air-duct becomes elaborated into a wind-pipe, with rings of cartilage, and perhaps an organ of voice. When you next see a boiled cod or haddock at table, look for the air-bladder. It will not of course be inflated with air, because all the air will have been driven out by the heat, but you will recognise it by its silvery coat. There is no air-duct in the cod or haddock.

A hard-roed herring is a female, and the hard roe consists of eggs. There are many thousands of them, and in a fresh herring you will notice how sticky they are. They are shed into the sea, fall to the bottom, and adhere to the stones. If the eggs are squeezed from a ripe female into a vessel of water, they stick to the bottom, and in half an hour are so firmly attached that the vessel may be turned upside down without the eggs falling out. Herring-eggs are saved by their density and their stickiness from one source of danger; they cannot be swept by currents into unsuitable hatching-places. They escape also vast numbers of voracious animals, mostly fishes, which are always searching the surface of the sea for something eatable. But they escape one danger only to fall into another. The bottom-feeding flat-fishes are on the look-out for herring-eggs, and often cram their stomachs with them.

The young herring has enormous eyes and a very slender body, from which at first a yolk bag protrudes. Until it has attained the age of three months, and a length of about two inches, it has no scales, and the body has not the thin flat shape which it afterwards acquires. Herrings of from three to six months are called "whitebait." They are fond of one another's company in all stages of growth, and swim about in shoals, approaching the shore at the spawning-times, which are spring and autumn. In order to obtain protected spots for their eggs, they will enter long narrow inlets where the water is almost fresh. The salmon goes farther still, and ascends rivers far beyond the reach of the tide, in order to spawn.

Sprats, shads and pilchards are all so like herrings that they can only be distinguished from them by close observation. Sardines are young pilchards.

XXVIII. THE NATURAL HISTORY EXCURSION.

The natural history excursion, which ought to be a first-rate teaching expedient, often fails to answer its purpose for lack of a good method. The leader observes, collects and names; the class accompanies, hears, and it may be, attends for a moment, but soon gets discouraged by the technical information that is poured out so freely. Then people get into conversation with one another, not all the time on natural history. I have heard such excursionists absorbed in political discussion, and have also remarked that young people of different sexes now and then separate in pairs, to talk about things that happen to interest themselves. This is excusable enough, but it is not natural history.

To make things go as they should, there must be work cut out for every member of the party. Field-lectures often fail to interest; the naming of a crowd of unfamiliar plants or animals is quite certain to come to nothing; but if you can persuade every member of the class to search for some particular thing, there may be a chance of a profitable time.

It is good, I think, to deal with one small department of natural history at a time. The special aim, for instance, may be the characters of the common trees, or the notes of the common birds, or the means of dispersal of fruits and seeds, or the habits of aquatic insect-larvæ, or the effect of difference of soil upon vegetation. We shall do well to avoid, for fear of distraction, the mixing up of different studies in one short ramble.

Having decided on the main object of the excursion, we shall consider how to persuade every member of the class to take his share of the work. I have found nothing better than to distribute a paper of questions and instructions. The leader should go over the ground in advance, and note the things which will lead to observation and discussion. Then the party may ramble on to a halting-place agreed on beforehand, where they will stop, examine, and discuss what has been found. Suppose that the main purpose of the excursion is to study the dispersal of fruits and seeds. The printed or type-written programme may be of this kind :—

EXCURSION PROGRAMME. No. I.

1. Note plants which are apparently dispersed by running water.

2. Gather specimens of the meadow geranium, with fruits in various stages of development, and especially some which have shot off their seeds.

3. See what happens when ripe fruits of wood sorrel are gently nipped, and try to discover something about the mode of dispersal of the seeds of this plant.

4. In walking through the underwood, notice what fruits and seeds cling to your clothes, and bring examples for identification.

5. Find two or three trees which bear winged fruits.

6. Find two or three trees or shrubs which bear fruits likely to prove attractive to birds.

7 Bring seed-vessels of dog-violet, some full and some empty.

8. Find fruiting heads of goat's beard, and try to make out how the fruits of this plant are dispersed.

9. Bring ripe pods of willowherb, for observation of the mode of escape of the seeds.

When the halting-place is reached, there will be a demonstration, with explanations and discussions.

Another day the scene may be a north-country moor, and the instructions given out may be somewhat of this kind :—

EXCURSION PROGRAMME. No. II.

1. Bring specimens of two or three moorland ferns.

2. Find seedlings of furze, and notice the leaves which they bear.

3. Bring specimens of two or three moorland plants with rolled leaves.

4. Bring specimens of two or three moorland grasses, and observe how they differ in general appearance from meadow-grasses.

5. A low coniferous tree, with a fruit like a berry, will be passed. Bring a branch of this.

6. Two kinds of crowberry, male and female, will be met with. Bring a specimen of each.

7. There is a small water-plant, which is only found in this district in springs, just where they break from the ground. Bring some of this.

8. Find a bilberry in flower, and notice how the pollen escapes from the anthers. Do you observe any other peculiarity about the anthers?

Let us next examine the animal life of a brook flowing through a rocky glen.

Excursion Programme. No. III.

1. Search the pebbles in the brook for the freshwater limpet (Ancylus), and bring an example in a glass tube.

2. Find a caddis-worm whose case is made of small shells, and another whose case is made of sticks and straws. Bring specimens in tubes.

3. In the mill-dam specimens of Cyclas can be got by dredging. Bring one of these.

4. Colonies of a freshwater Polyzoan are to be found in the same place, clinging to twigs under water. Bring a small piece.

5. Just above the mill a thread of water trickles into the brook over a bank of tufa. Here is a little pool, where the green Hydra is usually met with. Break off a little of the tufa, with a Hydra attached.

6. Two leeches are common in the brook, and will often be lifted out with the stones. Bring specimens.

7. Just above the waterfall the stones are covered with Simulium-larvæ. Bring a stone with attached larvæ.

8. In the Alisma-pond near the waterfall a large pond-

snail with transparent shell is found. Bring two specimens for the aquarium, taking care not to break the shells.

9. If the sun shines, Volvox may be found abundantly in the same pond by sweeping with a muslin net. Collect specimens, and float them into a wide-mouthed bottle.

Where animals, even animals of low grade, are captured, the greatest care must be taken to avoid cruelty. The specimens collected for examination should either be speedily returned uninjured to their native haunts, or, if required for study, killed expeditiously by immersion in a preservative fluid, such as alcohol, or a 4 per cent. solution of formalin. On no account should a number of different live animals be allowed to torment one another by being carried in the same vessel.

It is good to follow up the field-excursion by a meeting for examination of results. Things may then be studied which before were only glanced at; and things of great interest will very likely be brought to light which escaped notice when they were captured. The chief difficulty to be faced is that such a crowd of objects will often be brought home that there is not time to examine all carefully. When this happens, my advice would be: Avoid distraction, no matter how many curious objects are passed over.

XXIX. THE ORGAN-GRINDER'S MONKEY.

We call this a monkey, because he has a long tail; the man-like apes (orang, chimpanzee, gorilla and gibbons) have no tails at all, and the baboons, which live much on the ground, either have no tails or much shorter tails than this. His tail curls downwards at the tip; this tells us that it can be used in grasping.

The organ-grinder's monkey comes from South America: one could see that by merely looking at his face; for the nostrils are separated from one another by about their own width. Any monkey which is short-tailed or tailless, or which has cheek-pouches, in which it can stow away nuts, or has large, coloured, bare patches on the face, or at the top of the thighs (callosities), or has a thoroughly opposable thumb, comes from the Old World. On the other hand, any monkey which has the nostrils widely separated, or which can grasp with its tail, comes from the New World.

In the organ-grinder's monkey the hand has the thumb turned forwards like the fingers, and hardly opposable; one might say that it has five fingers and no thumb; such a hand is convenient for catching hold of a horizontal bough, or for running about on the branches of trees, but does not give quite so firm a grip as a hand with an opposable thumb. Both the tail and the hand tell us that this is a forest-monkey. In the great forests of South America a large proportion of the land-animals are adapted to life on trees; among the number are monkeys, sloths, tree-snakes, tree-frogs and tree-haunting beetles.

This is often called the Capuchin-monkey, because the hair stands up round his face, so that fanciful people have compared him to a monk, with face looking out from a cowl; his Indian name is Sapajou, or something like that. He comes from the forests of Guiana, where, I am told, the Indians capture him in a particularly cruel way. They look out for a mother with a young one, shoot the mother, and sell the young one into captivity. The Capuchin-monkey has olive-green hair mixed with brown and black; his bare, wrinkled forehead makes him look sad and old, but I dare say he can be cheerful when he is well treated. We sometimes meet the Weeper-monkey in the streets instead of the Capuchin; his hair is brown, and the top of his head dark-coloured.

There are some South American monkeys which are even more of tree-monkeys than the Capuchins. Their arms and legs are extraordinarily long and slender, the tail is not only very long, but has a bare patch near the tip, which increases its holding power, and the thumb has disappeared from the hand. These are the Spider-monkeys, of which there are several species. Their wonderful leaping powers are familiar to visitors to the Zoological Gardens, who can now and then see a Spider-monkey hanging by the tail alone.

It is said that the Capuchin-monkey when he is pleased can make a singing or whistling noise, but I have never heard this.

The monkey of fable, the monkey that Galen dissected, the monkey that was two hundred years ago a favourite pet of fashionable ladies, was not the organ-grinder's monkey, nor any American species, but the Barbary ape, a tailless Macaque, native to northern Africa and Gibraltar ; it has yellowish-grey hair, a flesh-coloured face, cheek-pouches and callosities. Many other monkeys have been caught young and tamed, but this more than the rest may be said to have made a place for itself in the history of mankind.

XXX. THE ROOTS AND STEMS OF TREES.

A balsam-poplar in my garden, having become hollow in the trunk by decay of the wood, had the top lopped off. Many vigorous shoots were sent off from the top of the stump, and after a time roots made their way down the hollow trunk to the ground. A much more perfect example of the same thing was pointed out to me by Mr. E. M. Langley in a pollard-willow growing on the bank of the river Ouse at Bedford. The birch in Norway is often lopped for the sake of its foliage, which is given to cattle, or for its wood, which is used for fuel, or for its sticks and withs, out of which the farmer makes upright hurdles for drying his hay. The mutilated trunk generally rots, and through the shell large twisted air-roots may pass down to the ground. The famous yews at Fountains Abbey, sole survivors of the grove which sheltered the first band of monks, also show twisted air-roots, and the ash, the lime and the alder have also been known to send down roots from the crown. In such cases an interesting fact may often be noted, which shows that nature sometimes refuses to abide by the distinctions of the textbooks. Botanists define a root by various characters, one of which is that it grows downwards; they define a stem by other characters, one of which is that it produces buds. The woody growths inside hollow trees must be called roots, for they descend towards the earth, and indeed enter it, forming branched rootlets and root-hairs, just like an ordinary root. But though they are undoubted roots, they are also by definition stems, for they produce buds and shoots.

Uninjured aspens, poplars, elms, peaches, plums, cherries, raspberries, roses and other woody plants more than I care to quote throw up stems from their roots.[1] Where trees grow on a river-bank, it sometimes happens that the soil is washed away from the main roots, which then send out a profusion of leafy shoots. Willow-trees are sometimes purposely bent down and their crowns buried in the earth. When a sufficient number of new roots have formed on the top of the stems, the bases are cut through and the trees inverted. They grow ever after upside down, but in full vigour. In the eighteenth century what was called "reverse planting" was fashionable for a time, and I have seen it practised forty years ago.

I have examined a yew-tree which grew in a hollow, where it was shaded by older trees to such a degree that it was unable to ascend. It grew out horizontally, and after reaching the light sent out many upright branches from its upper side, while from its lower side it sent out nearly as many air-roots, which entered the soil at different places. Spruce-firs when prostrated by wind, often behave in the same way.

[1] This has long been known. Virgil (Georg. II. 17) mentions the cherry, elm and laurel (bay-tree) as sending up shoots in this way.

The conversion of the aerial roots of tropical Figs (banyan, &c.) and Aroids into stems is well known. The same thing may sometimes be seen in European forest-trees, *e.g.* in horse-chestnuts at Guisborough Abbey.

Such examples as these make it clear that stems can send down roots, and that roots can send up stems. Botanists are not ignorant of these facts, and careful writers point out that no absolute distinction can be drawn between leaf, stem and root.

The formation of new shoots from trunks which have been felled may be seen in almost any timber-yard; it illustrates the store of available food which may be present in the wood of a tree. Elm, poplar and willow are particularly ready to sprout after being felled. A large elm-trunk will sometimes send out a multitude of young shoots, which overlay the old bark with a cake of new wood covering many square feet. Examples can be seen in Burleigh Park and many other places.

XXXI. HEDGE AND DITCH; A Summer Term's Work for a School Form.

THE HEDGE.

The hedge that I have in my mind shows a good variety of plants, though it is not richer than many others situated in that part of Yorkshire where the magnesian limestone underlies the soil. If I were a schoolmaster, and had such a hedge near at hand, I should make it part of my business to explore it with the boys. Before or during the natural history work I should try to get the hedge and two or three neighbouring fields surveyed. Among other things every large tree should be set down on the map in its proper place, and with its name. What practice in elementary geometry and mensuration we should get out of the survey! What light the construction of our own plan of a few well-known fields would throw upon the maps which are used in school! Ordnance maps of the district on more than one scale should be pinned up where they could be seen every day. The exercises in mensuration I pass over here, for we have not nearly time and space enough to treat of my proper subject—the natural history of the hedge and ditch.

Part of the inquiry relates to certain details of common plants which have often been handled in elementary books. Here I shall often put questions instead of giving information. Most of the questions are easy, and nearly all can be answered by direct observation of the objects concerned. Where help seems to be called for, a numeral refers the reader to the hints at the end of the chapter. Questions are not only excellent for revision of old lessons, but also for directing the investigation of new facts.

TREES OF THE HEDGE.

Eight kinds of trees grow in or close to our hedge, viz. sycamore-maple, hedge-maple, elm, ash, beech, hawthorn, holly and elder. These trees employ two distinct methods of dispersing their seeds. What are the two methods? Can any reason be given why elder, hawthorn and holly should employ a different method of dispersal from such trees as elm and ash? Which of all these trees comes first into leaf? Which last? Which first casts its leaves? Which last? Which bear evergreen leaves? When does holly change its leaves? Some evergreen trees change all their leaves at one time; is this true of all? Two of the trees on our list are defended by sharp points. Against what do they need defence? Are there any prickly shrubs or herbs in our hedge? Classify the following prickly plants (1) according to the use which they make of their prickles; and (2) according to the part of the plant which is prickly:—holly, hawthorn, furze, bramble, briar. Does hawthorn remind you of an old lesson on stipules? What is the difference between a stipule and a segment of a divided leaf? Which of the eight trees on our list cast their stipules when the buds open? Which keep their stipules through the summer? What is the use of the stipules in each case? Mention any trees on our list which have compound leaves. How do you distinguish a leaflet of a compound leaf from a simple leaf, and a compound leaf from a number of simple leaves growing on the same spray?

Our hedge is mainly a hawthorn hedge, and we must particularly attend to this tree. What is the *haw* from which it takes its name? Sometimes the tree is called *whitethorn;* do you know of any *blackthorn?* (1)

Hawthorn-trees, if left to themselves, grow tall, and cast a deep shade, which hinders the undergrowth and causes spaces to appear between the trunks. This does not suit the farmer, who wants a close hedge to keep his cattle from straying. How does he treat an overgrown hawthorn-hedge?

Many of the topmost sprays of the hawthorn-hedges around us end in knobs; what are these knobs? They cannot be buds, for you will find that they last all through the summer, and in the withered state through the following winter. If you examine them closely, you will find that they are galls, and consist of brown, stunted leaves. The growing tips have been pricked and gnawed, so that they could not grow into straight and regular shoots; they have done their best to put forth leaves, but some of the leaves have been killed, while others are crowded and distorted. What was it that pricked all these growing tips? The grub of a small two-winged fly, that you could hardly see without a lens. This grub fed on the soft, juicy tissues of the growing shoot until at length it stopped feeding, fell to the ground, and entered the earth, where it turned into a pupa; the pupa turned into a fly, and by midsummer only the distorted knobs remained to show where the flies had been reared. The fly bears a cumbrous name (Cecidomyia cratægi); we might call it the *hawthorn-*

fly. Nearly allied to this is the Hessian fly, which in some countries is a serious pest to the wheat-crops. Of late years the hawthorn-fly has been unusually mischievous in Yorkshire. Earlier in the season, before the hawthorn-fly begins its attack, a small caterpillar is often found in the hawthorn-buds.

There is more than one maple in the hedge. Besides the sycamore-maple there is a smaller maple which rarely grows higher than twenty feet; this is the hedge-maple.[1] Gather leaves, flowers and fruits of each when you have opportunity; see also whether they have the same kind of bark. (2)

Take a green elder-shoot, snap it across, and draw the ends gently apart; as you do so you will pull out some slender threads, which will lengthen to perhaps a couple of inches before they break. What are these threads? The microscope or even a pocket-lens will tell you that they are spiral vessels. Such vessels are characteristic of young wood, and are generally found in the first-formed bundles, close to the pith; the later-formed vessels have a different structure. Spiral vessels have the advantages of great flexibility and great power of extension, both of them important properties in a young and rapidly lengthening tissue; at first they are filled with a watery fluid, but in older stems they contain nothing but air. The analogy between the spiral vessels of a plant and the air-tubes of an insect is very close.

An elder-shoot contains a great mass of pith, which at first consists of small cells full of sap; in a later stage the cell-sap dries up, and the cells are filled with air. Of what use can dead, air-filled cells be to the stem? It is plainly advantageous that the wood of the young elder-branches should be placed far from the centre, and not collected in one solid mass. The rigidity of a hollow cylinder is far

[1] Bentham calls it the common maple, but that name would not enable most people to tell what species was meant; in many parts of the country the sycamore-maple is the commoner of the two.

greater than that of a solid rod of the same weight per unit of length.[1] I suppose that it does not matter much at the moment whether the central space is filled by pith or by a simple air-space, as in the stalks of cow-parsnep or the haulms of grasses. A continuous cavity would however be dangerous to a stem which was destined to thicken and last for many years ; it would give great opportunities to wood-eating insects and wood-destroying fungi ; if the branch should ever be broken across, water would get in and do great mischief. Pith is much safer, and it costs the plant next to nothing, for it contains hardly any solid matter. Here again we find animals using the same expedients as plants. A porcupine-quill or the shaft of a feather is very like an elder-shoot packed with pith. In all of them great firmness is attained with the smallest possible weight.

As the elder-trunk increases in diameter the pith remains unchanged ; does this mean that the disposition of the wood becomes less and less advantageous as the stem gets bigger ? Not necessarily, but the great relative rigidity ceases to be so important a consideration when the ascending stem has gained two or three inches of thickness. Henceforth it will have rigidity enough for every purpose ; the property of chief importance to the old stem is its weight-supporting power. This is mainly a question of the number of the wood-fibres, and hardly at all of their arrangement. The hollow cylinder placed vertically can support no greater load than a solid rod of the same weight per unit of length. The strength of the branches which stand out more or less horizontally, is of less vital importance to the tree ; they will grow as far as they can safely grow, and that must suffice. It is by no means an unqualified advantage to cover as great an area as possible, and the elder very likely thrives as well in its modest way as if it had the far-spreading boughs of a beech-tree.

[1] *Round the Year*, pp. 154, 262.

CLIMBING PLANTS OF THE HEDGE.

There are a number of climbing plants in our hedge. We will first learn their names, and then try to find out something about their mode of life.

Tamus. This plant is better known by its English name of *black bryony.* I much prefer English names for the use of schoolboys, but the name of black bryony seems to me open to serious objections. For it is so far from being a bryony that it does not belong to the same family, nor even to the same primary division of flowering plants. Bryony is a dicotyledon ; Tamus a monocotyledon. Further, red bryony takes its distinctive name from its red berries ; we should therefore suppose that black bryony would have black berries. No such thing ! It has green berries, which when ripe turn to a brilliant red ; there is nothing black about it but its root. I do not care to coin a new name, and the Latin name is neither long nor hard to pronounce.[1] Any of the descriptive books will show you how to tell a Tamus, and I will pass by all its other peculiarities in order that we may fix our attention upon its mode of climbing. The stem and its long, slender branches twine round their supports, and thus get sufficient hold. They are often angular ; what advantage is there in the angles ? (3) In what direction does the stem of Tamus twine ? Some twining stems form *right-handed* spirals, like a corkscrew or any other common screw, but Tamus makes *left-handed* spirals. A stem which twines like that of Tamus is also said to follow the sun, because its growing tip rotates from east by south to west. Before the movements of twining plants had been carefully observed, some people thought that their spiral growth was to be explained by their attempts to follow the sun. Mention facts which refute this supposition. (4) How many twining plants can you find in or about the village

[1] The proper spelling is, I believe, *Tammus*, which in Pliny is the name of some kind of wild vine, or creeper.

in which we live ? I know of six, besides Tamus. One is to be found in the hazel-copse, another only in a single corn-field, where it climbs up the wheat-stalks ; a third overruns the hedge of a cottage-garden, the fourth overhangs the vicar's front door, and two more are to be found in his kitchen-garden. (5) Look out for these, but do not ravage either the gardens or the fields. Try to make out the names of these twiners, and mark which follow the sun, and which twine against the sun. Here is a stick of hazel with a spiral groove running round it. What made the groove ? Can you find more grooved sticks in the hazel-copse ? The upper lip of the groove is thicker and more prominent than the lower lip ; why ? (6)

Hop. Watch the tip of a growing hop-shoot, and see how it bends round and round its support, swaying in turn towards every point of the compass. If the movement were much more rapid, we might compare it to the weighted string which the thoughtless schoolboy swings round his head. As the string curls close about a lamp-post which it happens to strike, so the hop-shoot, slowly swinging in a circle, curls round any support which it can reach.[1] The climbing hop-stem not only becomes curled, but twisted about its axis. If a shoot is marked not far from its apex by a spot of paint, the twisting can be measured. Darwin found that it is not constant for the same species of twining plant. The mere act of twining produces one twist for every circle completed, but if the climbing shoot gets a good hold of its support, it may develop a greater amount of twist than this. A long, free shoot, well-supported below, sometimes becomes extremely twisted by its own twining.

The observer who has a climbing hop under his eye should mark on paper the movements of the apex. Note the distance from the support with a pair of compasses, and the varying angular position by the eye. Measurements taken at intervals of a quarter of an hour will furnish

[1] This happy illustration is borrowed from Darwin.

a record of the direction and rate of the angular movement. If the young shoot is pulled about, it reverses its direction of movement for a time ; and a free shoot will sometimes do the same. Thus the exploring shoot is enabled to keep out of the way of moving objects, and to feel about for a fresh support when it has been brought to a stand. One of my hop-shoots was stopped by an overhanging stone cornice ; it persisted for a long time, as if trying vainly to force a passage, but at length sank to a lower position, and there found a suitable support. The rate of ascent may be unexpectedly rapid. Between May 20 and June 3, 1902, a hop-shoot climbed thirty-eight inches, that is, nearly three inches a day. When the growth was most rapid, the shoot gained four inches of height in twenty-four hours. In the same time the tip of the hour-hand of my watch travelled six inches.

Do you find in a hop anything which hinders the slipping of the stem or its branches ? They are rough to the feel, and on examining them closely, you will see that the roughness is due to a multitude of small hooks. Some climbing plants do not twine at all, but trust entirely to their hooks ; we may call these hook-climbers. How many more hook-climbers can you find in our hedge ?

Bramble. What parts of a bramble bear hooks ? I should like a drawing, or failing that, a photograph of a bramble-spray in the hedge. Choose your point of view carefully, so as to bring out the arching of the leaves and the curvature of the free end of the spray. Can you find a rooting-branch of bramble ? If so, remark its tip, and see what unexpected peculiarity it presents. (7) How does the bramble creep along a hedge ? How does it make its way to other hedges ?

Briar. From what part of the stem do the prickles proceed ? Do they contain any wood or any vessels ? Are the prickles of the bramble of the same structure as those of briar ? Point out the difference in structure between such prickles as these and the thorns of hawthorn. Point out also any difference in function.

Cleavers. A third hook-climber of the hedge is cleavers or goose-grass. Its hooks are so minute that you do not see them at all without a lens. Yet you know how it clings to clothes, and you see that it can cling to leaves and stalks in the same way. Draw some of the hooks with a microscope or lens, and see if you can discover any purpose besides climbing to which they are put by this plant. How does cleavers disperse its fruits ?

Ivy. There is no ivy in the hedge, but plenty on old walls in the village. How does ivy climb ? Bring specimens to prove what you say. Why do the tips of the leaves of climbing ivy always point downwards ? (8) How do the flowering and fruiting branches differ from the climbing stem ?

Clematis. If we lived in one of the southern counties of England, and particularly if we lived on a chalky soil, we should find the clematis or traveller's joy growing freely in our hedges. But it is not seen in Yorkshire except where planted. If you have an opportunity of examining this or any clematis of the gardens, observe how it grasps its support. The leaf-stalk is sensitive to contact on its under surface, and curls round any fixed object which is not too large ; then it thickens and stiffens along the curved part, and at last becomes immoveably fixed. The Tropæolum of our gardens climbs in the same fashion.

Bryony. The real bryony of our hedges, often called *red bryony*, has a method of climbing different from all the climbers which have been mentioned hitherto. It sends out a long slender tendril, which grasps a twig, and then contracts into a close-wound coil, dragging the stem nearer to its support, and securing it firmly, though with a certain amount of free play, which is useful in a gale of wind. Observe an unattached tendril ; and see how it reaches out for something to cling to ; its tip is curled, but it is almost straight for the greater part of its length. What is less easily seen is that the tip revolves steadily until it has caught hold, sweeping round and round as if exploring. The coil into which the tendril is thrown after it has secured itself is not a simple but a double coil, half being right-handed, and the other half left-handed; a short uncoiled piece unites the two. Why is the coil reversed? (9)

Vines and passion-flowers are excellent examples of tendril-bearers, but these can seldom be examined except in greenhouses. You can, however, easily procure the tufted vetch (Vicia cracca) which runs in the hedges, and this is well worthy of study. Charles Darwin, in his admirable book on Climbing Plants, which first incited naturalists to take special notice of their contrivances, tells us about many other tendril-bearers, and among the rest he describes the Virginia creeper. You can read, or better still, see for yourselves how the tendrils of the Virginia creeper seek the shade, because there they are most likely to find a surface of support; how the tips of the branched tendrils, as soon as they touch the bricks or plaster, swell, turn red, and form adhesive cushions, which are pressed into all the inequalities of the surface; how the tendrils coil themselves as soon as they have got a firm hold, and so drag up the branch; and how they hold fast for years, long after they are dead. None of the books of the great naturalist illustrate better than this one how the true student of nature will discover in the commonest plants and animals beautiful adaptations which had escaped the notice of all the generations of men. Even more worthy of study than the contrivances themselves are the qualities of mind and character which make a keen observer and a sagacious interpreter.

The advantages got by climbing are very obvious. The climber is enabled to throw the burden of its support upon other plants; it forms little wood and grows fast. In England there is only one climbing plant which can ascend tall trees; name that one. In hot countries there are many; can you tell why? Can you point out any peculiarity which helps us to understand how it is that ivy alone among our climbers should be able to ascend the highest tree? (10)

Sow a few garden nasturtiums (Tropæolum) at the foot of a hedge. When they come up, draw the leaf of a young seedling, a leaf preparing to catch hold, and a leaf which has got a firm hold.

We are told in systematic books that Tropæolum comes close to the Geranium family, but differs in some small details, such as the alternate (instead of opposite) leaves, and the want of stipules. Show by means of a very young seedling of Tropæolum that the leaves are at first opposite and furnished with stipules. What conclusion do yo draw from these facts?

Classify all the climbing plants that you have come across according to their modes of climbing. Do all the plants that climb belong to one family? Do all the climbing plants of the same family climb in the same way? (11).

NETTLE-LEAVED HEDGE-PLANTS.

A number of plants which seek the protection of the hedge have so similar a form, that they may perhaps be mistaken for one another when not in flower. They have upright stems, which give off ovate leaves, cordate at the base and coarsely serrate. The common nettle is a good example, so are the various plants called *dead-nettles* (a name that should be dropped as misleading), plants not allied to the true nettles in any way, but having the same form of leaf, and something of the same general look. Among these are the water-mint, hedge Stachys, catmint, the common Galeopsis or hemp-nettle, black horehound, the white, spotted and yellow Lamiums and wood-sage. Though all these have stalks and leaves which resemble those of a stinging nettle, they belong to the Labiate family. We have also in the Crucifer family the nettle-leaved garlic-mustard (Alliaria). Evidently it is not close relationship that causes these plants to look so much alike. Do they profit by their resemblance to the stinging nettle, being mistaken for it and so let alone ? Is there anything in the shape of the leaf particularly appropriate to a plant which is shaded on one side and tolerably illuminated on the other ? Has this shape of leaf anything to do with rain-drip, or with bud-packing ? I have put such questions to myself for many years, but cannot answer them.

THE DITCH.

The ditch beneath the hedge is partly dry and partly wet. Where it receives the oozing from a bog in the next field, it always has standing water in it, and the little pool thus formed is a great resource to us, for there are no ponds nor any other bit of standing water near at hand. The ditch yields us three flowering plants (duckweed, float-grass, and starwort), tadpoles, pond-snails, and a great number of microscopic organisms. Duckweed I have already written about ;[1] of starwort I have nothing to tell as yet ; some account of the leaves of float-grass will be found on p. 267.

MOLLUSKS OF THE DITCH.

Two species of mollusks abound in the ditch ; one of these (Cyclas cornea) is a bivalve ; the other is a water-snail with a spiral shell (Limnæa peregra). What are the most convenient names for these two mollusks ? I cannot bring myself to call Cyclas a *freshwater cockle*, as some do, because that is a name which must be unlearned by everybody who comes to know what a cockle really is. Perhaps we may tolerate the not very difficult Greek name, Cyclas ; *pond-snail* will do for the various kinds of Limnæa, if we are careful to use it for no others ; *peregra* means *travelling*, and the name of *travelling pond-snail* will distinguish the species found in our ditch from all others.

Cyclas, which is also called Sphærium (what a plague to

[1] *Round the Year*, p. 192.

natural history are the writers who give two names to the same thing !) has a double shell, thin and semi-transparent, almost circular in side-view, but strongly biconvex when seen edgewise. The general structure of the animal within the shell is similar to that of the pond-mussel (Anodon), so well known in biological laboratories, but differences will be discovered by dissection. In Cyclas there is only one pair of gills ; every individual is both male and female ; and there are two siphons which can be protruded from the shell, one serving for the entrance and the other for the escape of a stream of water. When a Cyclas is kept for a few hours in a dish of muddy water the siphons are sometimes protruded. Any naturalist who has a microscope and knows his Anodon pretty well, will find Cyclas an interesting object of study. The animal is so transparent that most of its structure can be made out by removing the shell and turning the soft parts over with a needle ; indeed nearly everything can be seen in a young Cyclas removed from the gill of its parent, and studied alive and uninjured with a low power. I have seen the heart beating and the otoliths vibrating in such a specimen. As in Anodon, the young are hatched in the gill during the winter-months ; at this season the Cyclas is often torpid and buried in the mud.

Here is a question for students who love biological problems ; it is not exactly an easy one, but soluble by anybody who has a fair knowledge of animals and some thinking power. Most bivalve mollusks are marine, and produce multitudes of eggs ; Cyclas, which is a freshwater bivalve, produces very few ; Anodon, which also inhabits fresh waters, produces very many. How can these facts be explained ? (12)

In summer a Cyclas will protrude its broad fleshy foot, and move about freely ; occasionally rising to the surface of the water and creeping on the surface-film as on a ceiling. A young Cyclas can climb much better than a full-sized one, and it is chiefly young ones which rise to the surface, for greater size means diminished power of using capillary forces. A Cyclas, especially when young, will also attach slime-threads to the bottom of a vessel, or to floating plants, and use these as a means of ascending and descending. Such threads, being perfectly transparent, are not easily seen. Occasionally they become visible by their reflecting a beam of sunlight, or by air-bubbles clinging to them, especially when the water has recently been changed, or by particles of fine mud becoming attached and giving them a brownish tint. It is only close observers who will see the slime-threads at all, and even they may have to wait long. Sometimes a young Cyclas has been seen to hang from a floating plant, and to rotate for hours by means of the stream of water issuing from one of its siphons.

The travelling pond-snail is the commonest of water-snails. Like a garden-snail or a slug, it breathes air by a kind of lung, which has however no communication with the mouth. This is a strange feature in an animal which is usually immersed in water, and points to descent from land-snails—a derivation which is on all accounts highly probable. Travelling pond-snails are able to leave the water at pleasure, and are not uncommonly found on a bank, or in wet grass, or on the roots of a tree, but they love damp places and soon perish in dry air. They often come up to the surface of the water to breathe, and at such times a pore may be seen to open on the right side of the body, close to the thin lip of the shell. This pore, which is placed as in a slug or a garden-snail, leads into the lung. Fresh-hatched pond-snails have the lung filled with water, and the same thing is said to be true of the pond-snails which dwell in the depths of great lakes, though they replace the water by air whenever they have an opportunity of doing so. The freshwater limpets (Ancylus), which may be considered as a kind of pond-snail, regularly fill their lungs with water, and keep them filled.

It is easy to study the form of a pond-snail which is kept in an aquarium. In many respects it is like the garden-snail, but it has its points of difference. The tentacles are of a different shape, being flattened at the base, and the eyes, instead of being borne at the tips of the tentacles, are placed at their bases, on the inner side. The tentacles of a pond-snail cannot be telescoped, like those of the garden-snail. The broad creeping foot, the mantle applied to the shell, and the breathing-pore are much the same in both animals. In these, as in all snails, the tip of the spiral shell is turned away from the head, and the mouth of the shell opens on the right side.

Pond-snails, and some other aquatic mollusks, are fond of creeping on the surface-film of water. Semper [1] and some other naturalists have tried to correct this statement; they maintain that the snail creeps on the air. A simple experiment will decide who is right. When a pond-snail is found travelling foot uppermost at the top of a tank, dust the water with lycopodium or some other light powder. You will see that as the snail travels along it does not part the thin layer of powder, but glides beneath it. Hold a wet finger over it, and let a big drop fall upon the foot; this looses the hold upon the surface-film, and causes the animal to capsize. As it is lighter than water in consequence of its air-filled lung the snail continues to float; only when seriously alarmed does it expel a bubble of air from its lung, and sink to the bottom. To regain its position at the surface, when it has sunk to the bottom, the snail must climb up the side again, which might be a long and toilsome business in a large pond. Threads of slime are occasionally used by pond-snails to facilitate ascent or descent, and I believe that if the threads were easily visible, we should find that they are often employed to get over a difficulty. It appears from the testimony of several observers that a pond-snail, when rising from the bottom by virtue of its buoyancy, may check its ascent by a thread attached below; that when sinking,

[1] *Animal Life*, p. 295 and note 97 (Eng. Trans.).

it may remain connected with the surface-film by a thread; and that it may go up and down with the help of old threads extending from the top of the water to the bottom. This is not all; threads are certainly seen at times to stretch from one leaf or twig to another, and under favourable circumstances tracks of slime several feet long and half an inch wide, have been seen to cross the surface of standing water.[1] Any one who finds a water-snail suspended between the surface and the bottom should investigate the circumstances with all possible care, as more facts are still desired.

Pond-snails of several species may be kept in an aquarium. Even small glass globes, holding a pint of water or less, will do perfectly well, if adequate food and air are supplied. Fill the globe with water a fortnight in advance, and set it in a sunny window; the sides will soon be coated with a green film of minute green water-weeds, and a pond-snail requires no more. Watch the operation of feeding. The upper lip is raised, and the sides of the mouth drawn back; a brown mass protrudes for an instant, and then the mouth closes. This action is repeated many times in a minute, and each time a morsel of the green weed is licked off and swallowed. Those who possess the requisite skill in dissection can open the mouth, and examine the parts. There is a transverse cutting blade, the mandible, which projects from the upper lip, and can be made to descend, like a guillotine; there is also a lingual ribbon, a long, brownish, flexible membrane, set with countless pointed, backward-directed teeth, which rasp the food; it is this which protrudes from the mouth at the moment of opening. The snail, as it travels over the glass, clears a narrow track, and by examining the track with a lens, we can see exactly how much of the green stuff

[1] Crowther, "Mucous tracks of Limnæa stagnalis," *Journ. of Conchology*, viii. p. 230 (1896). The published observations respecting the mucous threads of snails have been collected and discussed by H. Wallis Kew in the *Zoologist* for July, 1900.

was removed at each bite. In all the stony brooks of the district the freshwater limpet (another objectionable name, naturalists call it Ancylus) abounds ; let us collect a few and put them in a separate globe. The biting track of an Ancylus is quite different from that of a pond-snail ; it zigzags, as if the creature bent its head by turns as far to the right and as far to the left as it would do without moving its whole body, and in each of the sidelong clearings you can distinguish the separate bites. Though pond-snails subsist mainly on vegetable food, they enjoy an occasional taste of flesh, and may now and then be seen devouring a dead minnow or some other carcase which fortune has put within their reach.

Pond-snails do not hibernate, but move about and feed all through the winter ; in summer droughts, when the water dries up, they bury themselves in the mud.

The sexes are united, and every pond-snail is both male and female. During the summer months they lay their eggs many together in gelatinous strips, which are made fast to stones, or to the stems and leaves of aquatic plants ; in an aquarium the eggs are often glued to the glass. Owing to their transparency, these egg-masses are very convenient for microscopic study ; like the egg-ropes of Chironomus or a caddis-fly, they can be examined alive time after time. Within each egg-membrane there can be seen a globular mass of yolk ; after a little while transparent cells appear on one side, the first cells of the future body. When the little snail begins to take a definite shape, it is found to be encircled by a ciliated girdle, which lies in front of the mouth, and sets up a steady rotation of the embryo within the egg-membrane. In a later stage of development the simple girdle becomes drawn out into paired lobes, which project on either side. All this is just the same in any larval sea-snail, except that the ciliated girdle there becomes an effective organ of locomotion, enabling the footless and finless larva to propel itself through the sea, and, with the help of currents, to transport itself far from the place of its birth. In the pond-snail the girdle soon loses its cilia, and ceases to resemble an organ of aquatic locomotion; Lankester has shown that part of it is represented in the adult by the tentacles. The ciliated girdle of the embryo pond-snail is therefore the last vestige of a migratory larval stage, which is still effective in the sea-snails. Remote progenitors of the pond-snails, it would seem, inhabited the sea. When they betook themselves to inland waters, so restricted that a crawling snail could traverse them in almost any direction, the original purpose of the ciliated girdle ceased to exist. What had been a free larval stage came to be included in the period of embryonic development. The cilia, if useful at all under the new conditions, are useful in a totally different way. It may be that they still serve to prevent adhesion to the embryonic membranes, a danger incident to all animals which undergo a protracted development within an egg. One part of the disused organ has undergone a strange transformation, being converted into a pair of tentacles. The gelatinous egg-chain of a pond-snail, familiar to every naturalist and so easily examined that it may be put into the hands of a beginner as a first piece of independent study, is at the same time worthy to occupy the thoughts of the most advanced speculator. It leads us far from the conditions of life of the existing pond-snails, forcing us to consider the larval migrations of their remote ancestors, their subsequent adaptation to terrestrial, and finally to fluviatile existence, and the persistence through long ages of faint but unmistakeable vestiges of ancient history.

The Mud-Flats in August.

It is now August, and the summer heats have dried up the ditch until only one deep pool and one thin runnel of water are left. The black ooze stiffens and cracks. Some of the mud-flats, which have been long exposed to the air, are covered with a mat of green threads, and in places this mat has been lifted by the growing bulrushes, so that it looks like a torn green veil, partly bleached by the sun. This is the *meteoric paper* of eighteenth-century naturalists, with whom a *meteor* had come to mean rain, wind, snow, or indeed any weather-phenomenon. The microscope tells us the real nature of meteoric paper.[1]

What are these little green stalks, $\frac{3}{4}$ in. high, each surmounted by a yellow head, which stand up from one of the mud-flats? Dig up a good-sized patch, take it home, and keep it moist for a few weeks, to see what it will grow to. Every yellow head is a seed of the toad-rush (Juncus bufonius), and the green stalk on which it is mounted is the cotyledon; just where the radicle and the cotyledon meet a circle of fine rootlets is given off. On the same flat can be seen many plants of Limosel, a little creeping herb, with slender shoots, and here and there a tuft of narrow green leaves an inch or two long. The pinkish corolla is so small, that we cannot study it without a lens. We must observe these things now, for the first thunder-rain will fill our ditch, and it may be long before we see anything more of either the germinating toad-rush or the limosel. Many of the pond-snails lie out of the water, and they are probably ill at ease, for none of them are feeding.

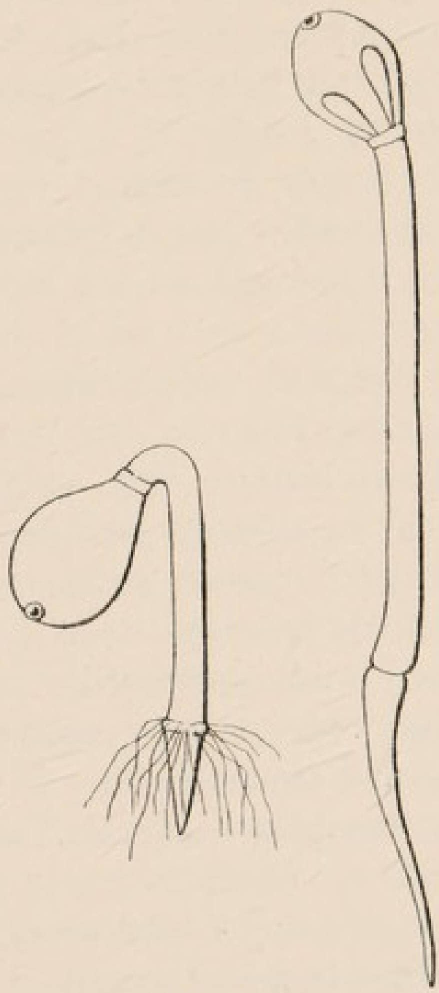

FIG. 37.—Seedlings of Toad-rush, magnified. After Mirbel.

[1] Meteoric paper consists of the matted filaments of green algæ (Œdogonium or Cladophora), entangling multitudes of diatoms. It was first investigated by Ehrenberg and Cohn, but had been remarked long before their day, for instance, in 1736, when it covered acres of low-lying ground near Breslau.

THE WATER-FLEA (DAPHNIA).

Let us search the pool. I lower a dipper into the water, and bring up a cupful. As soon as the mud has settled, I see a number of whitish specks, which swim with short jerks or run on the bottom ; these are the so-called water-fleas. One is tempted to find fault with the name, for the water-flea has very little in common with the domestic flea, but the name is Swammerdam's, and will not easily be forgotten while Swammerdam continues to be read.

Every zoological textbook gives a description of the water-flea (Daphnia), and excellent figures abound, so that our account of its structure may be very brief. It resembles a very small shrimp, covered by a sort of cope (the carapace), which is made fast to the back of the head, and doubled in two, but not hinged. The carapace is flattened from side to side, and so big that head, body and limbs can be almost completely retracted within it. A pair of large branched antennæ are used as sweeps, and it is these which jerk the body through the water ; the other limbs are small, and hardly project from the narrow slit between the edges of the carapace ; the forked tail is turned forwards beneath the body, and is constantly engaged in a sweeping movement, baling the water out of the enclosed space. Both carapace and body are transparent, allowing us to see the beating of the heart and the streaming of the blood in a live specimen laid on the stage of the microscope. The paired eyes, usually found in crustaceans, coalesce in the water-flea, and form one big compound eye, which is always trembling. Water-fleas show no distinct colour, except where many are collected in a small space, when they are said to give a reddish tint to the water, which is particularly evident in spring.[1] They often swim near

[1] Swammerdam speaks of water being changed to blood, according to popular belief, when examination showed that the colour was due to crowds of Daphnias. This appearance I have never seen myself.

the surface when the light is weak, but sink when the sun shines upon the pool.

The water-flea, being very abundant and easily kept in captivity, is an excellent study for the young naturalist, who, let us suppose, has just come into possession of a microscope. I would recommend such an one, if he really means to improve, to put aside all the favourite curiosities, and not to distract his mind by frequent change of object. Let him observe steadily and patiently some one living thing, until he has mastered his instrument and learned how to work. A fair set of drawings of Daphnia, made without the help of books, would give proof of the kind of ability which really advances natural history. Few will take the advice, and we must leave the majority to their cabinets of bought slides.

When the general structure of the water-flea has been made out, I would suggest that its modes of egg-production should be particularly studied, as it is chiefly these which have made Daphnia notable to every biologist.

Remark first that all the water-fleas that we have fished out of the pool are of one sex. Such as are full-sized bear eggs in some stage of development. When mature, the eggs are lodged, two or three together, in a recess (the brood-pouch), which lies between the carapace and the back of the body; now and then a fresh-hatched water-flea may be seen imprisoned in this space, waiting till the mother moves aside some long spines which close the passage, and so allows it to escape. Before the eggs were passed into the brood-pouch, they lay in the ovaries, long paired organs, situated below and to either side of the alimentary canal. The duct by which the eggs escape into the brood-pouch can rarely be seen except when a dark egg is passing along it. Since there are no males at this time of year, all these eggs are unfertilised, but they develop none the less, and the new generations succeed one another with great rapidity.

At the approach of winter our common water-flea produces another kind of egg, distinguished by several peculiarities from the eggs mentioned above, being larger, much darker in colour, lodged in a special protective case, fertilised by the male, and capable of lying dormant for weeks, months, or even years before they develop. These eggs have long been called "winter-eggs," while the smaller, paler, unfertilised eggs, which have no covering except their own shells, have been called "summer-eggs." These names, as we shall soon have occasion to remark, are not altogether appropriate, for winter-eggs may be produced in the height of summer.

The formation of the outer protective case of the winter-eggs is very singular. It is fashioned out of part of the back of the carapace of a living water-flea. The specialised part becomes dense, dark-coloured, and bordered by a wide strip, which on close examination is seen to be impregnated with air, a great number of air-bubbles being lodged each in a separate cavity of the shell. When the time for liberation of the egg-case has come, it splits outside the air-containing border, and then doubles in two, catching up usually two, but sometimes more than two eggs, which have previously been fertilised and passed out from the ovary. The egg-purse (often called the *ephippium*, which means *saddle*) is now found, not merely to be doubled in two, but to possess an inner and an outer wall, separable from each other. The greater part of the carapace is really hollow at all times, its inner and outer walls being separated by a thin space in which before a moult the new carapace forms. Hence when a bit of the two-walled carapace is, so to speak, punched out, it is found to consist of two separate layers, each doubled in two. The walls of the egg-purse are springy, and the edges meet elastically without the help of muscles or any visible appliance, locking up the eggs automatically. The purse never opens again until the young Daphnias developed within it force a passage for themselves. When the egg-purse is set free. it floats away on the top of the water, and naturalists who skim the surface of a pond or lake with a tow-net sometimes take them in great numbers. The winter-eggs always produce females only, generally after a long interval, and these females are never capable of laying more winter-eggs, but only unfertilised summer-eggs. The male water-flea is only found at the seasons when winter-eggs are due. He is much smaller than the female, has no brood-pouch, and differs in many small details.

Weismann, who has closely studied the reproduction of many species of Daphnids, finds that the succession of generations is not the same in all. Sometimes many generations of summer-eggs succeed one another, until at last the cycle is completed by the recurrence of winter-eggs; sometimes every other generation is capable of producing fertilised winter-eggs. In our commonest species there are two seasons for sexual individuals, viz. early summer and late autumn. There is a relation between the frequency with which fertilised winter-eggs are produced and the conditions of life. Where drying up of the pools which a particular species frequents may be expected to happen many times in the year, the sexual stage recurs more frequently; in a species which is not liable to be dried up, and where winter-cold is the only hardship to be faced, the sexual stage may come round but once in the year. Indeed, it is found that in deep lakes, where neither drought nor winter-cold can seriously affect the Daphnias, they propagate all round the year by unfertilised or summer-eggs, and winter-eggs are perhaps never formed at all.

Where there is a well-marked dry season in every year, the winter-eggs may lie dormant for months, or even for years without losing their power of hatching. Dried mud, collected from pools in Jerusalem or Khartoum, regularly produces large and handsome Daphnias, besides other crustaceans, whenever a spoonful is dropped into a tank in an English parlour. A little dry mud from the pool of Gihon, which contains water only for two months of the year, was placed in a globe of water, and the crustaceans duly appeared. When they had enjoyed a few weeks of active life, and laid their eggs, the water was drawn off, and the mud left to dry. Next spring the same mud was again placed in water, and the process was regularly repeated for many years. A sample of the mud which had been kept dry for ten years still contained live eggs.[1]

The small size of the eggs of a Daphnia and their power of withstanding long-continued drought, help to explain their wide dispersal. The wind that scatters clouds of summer dust often scatters crustacean eggs as well, and makes it easier to understand how pools of insignificant size, separated from all others by miles of desert, sea or snow, should now and then be found to swarm with live Daphnias.

The biological questions which the history of Daphnia suggests are of the deepest interest, but many of them are at present insoluble, and nearly all of them are difficult—too difficult for the young observer at least. Keep the facts in mind, and you will come across other instances of the same thing as your experience widens. Certain insects, polyzoa, rotifers, and other animals show in their life-histories an alternation of sexual and asexual generations, very similar to the alternation of summer and winter-eggs in Daphnia. In all there is rapid multiplication during the season when food abounds ; resting-stages, mating, and all that takes up time are then left out. When the season of difficulty comes round, the season of drought or the season of cold, loss of time signifies nothing, and safety is all in all. No one, I believe, can explain why only the fertilised egg can outlast the season of cold or drought, nor can we make it clear to our own minds what lasting benefit to the species can result from the exuberance of new individuals in one particular season, if that season is immediately followed by another in which the numbers are cut down to a minimum again. The advantage may be merely this, that if only one per cent. of the individuals

[1] Atkinson, *Ann. and Mag. of Nat. Hist.*, Nov., 1898.

produced under favourable circumstances can be expected to survive, still one per cent. of a million will be a thousand times as great as one per cent. of a thousand. But we are mere beginners, learning to spell, and what we think about the more difficult questions of life signifies little until we are in possession of wider and deeper knowledge. Let us concentrate our attention upon the problems which are soluble in our own day, not dismissing altogether from our thoughts such as are at present insoluble, but waiting for the lucky moment when the clue shall offer itself. Some day we may be able to explain why an egg which has to remain long dormant must be fertilised, while an egg which is to develop at once may dispense with fertilisation.

HINTS FOR THE ANSWERING OF QUESTIONS ON "HEDGE AND DITCH."

(1) We now speak of the *haw* as the fruit of the hawthorn, but in old time *haw* meant a hedge or inclosure. Skeat quotes from the Canterbury Tales, "And eke there was a polkat (polecat) in his *hawe* (yard)." *Hedge* and *hey* are other forms of the same word, which becomes *Hecke* in German, and *Hage* in Dutch, whence the familiar place-name, *Hague*. *Hawthorn* (German *Hagedorn*) originally meant the thorn of which men made hedges. *Whitethorn* is a name given to the hawthorn because of its white flowers; very illogically we have given the name of *blackthorn* to the sloe (which is white-flowered too) because it has a black fruit.

(2) *Sycamore-maple.* Leaves toothed, flower-bunches hanging, halves of the fruit inclined at right angles to one another, bark smooth. *Hedge-maple.* Leaves with entire margin, flower-bunches erect, halves of the fruit in a straight line, bark fissured.

(3) A bryony-stem has several sharp ridges, which become spiral by the twist of the stem; they have probably some effect in preventing slipping. Every skater knows

the value of the sharp edges of a skate-iron, and the spiral ridges on the rollers used in flour-mills are to some extent similar contrivances.

(4) Twining stems do not all twine in the same way, but more often move against the sun than with it. The revolution of a free shoot is generally much more rapid than the apparent revolution of the sun.

(5) The plants referred to are honeysuckle, climbing Polygonum, larger Convolvulus, hop, scarlet runner, and French bean.

(6) The hazel-stick was indented by honeysuckle twining round it, and at last becoming hard and woody. The upper lip is thickened because the nutriment descending from the leaves is checked by the ligature.

(7) The free end is often considerably enlarged.

(8) The down-pointing tip serves to drain off the rain-water.

(9) A thread, which is attached at both ends, can only contract spirally when half the coils are reversed.

(10) In hot countries there are many climbers which can ascend tall trees; in England the season of rapid growth is too short for the purpose; ivy, however, being evergreen, and thus able to take advantage of the months when the trees are bare, can climb tall trees.

(11) TABLE OF SOME COMMON CLIMBING PLANTS.

Twiners.

Scarlet Runner	against the sun	Leguminosæ.
French Bean	do.	do.
Wistaria	do.	do.
Honeysuckle	follows the sun	Caprifoliaceæ.
Convolvulus	against the sun	Convolvulaceæ.
Climbing Polygonum	follows the sun	Polygonaceæ.
Hop	do.	Urticaceæ.
Tamus	do.	Dioscorideæ.

Leaf-climbers.

Clematis	Ranunculaceæ.
Tropæolum	Geraniaceæ.

Tendril-bearers.

Vetch	Leguminosæ.
Bryony	Cucurbitaceæ.
Vine	Vitaceæ.
Virginia Creeper	do.
Passion-flower	Passifloraceæ.

Hook-climbers.

Bramble	Rosaceæ.
Briar (wild rose)	do.
Cleavers	Rubiaceæ.

Root-climber.

Ivy	Araliaceæ.

(12) The number of eggs produced depends upon the risks to which the developing animal is exposed ; in the sea the risks are much greater than in fresh waters. Both Cyclas and Anodon as freshwater animals might be expected to produce few eggs. This is true of Cyclas, but Anodon has developed a singular kind of temporary parasitism ; its young attach themselves for a time to the fins of fishes and tadpoles. The opportunities for so attaching themselves are very precarious, and many must fail to develop because no fish has come within reach ; hence the great number of eggs which Anodon produces, very unlike in this to most freshwater animals.

XXXII. THE FROTHING HOPPER.

Never surely was a common native insect so ill off for an English name as this. *Cuckoo-spit*, which is best known, suggests a ridiculous fable ; *frog-hopper*, which Kirby and Spence employ, is almost equally unmeaning, though less nauseous. Fabre, to whose French readers *Cicada* is a familiar word, has coined the pleasing name of *Cicadelle*, but

Cicadelle would be unintelligible on this side of the channel. The name of the systematists (*Aphrophora spumaria*), which, being interpreted, means *foaming foam-bearer*, does not help us in the least. On thinking the difficulty over *frothing hopper* seems to be a tolerable name, which will at all events do quite well for the short chapter now in hand.

In May and June one sees almost everywhere in garden and field little masses of white froth, about as big as nuts, which cling to plants of many kinds. Searching the froth with a camel-hair brush, or even a grass-stem, one soon discovers that every mass of bubbles lodges a grub, sometimes more than one. The grubs are green, with yellow eyes, and measure perhaps a quarter of an inch in length, more or less according to age.

The froth, when wiped off, is soon renewed, and if the operation is carefully performed, so as not to injure the grub or its food-plant, the secretion of a fresh mass of froth can be studied without much difficulty. I was curious in the first place to find out where the liquid came from, and how it was mixed with air, so as to form a mass of bubbles, all of the same size. The liquid might possibly be exuded from the mouth ; it was most unlikely that the air issued from the mouth, for no insect is known to breathe through its mouth. On observing a larva freshly cleared from froth, it was not hard to see how the thing is done. The abdomen narrows behind, and the last joints are capable of a telescopic movement. The larva raises and extends what we may call its tail, and then withdraws it. A pouch, with a two-lipped opening, is placed at the extremity of the tail ; this pouch opens whenever the tail is raised, and closes when it sinks. Every time the action is repeated, a fresh bubble is formed. Within the pouch lies the end of the intestine, so that we can to some extent understand what goes on, if we are at liberty to suppose that a sticky fluid is continually passed out from the intestine, but of this I have been unable to get direct proof.

Undoubtedly the pouch is lined with a sticky fluid, whatever its source, and the air comes from without, being enclosed by a liquid film at the moment of the closing of the valve. The different writers who have described the frothing hopper give quite contradictory accounts, and Fabre is the only one whose statements agree with what I have seen.

Shelter within a mass of foam has become necessary to the grub of the frothing hopper, and it dies if its protecting envelope is removed. The skin is so thin that the body soon dries up. It seems probable that the artifice of a covering of froth was adopted in order to defend the insect from its enemies, and the purpose is attained, though not with unfailing success. Predatory insects of the wasp-kind and insect-eating birds have been seen to pick the grubs out of their hiding-places and carry them off.

Like many other insects of the Hemipterous order, the frothing hopper feeds on the juices of leaves or soft green stems. It is provided with a flexible proboscis well adapted for piercing. When the fresh-hatched grub has found a convenient place of abode upon a green shoot, it drives in its proboscis, and without moving again feeds upon an inexhaustible supply of sap.

When summer is at its height the frothing hopper undergoes a change of form which almost amounts to transformation. The hind legs of the grub are replaced by a pair of much greater length, which are adapted to leaping, for though the adult insect has wings, it generally moves by leaps. The change takes place within the frothy mass, which hardens externally, and encloses at this time a large empty space.

When the fully formed insect becomes free, it justifies its name of frothing hopper, for in late summer it hops about the bushes with much agility, taking leaps of several feet when alarmed. The female at last becomes so laden with eggs that she is unable to leap any more. It is said that the eggs are laid in the earth, and hatch out in spring. Full-grown frothing hoppers continue to feed on the juices of plants, and occasionally exude drops of liquid from the intestine, but they never blow bubbles.

Naturalists who can use the microscope will find the hind legs of the full-grown frothing hopper an interesting study. Notice the spines which hinder the foot from slipping at the moment of leaping, and compare them with the corresponding parts of a cricket (see p. 187).

XXXIII. ANIMAL GLOBES.

The ready and complete adaptability of animals to external circumstances is shown by the resemblances which like conditions produce in the most diverse animals, and the differences which unlike conditions produce in nearly related ones. Let me illustrate this general statement by examples of animals which are defended by their globular form, and often by spines as well.

No common quadruped is better protected from its enemies than the hedgehog. The sharp spines and the habit of rolling up are first remarked. On dissection we discover a dome of circular skin-muscles on the back, which is bordered on all sides by a thick muscular rim. When the hedgehog walks, the mass of circular muscles forms a hump upon his back, but when he is alarmed, he draws the head and legs within the rim, which tightens like an elastic ring surrounding the mouth of a bag. The mere act of rolling up erects the spines, and makes them point stiffly in all directions. The prickly sphere rolls when pushed, and can neither be bitten nor grasped. A hedgehog can defy dogs or any other predatory animals. It can also when rolled up drop safely from a height of several feet, and adopts this method of getting down a low cliff. Very like the hedgehog in outward appearance, and covered in the same way with strong sharp spines, is the Echidna, a monotreme quadruped found in Australia, Tasmania and New Guinea. The Echidna does not roll itself into a ball, but crouches when alarmed, and hides its head between its fore legs.

The porcupine too has spines, but he does not use them like the hedgehog; instead of curling himself up, he charges backwards at his enemy. The spines of the hedgehog, porcupine and Echidna are simply gigantic hairs.

Some animals, which are covered, not with spines but with fur, such as the Ornithorhynchus, the Thibetan Sun-bear and the Koala (the "Native Bear" of the Australians) also roll themselves up. Comfort and warmth during sleep seem to be the chief object with these animals, but some degree of protection is indirectly gained. Resting in this attitude, the animal exposes the smallest possible surface to inquisitive eyes, and makes itself as unmanageable as possible to biting enemies, which must fill their mouths with fur as a preliminary, and can only inflict serious wounds when they are decidedly superior to their prey in size and strength.

The dormouse curls itself up in its nest at the approach of winter, and makes itself still more secure by wrapping its body in grass and leaves. Then it goes to sleep, loaded with fat by its abundant meals upon the berries, nuts and grain of autumn. Part of its food it stores for winter use, and when waked from its long slumber by a spell of warm weather, it feeds and goes to sleep again. The dormouse is rare in the north of England, and even in the south it is a very unusual thing to meet with a hibernating dormouse. Much more common are hibernating hedgehogs, which also wrap themselves up in leaves and grass.

The South American Armadillo, of which there are several kinds, is completely furnished with the means of defence. Its skin is ossified, not into a rigid shield, but into a mosaic of six-sided plates. Across the back the plates are arranged in bands, with flexible lines between. The face is protected by a pointed shield, and even the legs and tail have their share of armour. When the armadillo is suddenly attacked, he closes up with a snap, and nothing can harm him. Even the jaguar cannot bite through his bony skin, nor tear him with his powerful claws. If surprised on soft ground, the armadillo burrows out of sight, and it is hard work for a man with a spade to follow him. The pangolin of the East Indies, a sort of first cousin to the armadillo, has the upper side of its body and of its long tail covered with stiff, sharp-edged, overlapping scales. When alarmed, the pangolin bends himself together, and wraps his great tail about him. The sharp edges of the scales now stand out, and form a complete defence.

The Tetrodons and Diodons (file-fishes and globe-fishes) of tropical seas resemble hedgehogs in their spines, and in their power of assuming a spherical shape. But there is no rolling up here. The fish distends its body with air, and floats at the surface of the sea, usually back downwards.

Sea-urchins furnish beautiful examples of the spherical shape protected by spines. Here again there is no rolling up; the shape is unalterable by the will of the animal. Globular sea-urchins, with dense calcareous armour and flexibly jointed spines, inhabit the rocky shores, usually well below tide-marks. Flattened species are fond of burying themselves in sand.

How does an Echinus enlarge its shell? It cannot be cast, nor changed in shape. If you break up an Echinus shell, you will see how the problem is solved. The shell is compound—a spherical box consisting of hundreds of separate pieces fitted together with the utmost nicety. Running from top to bottom are five regular bands, alternating with five others of different size and form. Each of these ten bands is divided by a zigzag line running along its whole length, and each half-band is again divided by transverse joints into a great number of plates, arranged with geometric regularity. The mouth of the Echinus is beneath, at the meeting-place of all the bands. The shell grows by the continual addition of fresh material to all the edges of all the plates, and it is singular that the resulting figure should be one of such perfect symmetry.

What are *urchins*, and are there any urchins besides sea-urchins? *Urchin* originally meant a hedgehog, then it came to signify a bogey, and lastly a child. The word is got, through the French *hérisson*, from the Latin *ericius*, and may be translated *bristly*. *Oursin*, the French name for the sea-urchin, notwithstanding the similarity of the sound, has nothing to do with *hérisson*, but means *little bear* (*ours*).

The hard and jointed shells of crustaceans and insects lend themselves easily to this mode of defence. Woodlice, which are terrestrial crustaceans, roll themselves up when alarmed, and one kind has even been named Armadillo (to the confusion of zoological speech). Hairy caterpillars often roll themselves up for defence, or to break the shock when they find themselves falling to the ground. The ruby-wasps (Chrysididæ), which live at the expense of stinging Hymenoptera, can roll themselves up into impenetrable balls.

Most snails are protected by spiral shells, but in the Chitons the shell is neither spiral nor in one piece; it consists of eight valves, one behind another. The valves are flexibly connected, and can be rolled up. The segmented shell also enables the animal to accommodate itself to the inequalities of the rocks to which it clings.

The winter-eggs of a freshwater sponge and the microscopic bodies of many Foraminifera and Polycystina are defended by radiating spines; sometimes these spines seem to have other uses than defence.

We have in this country three common Insectivores, the hedgehog, the shrew and the mole. Though closely related, they are very unlike in mode of life, and seem hardly to hang together till they are carefully examined. In the quite distinct order of Rodents each of the three finds its *analogous* form, as zoologists say. The porcupine is analogous to the hedgehog, the field-mouse to the shrew, the lemming, the mole-rat and others, not so well known, to the true mole. Among the monotremes again, the hedgehog-form is reproduced in Echidna. Affinity may thus be disguised by adaptation to different modes of life, and adaptation to the same mode of life may exist without affinity. Think of other examples of the same kind. You can easily find them among aquatic quadrupeds, among birds and reptiles, among moorland plants, desert plants and aquatic plants.

XXXIV. THE HOUSE-CRICKET.

Any naturalist who attends to insects, will be sure to make acquaintance with the common house-cricket, and may, if he dwells in the right part of the country, become familiar with the field-cricket also.

Crickets belong to the Orthopterous order, and have biting mouth-parts, two pairs of wings of unequal texture, the fore pair (wing-covers) being relatively stout and opaque, the hind pair membranous and folded fan-wise when at rest ; they go through no transformation, though they gradually acquire wings, and they have no resting-stage. Crickets are leaping insects, as the thickened thigh on the hind leg and the angle which it makes with the following joint show at a glance. They have long antennæ, and only three joints in the tarsus or foot.

It is easy to tell a male from a female cricket, for the female always has a long sabre-shaped egg-laying tube (ovipositor) projecting from the end of the abdomen ; it is used to pass the eggs into crevices, and in the house-cricket is about half an inch long. No such appendage is possessed by any male insect.

The field-cricket is larger and much darker than the house-cricket. The black head of the field-cricket is enough by itself to distinguish it, for in the house-cricket the head shows yellow bands on a brown ground. The field-cricket burrows in the earth, and there makes a retreat sufficient for its own protection and for the protection of the eggs. Gilbert White's pleasant sketch of the habits of the field-cricket, given in the 86th letter of the Natural History of Selborne, will suffice for an insect which few readers will have met with, since it is restricted to the southern counties of England.

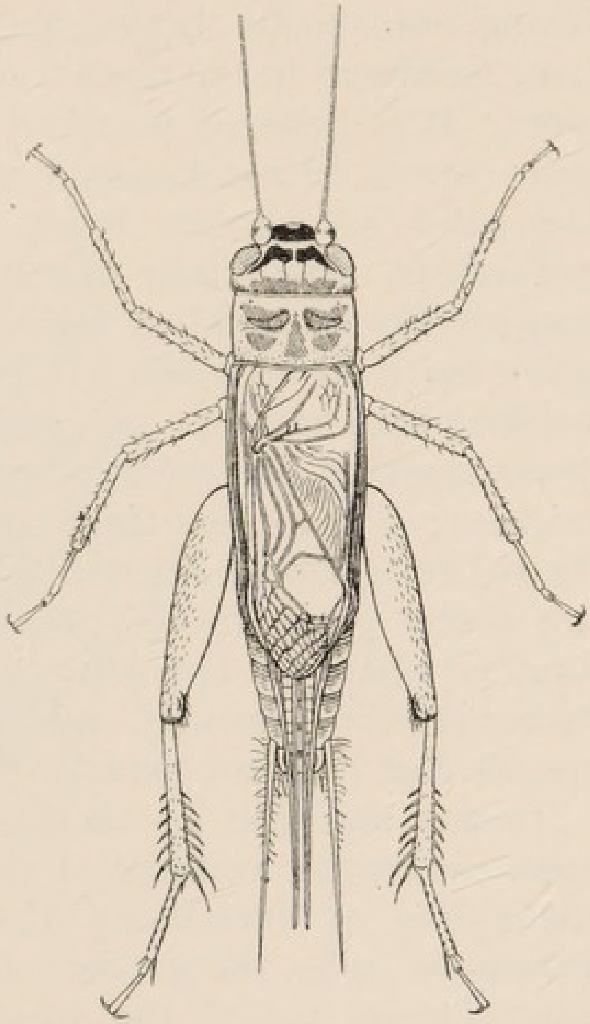

FIG. 38.—Male house-cricket The antennæ, which are longer than the body, are cut short.

The house-cricket finds rather than makes its shelter. Chinks where the mortar of the wall has crumbled away, when enlarged a little by gnawing, are its refuge by day. In the evening, when all is still, it comes forth to feed upon the crumbs and vegetable refuse of the kitchen. It seems hardly possible for house-crickets to be too warm; they are even less tolerant of cold than cockroaches, and keep as near as possible to the kitchen-hearth. Only in the height of summer do they venture out of doors. If surprised by a low temperature, as when the kitchen fire is not lit for several days in winter, they become torpid. Running is the cricket's ordinary mode of locomotion; he has recourse to leaping only in an emergency, and flies only when he wishes to change his quarters. Gilbert White with his sharp eyes saw crickets flying out of his windows, and over the roofs of the neighbouring houses, in the dusk of summer evenings. Egg-laying seems to be always going on, for crickets of all ages may be caught in the same traps, and at any season of the year. It is believed that the duration of life is about a year, but I do not know of any careful observations on the point. A popular belief, which is shared by many naturalists, would lead us to suppose that crickets and cockroaches cannot live together; the cricket is said to drive out the cockroach. In two houses which I have inhabited both crickets and cockroaches were plentiful for years together, the cochroaches greatly outnumbering the crickets; I have seen them come out of the same chinks. There are some grounds therefore for saying that they are pretty good friends, not that they will not eat one another when the opportunity offers; most insects with biting jaws will do that, even with members of their own species, but I cannot consider them irreconcilable foes.

To any one who knows the cockroach pretty well the most interesting features of the cricket will naturally be the points of difference. These are (1) the structures associated with the power of leaping, (2) the peculiar mouth-organ, called the tongue, which is much more elaborate in the cricket than in the cockroach, (3) the gizzard, which, though similar in many respects in both insects, shows peculiar features in the cricket, (4) the organ by which the chirp of the cricket is produced, and (5) the auditory organ, by which the chirp is perceived.

Leaping in a cricket, a grasshopper, or any other insect with thickened thighs, is effected in this way. The thigh, leg and foot are first strongly flexed, as in a man who sits on his heels. Then the powerful extensor muscles, which are lodged in the thighs, contract, the limb is straightened, and the body is raised, not gradually, as when we rise from the sitting position, but with a violent jerk, which throws it into the air. The flexion is extreme, and the moment before the leap the joints lie parallel to one another, as is indicated by the fact that the thigh (femur) is grooved

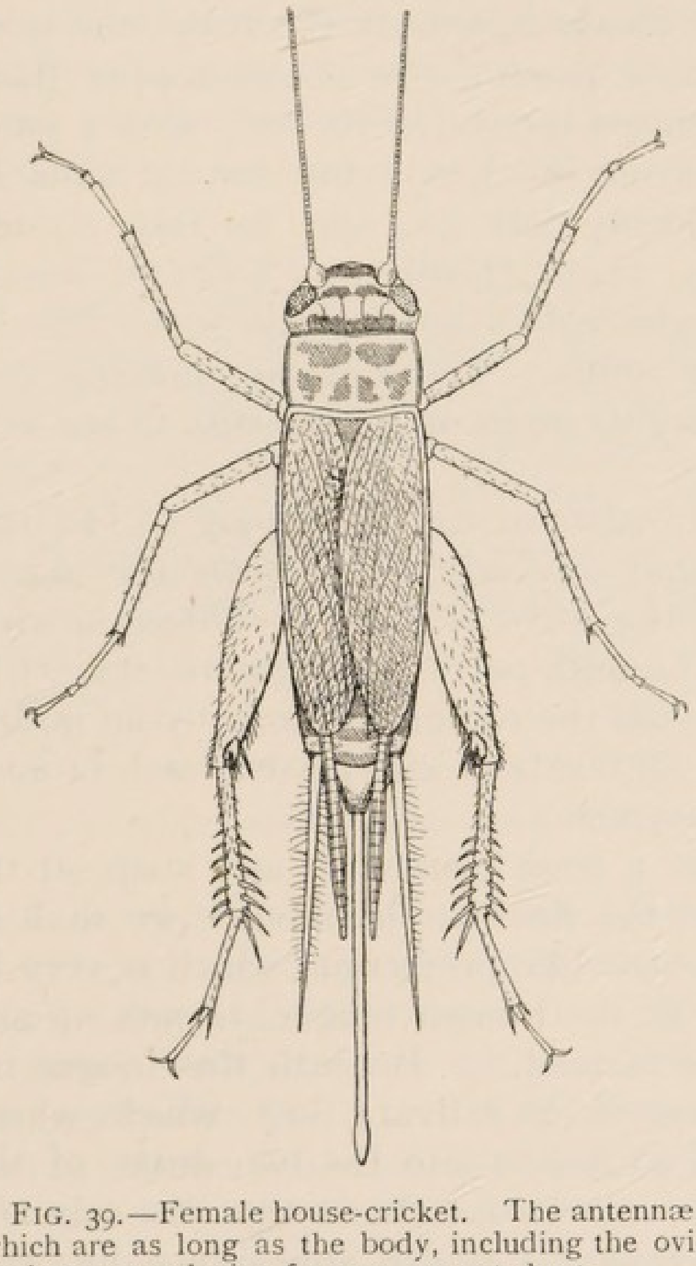

FIG. 39.—Female house-cricket. The antennæ, which are as long as the body, including the ovipositor or egg-laying forceps, are cut short.

along about two-thirds of its length, so that the next joint (tibia) can be received into it. Lest the foot should slip, and the effect of the upward thrust be lost thereby, the lower end of the tibia is armed with stiff spines, which stick into the ground.

All leaping insects do not adopt the method of the cricket; the click beetles, lying on their backs, first arch the body, and then suddenly reverse the curve, so that the elytra strike the ground with a smart blow; the spring-tails leap by straightening a forked tail, which was previously bent forwards beneath the body, and in many cases secured with a catch; the cheese-hopper (larva of the cheese-fly) grasps the end of its body with a pair of strong hooks borne on the head, and having thus bent itself double, suddenly lets go, and forcibly straightens the body (see p. 114). Hardly any order of insects can be mentioned which does not include some that leap either as larvæ or adults. The Mexican jumping bean is well known to owe its amusing movements to the activity of a caterpillar.[1]

The mouth-parts of the cricket are so like those of the cockroach that anybody who knows the one can easily understand the other. There is indeed a striking uniformity of mouth-parts throughout the Orthoptera—striking because the common plan is by no means a simple one, but an aggregate of many parts, each prone to assume special adaptations.

If we take a fresh cockroach and strip off the labium, which forms the floor of the mouth, we shall find on its surface a tongue-like projection, which is very likely used somewhat like the human tongue, to mix up and moisten the particles of food. Beneath this tongue is the large single opening of the salivary duct, which, when followed, can be seen to divide into the two ducts of the salivary glands. The microscope shows that the salivary ducts of the cockroach have a ringed appearance, like the air-tubes of an insect. Stiff threads, which branch frequently, are wound about them, and keep them from collapsing, acting indeed just like the spiral threads of an air-tube, which they closely resemble. A tongue and a salivary duct are

[1] The caterpillar is that of a small moth (Graptolitha sebastianæ); the "bean" is the fruit of a spurge (Sebastiana).

found in the cricket also, but with remarkable modifications. The outlet of the salivary duct now becomes double and capable of protrusion. When protruded, it spreads out fan-wise, and each half forms a quadrant, upon which the stiffening fibres ramify. When not in use, the whole is retracted. The two expansions when protruded form a semicircular plate, convex towards the mouth, and well adapted for spreading the salivary fluid upon the food. Since the house-cricket is notoriously thirsty, it

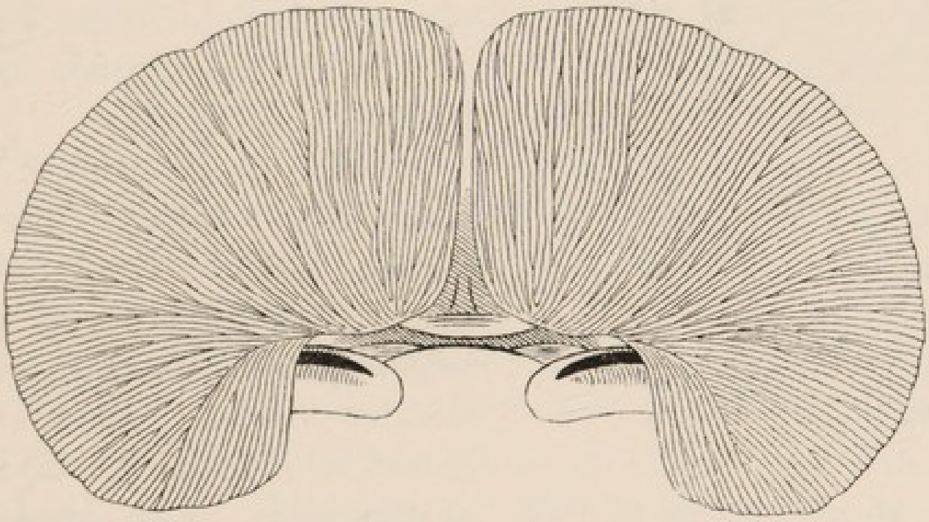

FIG. 40.—Protruded tongue of house-cricket, highly magnified.

may be that its expanded tongue finds a special use in the lapping up of liquids spilt on the hearth.

Beyond the capacious pear-shaped crop of a cockroach comes the gizzard, a blunt cone with muscular walls, applied by its base to the broad end of the crop, and tapering at the other end into a tube with folded walls, which passes a long way into the stomach. It is easy to slit open this gizzard, and clearing it with potash solution, to study the arrangement of the strong chitinous ridges which project inwards from all sides. The cricket has a similar gizzard, which may be prepared for examination in the same way. Here the ridges are broken up into a great many sharp teeth, and seem to be adapted for tearing the food, while in the cockroach one might suppose that they act rather as a press than as an organ of mastication. The crayfish furnishes a third example of an animal in which the mixing and mastication of the food is performed by internal teeth far from the mouth. All three agree in this, that their internal teeth are placed in the mouth-section of the alimentary canal, which is formed by an inward growth of the epiderm, and in Arthropods is lined by the same kind of chitinous skeleton as covers the outside of the body.

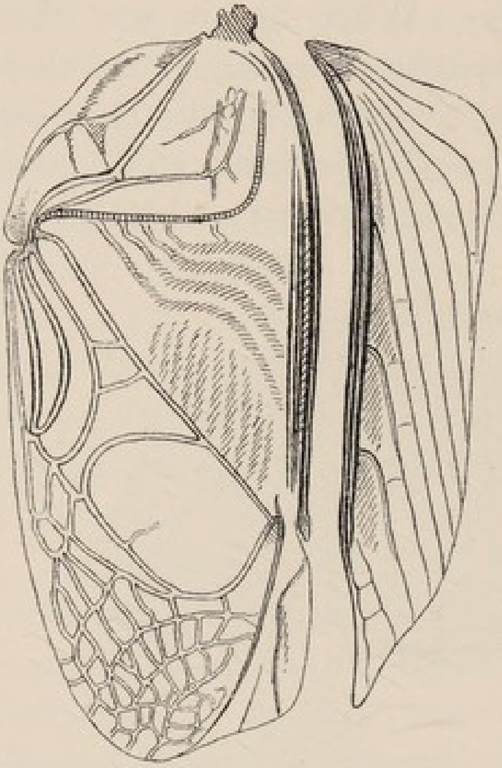

FIG. 41.—Wing-cover of male house-cricket. The lateral portion, which is bent down at a right angle, is separated. The file is shown as a bent line with cross markings, and just below it is the roughened triangular space, against which the file is rubbed; the resonator comes beneath this again. Magnified.

In the house-cricket both sexes are winged. The fore wings (wing-covers) almost conceal the folded hind wings, which project behind as two slender tails. Each wing-cover is adapted to the shape of the body, being broad and flat where it covers the back, and bent down at the sides as if hinged. When at rest, the right wing-cover usually overlaps the left. All this is the same in both sexes, but a closer examination shows that the pattern formed by the veins differs. In the female the wing-cover is covered by a radiating system of veins, not unlike that found in the male cockroach, but in the male cricket the veins are curiously distorted. There is a large space nearly clear of veins, which appears to act like a sounding-board or resonator. The microscope shows, near the junction of the basal third with the rest of the wing-cover, a strong bent vein starting from the inner border, and this is seen to be set with innumerable cross-ridges, like a file. When the cricket chirps he slightly raises the wing-covers, and rubs them rapidly together. The file of one wing-cover plays upon a roughened triangular space, just behind the file of the other wing-cover, and sets up a squeak, like that of a fiddle-string touched with the bow. The vibrations produce a trembling movement in both wing-covers, and it is probable that the clear space becomes strongly agitated and enforces the sound. Usually the right wing-cover plays upon the left, but the action can be reversed. An imitation of the natural sound can be produced by moving the wing-covers of a fresh-killed cricket with a pin. In the female file, roughened surface and resonator are all wanting; hence she is dumb, and unable to return the call of her mate.

FIG. 42.—Part of the file of male house-cricket, highly magnified.

In the large green grasshopper (not really a grasshopper) of the south of England the sound is produced in much the same way, though the details of the mechanism are changed. But in the common grasshopper, which is a totally different insect, belonging to another family, the outer surface of the wing-cover is rubbed against the inner surface of the thigh. A row of minute projections on the thigh plays the part of the file of the cricket, and when rubbed against the sharp edge of a prominent vein, throws the wing-cover into active vibration.

Many insects of the most diverse kinds are able to produce sounds. The commonest way is to rub a surface roughened by close-set ridges against a projecting edge, and the surfaces made to play one upon the other may belong to almost any part of the body; legs, body-segments, palps, proboscis, wing-covers and wings may be employed for this purpose. In particular cases organs so important as the wings or hind legs are altogether devoted to sound-production, and rendered useless for ordinary purposes. Sometimes it is the vibration of the wings which sets up a musical sound, such as constitutes the signal to the mate in many flies. Other insects are able to produce sounds by tapping dry leaves, or the wood in or upon which they lurk (see p. 226). No clear case is recorded in which an insect produces a sound by the emission of air from any part of the respiratory system, and the mouth is never concerned.[1]

The chirp of the male cricket is no doubt meant to be heard, both by himself and by some other cricket, most probably a female. In a few Orthoptera the female replies to the chirp of the male by a sound which is much less distinctive and prolonged. Signalling backwards and forwards by rasping sounds implies the possession of ears or some kind of auditory organs. Where are they to be looked for, and what is likely to be their nature? I suppose that most of us would think the head of the cricket the likeliest place to examine, and the examples of the higher animals suggest that the auditory organ may turn out to be a tense membrane with a special nerve passing to it, such a membrane in fact as the drum of the human ear. There is no membrane on the head of the cricket which can possibly be taken to be auditory, but by searching the body through, membranes which conform to our notion of an ear can be found. They appear in a very strange place, viz. on the fore legs, near

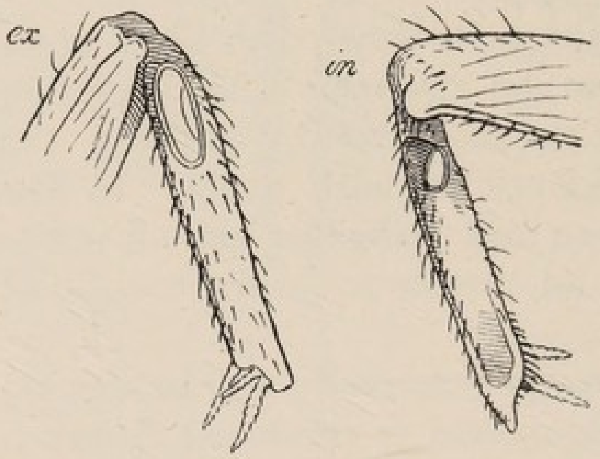

FIG. 43.—Fore tibia of house-cricket, showing the auditory membranes. The outer surface is marked *ex*, and the inner surface *in*.

[1] Examples of many cases of sound-production by insects can be found by consulting the index to Dr. Sharp's Insects (Cambridge Natural History) under the headings of Sound-production, Stridulation, and Phonation.

the top of the joint which is called the tibia. Here are two oval membranes of unequal size, the larger being on the outer surface and the smaller on the opposite one. If the tibia of the cricket is mounted whole in canada balsam, both will be seen together when the part is examined with a lens. A large nerve with a ganglion on it is found within the tibia, and the structure of the parts strongly suggests that they are useful in hearing. The organ of hearing occurs in both sexes; the male cricket hears the sound which he produces, and the female hears the call of the male. Many insects which emit sounds have similar membranes, either placed in the tibia of the fore leg, as in crickets, or near the base of the hind leg; in fact, when an insect utters a sound audible by man, its own auditory organ can generally be pointed out. It ought not, I think, to surprise us greatly that there are a good many insects which have the supposed auditory organ without any known means of producing sound. They may utter sounds which are audible and full of meaning to one another, but beyond the range of the human ear. Besides it may be necessary for them to perceive sounds which they are unable to produce.

Nothing has been said of the two jointed tails which stick out from the hinder end of the body in both sexes. Possibly they are feelers which protect the hinder part of the body when the head is busy guarding the mouth of the hole, and other uses have been suggested.

I should like to leave the inquirer into insect-structures something to investigate without help, and I can think of nothing better than the ovipositor or egg-laying forceps of the female cricket. It is mechanically interesting on account of its perfect adaptation to the end in view; it is not too minute nor too elaborate for the student who has only low magnifying powers at command, and lastly (this will be a spur to some minds) it has never, so far as I know, been completely and intelligently described. I hope some day to read such an account of it as may deserve to be called complete and intelligent, and to see the kind of illustrative figure that would make its action plain; it is needless to say that the interest would be heightened, to me at least, if the describer should turn out to have been incited by the hint with which I now close my account of the house-cricket.

XXXV. COMMON TREES.

HOW TO TELL THE COMMON TREES.

To be able to name the common trees at sight is a necessary part of nature-knowledge. Country-bred children learn to tell the trees as easily as they learn to tell the faces of their neighbours, but town-children often grow up totally ignorant of them, missing thereby a piece of useful knowledge, and a capital lesson in observation.

Every naturalist ought to know the common trees by their leaves, by their winter-boughs, by their buds, or even by a piece of the bark. He ought to be able to tell them at a field's length, and this either in winter or summer. If he should lack this familiar knowledge of trees, he would find it useful to compare the trees of his own country-side, one by one, with a description, and to do this both when the branches are in leaf and when they are bare. Those who do not know the names of the commonest trees, even in full leaf, are advised to take a country walk with some better-informed friend, who will be good-natured enough to name every tree that is passed on the road. Do not suppose that it is enough to hang up in the schoolroom a frame in which the leaves of the common trees are exhibited and named. Knowledge, supplied without effort on your part, does not stick.

Alder (Family of Catkin-bearers). A small tree, usually springing up on the banks of streams, the floating seeds being transported by water. An alder may be recognised at any time of the year by the old, black, woody cones, which remain on the tree after the seeds are shed. The catkins and cones of the next year are plainly visible throughout the winter, and may be found even earlier. The young twigs are sticky, resinous at a later time. Foliage rather dense ; leaves dark-green, broad, blunt-tipped, stalked, irregularly toothed ; buds set spirally, stalked, protected by two scales, resinous ; old bark black.

Poplars (Family of Catkin-bearers). Closely allied to the willows, as the catkins and capsules show. The poplars are often tall trees, especially the Lombardy poplar. Leaves broad, long-stalked, often springing in bunches from side-shoots. The chief groups of poplars are :—

(1) *Aspen-poplars.* The upper part of the leaf-stalk is flattened from side to side, and the leaf is on this account ready to quiver with the slightest breeze. All the leaves of a tremulous poplar do not quiver ; those which spring from the upper side of the branch are smaller, have short leaf-stalks, and move little. It is the lower, hanging leaves which quiver, and they are enabled to do this by the compression of the leaf-stalk in a direction perpendicular to the plane of the leaf-blade. When the lower leaves are agitated by wind they move chiefly from side to side, the leaf-surface facing the light all the time, but deviations from the rule are frequent. Possibly the shading of the lower leaves by the upper ones is thus avoided. The nectaries common at the bases of the early leaves of a poplar-branch are wanting in the tremulous leaves.[1] In aspen-poplars the leaf-buds are resinous and pointed, the flower-buds blunt. White poplar, which belongs to this group, has its leaves silky beneath ; old trunks of white poplar have a grey bark, with large transverse lenticels, reminding us of birch, and very different from the fissured bark of the next group, though the base of an old trunk of white poplar may be fissured too. In

[1] See Wiesner in Ludwig's *Biologie der Pflanzen.*

wind-swept places the aspen-poplar slopes regularly away from the wind, and the side-branches which spring from the upper side of the trunk are larger than those which spring from the opposite side.

(2) *Black-poplars.* Leaves quivering; buds and young shoots sticky; bark fissured. The Lombardy poplar runs up to a great height, and its branches ascend instead of growing outwards; hence the familiar fox-tail shape of this tree.

(3) *Balsam-poplars.* Leaf-stalks cylindrical throughout; leaves not quivering; buds and young shoots sticky.

Willows (Family of Catkin-bearers). We have many willows, which differ much in stature and in leaf-form. Some are big, much-branched trees; others are small trees, others upright shrubs, while a few are prostrate shrubs, found only at considerable heights on mountains. The tall and spreading species are the crack willow and the white willow. Pollard-willows are mostly white willows, which have been lopped at 8 ft. or so above the ground, and thus caused to send out a crown of young shoots. The sallow is a common hedge-tree, conspicuous in early spring by its many golden catkins. The osier is often cultivated for the sake of its pliant withs. The bay willow is a small tree, usually planted, and most frequent in hilly districts. All willows are diœcious, with completely separated flowers; they may bear either catkins or spikes of seed-bearing capsules, but not both. Leaves very various, often long, narrow, pointed and sessile (without leaf-stalks); in the bay willow and the sallow they are stalked and rather broad; they are silky beneath in the sallow and osier; silky on both sides in young leaves of the white willow, the hairs of the upper surface being cast early. Buds set spirally, smooth, apparently protected by a single bud-scale, really by two scales joined together. Old bark fissured in most, rarely flaking.

Beech (Family of Cupule-bearers, with cupuled fruits). Branches often running out to a great length as slender, tapering shoots, pointing upwards, outwards or downwards, according to the part of the tree from which they spring. Foliage in sheets (connect this with the arrangement of the buds). Leaves thin, shiny, ovate, the veins parallel on either side, but set at an angle with the midrib; margin entire; often remaining on the boughs after withering, especially in young trees. Buds long and pointed, covered with shining brown scales, and set alternately to right and left of the shoot, at angles of about 45°. Old bark smooth, dark-grey.

Oak (Family of Cupule-bearers). Crown broad and compact, on a short thick stem, if growing in the open; branches stout and crooked, often bending at sharp angles; the chief branches of the crown almost horizontal, the leafy twigs often ascending, furrowed, and slightly buttressed beneath the buds; foliage scattered, in small bunches, standing out from the twig on all sides; leaves widening towards the tip, with sinuous margin, often remaining on the boughs after withering, especially in young trees; buds blunt and short, reddish, set spirally on the twig, often crowded at the tip, the scales numerous and crowded; old bark rough and fissured.

Common Elm (Nettle family). A tall tree, with erect stem, often branching little till near the top, where it sends out a close leafy crown with many upright branches; trees with big side-branches, however, are not rare. Crowded small branches are often given off from the main trunk and the larger branches, or sent up from the roots. The flowers appear in spring before the leaves; the winged fruits are conspicuous in June. The common elm seldom ripens seed in England, most frequently in the south-eastern counties, and there not every year. The twigs soon become fissured by expansion. Towards the extremity of a young twig many fine siliceous hairs clothe the bark.

Witch Elm (Nettle family). Differs from the common elm in the trunk, which branches much lower down and more freely, in the larger leaves, and in the fruit, which is less deeply notched, and bears the nut in the centre (in the common elm the nut is a little above the centre). The twigs stouter, not fissured, but smooth up to a diameter of several inches.

Ash (Olive family). A tall, handsome tree. Flowers in bunches, appearing before the leaves; staminate, pistillate, or with both stamens and pistil; the large, dark-purple anthers are often conspicuous. Fruit of bunches of winged nuts, ripening in autumn, and dispersed in winter. Some trees fruit abundantly, while others never fruit at all, so that there is a tendency to separation of the sexes. Twigs stout, greenish, smooth, with buttresses below the leaves or buds; often upturned at their ends. Leaves appearing late and falling early, in opposite pairs, pinnate, with 4–7 pairs of leaflets and an odd one; the segments acute, the margin toothed. In autumn and early winter the bare leaf-stalks and flower-stalks often stand out prominently for a time. Buds in opposite pairs, or terminal, dark brown or black, scaly, the scales of the terminal buds keeled. Old bark greenish, fissured.

Horse-chestnut (Maple family). A tall, bell-shaped tree, when undistorted. Twigs stout; leaves in opposite pairs, digitate, usually of seven leaflets; buds in opposite pairs, with a large terminal bud, scaly, and sticky near the time of bursting; old bark rather smooth, grey.

Sycamore-maple (Maple family). A tall, shapely tree, with rounded crown and horizontal foliage-masses (not true foliage-sheets with the leaves in one plane) on the lower boughs. Green flowers in hanging bunches in early summer, succeeded by winged fruits attached to each other in couples, the wings being set at an angle, often a right angle; the fruits dispersed by wind in autumn; leaves large, 5-lobed, palmate, in opposite pairs; buds large, in opposite pairs, scaly, the terminal bud often larger; old bark smooth, dark-grey.

Hedge-maple (Maple family). A small tree, differing from sycamore-maple in having its flower-branches erect, the wings of the double fruit in the same straight line, and the bark rough.

Sycamore-maple, hedge-maple, horse-chestnut and ash are the only common trees with opposite leaves. Horse-chestnut and ash have completely divided leaves, and may be at once distinguished by this mark from the other two.

Lime (Lime family). A tall, freely branching tree. The flowers, which appear in June or July, are scented and abound in honey; they are furnished with a long bract, which facilitates dispersal of the fruit by wind. Foliage dense, in sheets (connect this with the arrangement of the buds); leaves heart-shaped, with drawn-out tips, often unequal-sided, the margin finely serrate; buds two-ranked, alternate, somewhat pointed; old bark remaining smooth for a long time and showing the lenticels.

SOME COMMON CONIFEROUS TREES.

Coniferous trees are nearly all evergreen, and have their seeds concealed in scaly cones. Each scale usually consists of two parts, a fertile scale, in contact with the seeds, and just beneath this a cover-scale. One of the two parts may be wanting or small, or both may be well-developed and appear on the surface of the cone. Besides the ordinary branches, which lengthen indefinitely, small spurs may be formed, which remain very short and bear a small number of leaves.

The Scotch Fir has needle-shaped leaves, which spring in pairs from the leaf-spurs. The cover-scales are very small, and do not reach the surface of the cone; the fertile scales are thickened at their free ends. The cone does not ripen till after the second year.

The Silver Fir takes its name from the silver-grey colour of the old bark. No leaf-spurs are formed; the leaves are flattened, and though really springing from all sides of the branch, become twisted into a horizontal double comb. The cones stand upright on the branches, and show the down-pointing cover-scales externally; the scales are not thickened. The cone ripens in one year. Silver Fir cones (unlike those of Scotch Fir and Spruce) break up when ripe.

The Norway Spruce or Spruce Fir is somewhat like the Silver Fir in general appearance. There are no leaf-spurs, and the leaves form a double comb. The cones hang downwards, and do not show the cover-scales externally. The fertile scales are not thickened at their free ends. The cone ripens in one year.

The Larch is most easily distinguished by its deciduous leaves. Leaf-spurs are present; the leaves are scattered on the young branches, and clustered on the spurs. The scales of the cone are not thickened. The cone ripens in one year.

The Yew has no leaf-spurs, and the leaves form a double comb. The flowers are completely separated, so that a tree bears only pollen, or only seeds. The cone contains a single seed, which is sunk in a fleshy red cup.

APPLE AND PEAR TREES (*Rose family*).

Most people, even if town-bred, can pick out certain trees as either apple or pear, but some fail to distinguish the two. The following marks will be of use, but do not hold good in every case.

Apple.	*Pear.*
A low, spreading tree.	A taller, more pyramidal tree.
Leaves woolly beneath.	Leaves not woolly.
Young twigs hairy.	Young twigs bare.
Flower-bunch spreads from a point (umbel).	Flower-bunch spreads from an axis (corymb).
Petals rosy outside.	Petals white on both sides.
Anthers yellow.	Anthers red or purple.

PLUM AND CHERRY TREES (*Rose family*).

Through these trees often look very different from one another, it is not easy to find a certain means of distinguishing them when not in flower or fruit. The plum has, I think, always hairs on the leaves, at least on the veins of the under side ; but the leaves of a cherry are perfectly smooth and shining. The long transverse lenticels on the brown shining bark are fairly characteristic of cherry.

NATIVE AND INTRODUCED TREES.

It is impossible to say with any certainty which of the trees usually planted in England are truly native, and would flourish here if man had never interested himself in the matter. In remote times the woods probably consisted exclusively of oak, beech, birch and Scotch fir, the beech being perhaps restricted to the chalk hills of the south of England. Ashes were probably dotted about the limestone hills. Alders followed the courses of the streams. Willows of several species flourished under a great variety of conditions and at all levels. There were plenty of hazel-copses on stony ground. Here and there a mountain-ash, a hawthorn, or a wild cherry would spring from a crevice in the rock, where a seed had once been dropped by a bird.

Under severe conditions oak outlasts nearly all competitors, by reason of the toughness of its wood and the open character of its foliage, qualities eminently advantageous in wind-swept countries. Birch is even better able than oak to endure storms of wind and rain. Its wood, though tough, is flexible, and the young boughs often hang down. Oak profits by its rigidity, birch by its flexibility. In the scantiness of its foliage, birch goes far beyond the oak.

Long before the oak and the birch give up the struggle, evergreen trees of a special kind come in. Their leaves are not broad, like the leaves of evergreen trees in Mediterranean countries, but small and needle-shaped, giving as little hold to wind and as little lodgement to snow as possible. The deciduous trees as the cold increases become dwarfed, and at length prostrate. On a hill-side in the Dovre or in Lapland, you will often find that the only trees are willows and birches, which do not rise nearly so high above the ground as the grass in an English meadow.

Sycamore, lime, the great willows and poplars, elm and witch elm are all more or less doubtful natives. Spanish chestnut, horse-chestnut and walnut, besides many others, are known to have been introduced by man. All our horse-chestnuts, for example, are said to be descended from a tree which was brought to Constantinople in 1557, probably from some part of Turkey. (See p. 61.)

XXXVI. THE HUMAN FACE.

Take a concave mirror, such as is now sold as a shaving-glass, and in this carefully survey your own face. The concave mirror enlarges any part of the face that you wish to study closely.

You will see that everywhere, even on the forehead and the ridge of the nose, which to ordinary inspection are quite bare, there are either hairs, or the little pits which mark the places of old hair-follicles. In most people, whether old or young, male or female, the cheeks are downy. I can often see exactly how far a man's razor reaches, for though the edge of the shaven tracts comes in a part of the face where hairs cannot be discerned by the naked eye, the downy part of the cheek reflects the light differently from the clean-shaven part. In human embryos the face is covered with plainly visible down, only the red edges of the lips being completely bare. At this time the whole body is hairy, except the palms of the hands and the soles of the feet.

It would be hard to explain the distribution of strong hairs upon the human head. The bare face was probably developed by sexual selection, those suitors being preferred who showed it most plainly, and this explanation may apply to all the other details. The recesses beneath and behind the jaw would naturally retain the hair longer, as other recesses on the body do. Perhaps the eyebrows and moustache are derived from the bunches of tactile hairs so often found in other animals above the eyes and the mouth. It might have been expected that the scalp, being prominent and exposed, would have become bare very early, but it has turned out otherwise, perhaps because the women did not like a bald crown.

Three points distinctive of the human face are the prominent nose, the prominent chin, and the hanging lobe of the ear. Hardly any ape or quadruped possesses one of them. I can only recollect three monkeys which have prominent noses. I do not think that we can give any physiological reason why man should have a prominent nose; certainly it does not indicate unusually keen scent, nor is the olfactory surface either so large or so sensitive as in many animals which have the nose blended with the upper jaw to form a snout. The Siamang Gibbon is the only ape which has even the rudiment of a chin. The hanging lobe of the ear is totally deficient in all animals except man and the gorilla; and in the gorilla it is very slightly developed.

Examine next the eye and its appendages. At the inner angle, next to the nose, is a red, wart-like fold, which exactly agrees in position with the third eyelid of many lower animals (nearly all quadrupeds, birds, higher reptiles). When fully developed, it can be drawn across the eyeball, and employed to cleanse it from dust. Animals which possess a third eyelid wink with it, and not with the upper eyelid, as we do. One proof that the eye-wart of man is really a vestige of the third eyelid has been furnished by careful dissection. Every functional third eyelid is supported by a thin cartilage, which forms the bulk of its substance. Now Giacomini has proved that in man, and more frequently in negroes than in Europeans, this cartilage is often retained. He found it to be present in twelve out of sixteen negroes whom he examined.

On the edge of the lower eyelid, not far from the inner angle of the eye, there can be seen a small but distinct prominence. Just above it, on the corresponding part of the upper eyelid, is another prominence of the same size. Your concave mirror will show you that each prominence is perforated by a small hole. The holes are the openings of canals, which soon unite, and open into a larger duct, this passes straight downwards, and discharges into the lower part of the nose. A watery secretion, discharged from the tear-gland, is employed to moisten the eyeball and eyelids, and wash away dust. The secretion, after bathing the parts, escapes through the ducts just described, leaving behind the dust, which accumulates in the neighbourhood of the eye-wart. The insensible flow of water escapes into the nose, but when irritation of the eye or strong emotion causes profuse secretion, the eye overflows, and we shed tears.

Sit so as to face a strong light, turn either the upper or lower eyelid outwards, and examine its inner surface; you will be able to see through a thin, transparent membrane the Meibomian glands. It is rather easier to see them in the eye of a second person. The glands look like white, beaded strings, and run at right angles to the edges of the eyelid; there are about thirty on the upper eyelid, and rather fewer on the lower one. Each gland opens separately on the free edge of the eyelid, and the openings may be made out with the help of the concave mirror. The glands are filled with an oily secretion, and it is supposed that they hinder adhesion of the lids, such as might be caused by hardened mucus. Is it possible that the oily secretion checks the overflow of the watery fluid which bathes the eyeball?

The face is a chief organ of expression, and we glance first at the face of a companion when we want to know the state of his mind. Even a dog will look into his master's face as if to read there the indications of satisfaction or displeasure, though our voice and gestures tell a dog infinitely more than the mere expression of our features can do. The signs of emotion are extremely varied, and shade into one another, so that a scientific classification is hardly possible. Strong feeling may show itself quite unmistakeably, and yet in a purposeless way, the physical manifestation having no power to alter the circumstances which excited the feeling. Thus we blush with shame, turn livid or green with fear, tremble with rage, catch our breath and become speechless with excitement. None of these involuntary bodily symptoms are serviceable to us, and they may be highly inconvenient. They are apparently due to mental disturbance acting through the nervous mechanism upon various sets of organs, and primarily the organs of circulation and respiration. There is a second ill-defined group of expressions and gestures which may be called incipient acts ; perhaps they were once purposive and useful, but now they have often become habitual or even instinctive. The wild man, like animals of other kinds, probably crouched to avoid danger or to show submission, drew back his lips and exposed his teeth when preparing to fight, opened his mouth wide and shouted when suddenly startled. In civilised society the emergencies of life are less imperious, and we can better control our feelings. Nevertheless we shrug our shoulders, that is, we begin to crouch, when in real or feigned terror, sneer by raising the upper lip a little, and open our mouths when surprised. Our savage progenitors were probably used to accompany any sudden fit of determination with muscular effort of some kind, clenching the fist, setting the foot firmly on the ground, or fixing the eye on a near object, and bringing down the eyebrows to exclude superfluous light. Even now, when we are displeased or intent upon some purpose, we sometimes clench our fists or stamp, but it generally relieves our feelings sufficiently to frown. The habit of scrutinising one another's faces soon gives a meaning even to these vestiges of acts and intentions. The incipient acts shade into a third class which we may call symbolic or conventional expressions. Nodding or shaking the head, and most of the gestures executed by the arms and hands are of this sort. They may become habitual and even unconscious, but they are most practised by those nations or individuals who habitually endeavour to express their feelings strongly, and thereby to influence their fellow-men. Smiling is a mode of expression whose origin is particularly hard to trace, but its significance has come to be entirely conventional.

XXXVII. LONDON PRIDE.

It would be hard to name a flower more characteristic of the town garden than London Pride. Better than almost anything else, it withstands smoke and shade, and its power of flourishing amidst mean surroundings somewhat damages the plant in our recollection. If we saw it only in its native haunts, and learned to associate it with rocks, the shade of trees, and the rush of water, we should more easily realise how beautiful it really is. London Pride belongs to the Saxifrages, a family which includes many plants cultivated for their good looks, such as the large-leaved and pink-flowered Siberian saxifrage (S. crassifolia), the Mother-of-thousands (S. sarmentosa), which is often grown in baskets, with its runners hanging down, and the Alum-root (Heuchera sanguinea), a Mexican plant with coral-red flowers. London Pride is native to the Pyrenees, Portugal and Corsica, and also grows wild on the hills of Killarney. It has been commonly grown in English gardens for some centuries, as old books on gardening show, but I am unable to give the date and circumstances of its introduction. It was formerly called "None-so-pretty," and "London Pride" is a name of later date. At Killarney it is called "Fox's cabbage."

The fleshy leaves of London Pride are clustered in rosettes. When old they contain much of a peculiar red pigment, soluble in water; this pigment is frequent in leaves and shoots which are much exposed to cold. New rosettes as they form are pushed outwards by runners, and it is chiefly in this way that the plant spreads. The flowers are carried in branched cymes. Both the flowers and the flower-stalks are defended by innumerable glands, which pour forth a sticky secretion, hindering the approach of ants and other small creeping insects. As in most saxifrages, the stamens ripen successively,

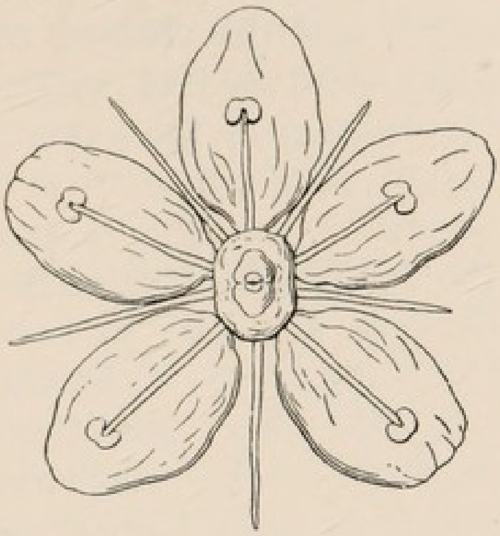

FIG. 44.—Flower of London Pride, showing the pistil, the ten stamens, half of which have lost their anthers, and the petals.

and when ready to discharge their pollen bend inwards, taking the position best calculated to dust an insect-visitor. The two stigmas are pressed together until the stamens have discharged their pollen, and self-pollination is thus avoided; nearly all saxifrages avail themselves of the same contrivance. London Pride is chiefly pollinated by a small fly, which is very common in gardens from early spring to late summer (Ascia podagrica, fam. Syrphidæ). This fly is less than a quarter of an inch long, dark-coloured, and recognised by the thighs of the long hind legs, which are thickened and distinctively

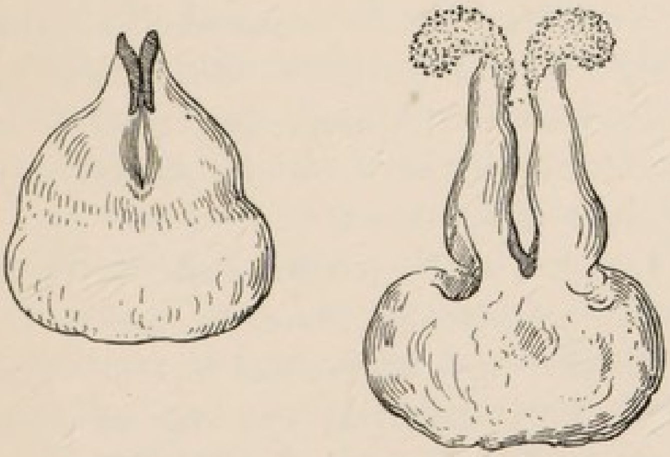

FIG. 45.—Pistil of London Pride, in side-view; on the left side the unripe stigmas are pressed together; on the right side the ripe stigmas are fully expanded.

coloured, being yellow at the base and black beyond. The colours of London Pride flowers are no doubt particularly attractive to this fly. To an Ascia the red spots on the petals and the crimson ovary glistening in the sun would look as attractive as sweetmeats to children. Quite at the bottom of the ovary each petal shows a pair of large yellow discs which to a microscopic eye would resemble honey-drops. The appearance is delusive, but before the fly discovers his mistake, his head is close to the real nectary, and here he finds his reward.

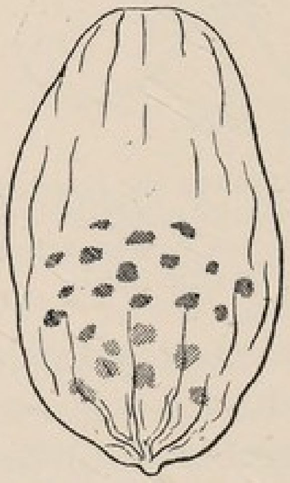

FIG. 46.—Petal of London Pride; the upper dots are red, the lower ones yellow.

Small, open flowers, growing many together, white or pale-coloured, spotted, and either scentless or giving out a scent which is disagreeable to man, are the usual marks of a fly-pollinated species. The umbel-bearers furnish many familiar examples. The flowers of Horse-chestnut, however, which are pollinated by bees, resemble in everything but size a fly-pollinated species, the colours being just the same as in London Pride. We have had occasion to remark that one saxifrage of our gardens, the purple or opposite-leaved saxifrage (see p. 87), is pollinated by butterflies, a circumstance which has strongly affected the form and colour of its flowers.

When the flowers of London Pride wither, none of their parts are shed, except the petals and stamens, and even these often persist in a dry and shrivelled state. The twin capsules of the fruit burst open at the top as soon as the numerous seeds are ripe. The dry flower-stalks are springy, and well adapted for throwing out the seeds in a high wind. When ripe fruits of London Pride were kept for a few days in a watch-glass set upon a large sheet of paper, it was found that the seeds simply dropped out, and were not shot off. Dry capsules with numerous small seeds are commonly emptied by rocking in the wind.

London Pride seeds are minute, elongate, black, and roughened by many projections. They sink at once when placed in water, and are therefore ill-suited for dispersal by streams. I have never known them to germinate in my garden, and suspect that they require a much damper soil.

XXXVIII. RARE SPECIMENS.

The gratified collector often sends to a journal an account of some rarity which he has just captured—a grass, a moth, or a bird's egg, and there is a little chorus of congratulation from his friends, especially if the rare object has been found in a new place. All this is perfectly natural ; and we have been accustomed to believe that such discoveries are gains to natural history, small gains perhaps, but deserving of recognition.

Where collectors are few, and the country in which they carry on their operations practically inexhaustible, no harm comes of their pursuit, but in a populous country like England, which has been diligently searched for more than two centuries, and where there is always a multitude to follow any leader, good or bad, it may be a question whether it is prudent to give glory to the naturalists who announce from time to time that they have added a rare specimen to their cabinets.

There can be no doubt, I think, that rare specimens become yearly rarer in consequence of the eagerness of collectors. Certain species of birds, butterflies, ferns and flowers, which are fancied by the collector have been altogether exterminated in places where they were once well established, and if things go on at the present rate we shall eradicate a good many species which have managed to survive so far, while we shall turn other species which are now moderately common into rarities. Years ago I knew of many uncommon flowering plants which were to be found by a diligent botanist in retired spots among the Yorkshire hills. But exchange clubs, and other societies which set an artificial value upon rarity, have come into play, and we now often find that the saxifrage or yellow star of Bethlehem that we have prized for years has been ruthlessly cleared out. The liberty that single naturalists can enjoy without damage to others becomes pernicious when it is claimed by large organised parties. It is no doubt desirable and necessary that parties of beginners should gather wild flowers and other natural objects, but why put into their minds the craving for rarities? The commonest examples that can be found are really the best for elementary teaching, and a naturalist who does not know the common things well can put the rare ones to no use.

In the name of science let us make it known that the worst thing you can do with a rare species is to bag it. The man who regularly enriches his own collection and cares about nothing else is not really a worthy member of scientific society; he is an enemy to natural history, and should be known as such.

The value of collecting as a means of promoting the study of natural history has in my opinion been greatly over-estimated. Ardent collectors are usually uninterested in every branch of their study which does not facilitate naming; they are seldom observers of the habits of living things, and they make few real, though many nominal contributions to biological science. Instead of helping to multiply naturalists of this type, let us try to make naturalists who will seek to understand a little better the plants and animals which come before their eyes every day.

The school-museum may be mischievous instead of profitable, if it keeps before the minds of the boys one ambition only, the ambition of making a large collection in which there are many rare specimens.

Some naturalists value the services of the collector because he helps to enlarge their lists of species. I have seen hardly any result from the lists of species which are printed so copiously, and doubt whether perfect catalogues of British plants and animals would compensate for the extermination of two or three of our native species.

XXXIX. OAK LEAVES.

The true shape of an oak-leaf can be recorded in several ways. Sprinkling and nature-printing are both easy and effective. Sprinkling I need not describe. Nature-printing can be done by any one who possesses a cyclostyle apparatus. Ink the leaf, just as the printer inks his type, and print from it by pressing the leaf against the paper with the finger. Printer's ink thinned with turpentine is better than cyclostyle ink, which is too oily. Drawing to scale is best of all, because it admits of intelligent selection of the most significant features.

There are three peculiarities of an oak-leaf which I invite you to consider:—(1) it widens from the base towards the tip; (2) it is unequal-sided; the midrib does not run exactly down the middle of the leaf, and one side is a little larger than the other; (3) it has a sinuous margin.

If you look at a leafy oak-branch, you will see that the leaves stand out on all sides. Looking endwise at the branch, they seem to radiate from a point, as in a rosette. In the case of radiating leaves it is convenient that they should be narrow at the base, where there is little room, and widen as they get further from their support. Some plants, such as dandelion and shepherd's purse, form leafy rosettes on the ground. Gather one or two, and see whether their leaves do or do not widen outwards.

An oak-leaf is unequal-sided because of the peculiar way in which it is packed in the bud. Take nine books, and arrange them in three concentric circles, each of three books. The books must stand tangentially and upright, resting on their edges, and every book should come opposite the interval between two of the books in the next circle, *i.e.* they should be set alternately. The covers of every book will represent the halves of a leaf folded in two. This rough model gives a good notion of the way in which oak-leaves are set in the bud, but the number is not always exactly nine, and other things besides leaves enter into the bud, which I omit for simplicity's sake. Now each leaf, being set in the manner described, will have one half facing the centre of the bud, while the other half will face outwards. The outer half will be less pinched for room, and will therefore grow bigger than the other. This is, I believe, the reason for the unequal-sided oak-leaf.

We have still to account for the sinuous margin. Lord Avebury, in his book "On Buds and Stipules," points out that though the leaves of oak and beech "are of about equal length, the buds of the oak are much shorter than those of the beech. The young leaves of the beech are able to lie straight in the bud; those of the oak have not room to do so, and are, consequently, bent somewhat like a bow along the midrib. Now, if the outer edge were straight, the result would be that when the young leaf emerged and straightened itself the edge must tear. This, however, is avoided by its being thrown into folds; and this, I believe, accounts for the lobes and bays so characteristic of the oak-leaf."

Oak-trees cast their leaves very late, and young oaks sometimes do not cast them till spring. All winter through the tree may bear brown, withered leaves, and in a very mild winter the leaves will even remain green till after Christmas. This is true, not only of our common oak, but also of the Turkey oak, which is not uncommon in parks and gardens. The beech, which is closely related to the oak, is another tree which when young keeps its withered leaves on the boughs. I sometimes fancy that this may be a vestige of the evergreen habit, which certain southern oaks, *e.g.* the evergreen oak, the cork oak and the gall oak still retain. Young trees, being sheltered in many cases by trees of greater stature, catch the wind less, and this may be the reason why young oaks and beeches keep their leaves through the winter more frequently than full-grown ones. Trees which do not cast their leaves at the approach of winter give a much greater hold to the wind, and have need of peculiarly tough and strong wood, such as oak and beech actually possess.

XL. HOUSE SPIDERS.

To give a plain account of the mode of life of any spider is no easy task. None of our native species are of large size, and the details of structure, such as the jaws, the eyes, or the spinnerets require the use of the microscope. Moreover spiders, especially such as make webs, generally work by night. Those which do not remain motionless by day are often hidden in corners where observation is difficult. Hence there are no animals equally common and equally interesting about which the untrained naturalist knows so little. It may be thought that these are good reasons for saying nothing about spiders in a book which is not meant for learned students. But the spiders force themselves on our attention. Only a very incurious person can be satisfied to remain quite ignorant of the house spider, or the garden spider, or the diving spider, and whatever the difficulties we must face them, trusting that even a beginner, without microscope or skill in dissection, may be able to learn some little about these most ingenious artificers.

The house spider usually makes an almost horizontal web in an angle between two walls. It prefers a cellar or outhouse to an inhabited room, not only because it loves peace, but because it thrives best in a damp situation. Spiders in general are fond of moisture, and their bodies shrink when they cannot obtain a due supply.

Several distinct kinds of spiders enter houses for shelter and food. Two of these are regular inmates and might be called the housemaid's spiders. The larger of the two (Tegenaria domestica) [1] may be over half an inch long, not counting the legs. Along the mid-line of its abdomen runs a brown stripe, and on either side of this is a row of pale dots on a dark ground. The second species (T. civilis) is a little smaller. Along the middle line of the abdomen is a row of black spots, and outside these the skin is speckled with black. Both of these spiders spin similar webs, and their habits are in all respects much alike. A third species (T. atrica) is distinguished by its much darker colour. Species of the spiders named Ciniflo, though regularly inhabiting crevices among rocks and other out-door retreats, are often met with in houses. They are nearly as big as the Tegenarias, but the upper surface of the abdomen is ornamented with a more intricate symmetrical pattern of light and dark brown, and the legs are usually mottled. Less commonly found than any of the above species are the small spiders named Liniphyia, which sometimes enter houses and make delicate webs, to the under side of which they cling.

The web of a house spider is secured by many threads, passing in different directions to fixed points, so that it can resist a pull from any quarter. The free border is strengthened by a thread of extra strength. The web itself is composed of multitudes of threads crossing in different directions without much arrangement. Well-fed house spiders continually add fresh threads to the original web, until it becomes firm and close, almost like tissue paper. Though artless in comparison with the geometrical snare of the garden spider, the web of the house spider is well adapted to secure a fly or other winged insect, buzzing about in a dark corner and unsuspicious of an enemy.

[1] So commonly named in English books. The true T. domestica does not occur in Britain. Our commonest Tegenaria is T. Guyonii, Guér.

Concealed by the web, and lying usually in the angle between the walls, is the retreat in which the spider lurks while waiting for its prey. It forms a short tube, secured by many threads both to the web and to the wall, and open at both ends. When threatened, the spider can leave its retreat by the further opening, and often has a favourite crevice in which to hide itself. The tube is both the home and the nest of the spider. Into this she drags her prey, and here she rears her young. In June or July, but occasionally much earlier in the year, the female spider weaves one or more cocoons of fine white silk nearly an inch across. Each cocoon is formed of two layers, the upper arched upwards and the lower downwards. Between the two she places about a hundred yellow eggs. The young spiders, when they appear, may often be seen crowded together in one part of the cocoon, while the empty shells from which they have escaped lie all around.

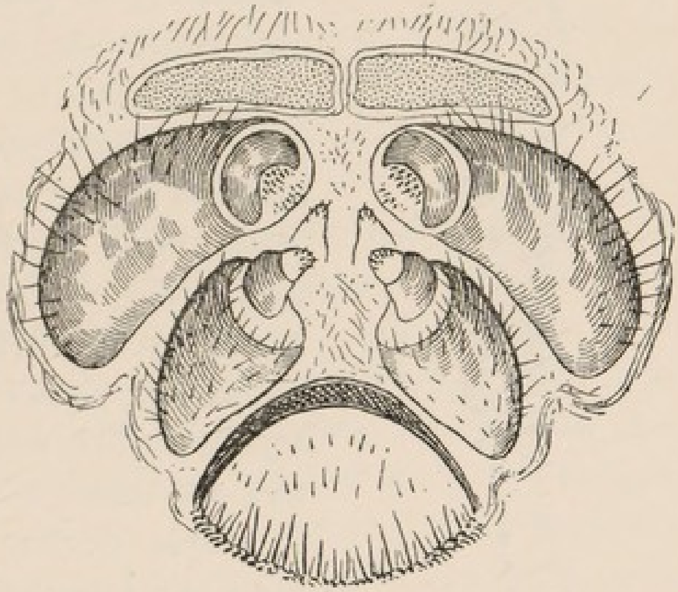

FIG. 47.—Spinning apparatus of Ciniflo, with four pairs of spinners.

The silk of which the web is composed is secreted by innumerable glands, and paid out from spinners, which project slightly from the hinder end of the body. In the house spider there are three pairs of spinners, which are jointed prominences, resembling stunted legs, and moveable in all directions. While spinning, the spider rubs the tips of the spinners together, and the thread issues from between them. When the tip of one of the spinners is examined by the microscope, a great number of spinnerets are seen, each mounted upon an enlarged base, and perforated by a fine canal. A separate thread issues from each spinneret, but all are blended into a single cord while still fluid, by the movements of the spinners. It is only when she is attaching her thread to its support that the spider allows the finest threads to come off separately. She spreads these over the supporting surface, in order to get a firm attachment by means of a multitude of distinct fibres. The hind legs are often employed to guide the thread as it is paid out. In certain spiders different spinners secrete different kinds of silk, but no such distinction has been remarked in the case of the house spider. Both male and female house spiders spin webs, and feed upon the insects captured thereby, but only the females construct nests. Male spiders are of lighter build, with relatively long legs, and are more active and more inclined to roam during the breeding season than the females. In spiders generally the colours of the male are darker and the spots less defined than in the female.

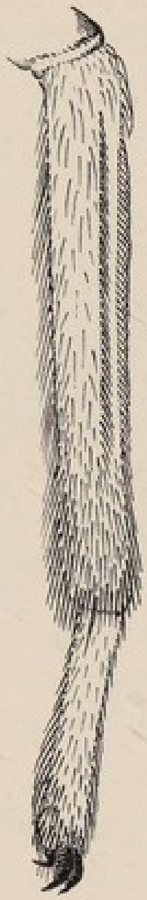

FIG. 48.—Extremity of hind leg of Ciniflo, showing comb (on last joint but one), and claws.

The spiders called Ciniflo, which are not uncommon in houses, have a comb of longish hairs on the last joint but one of each hind leg. The spinning apparatus is more complex than in any other spider, new and peculiar perforated plates being added to the three pairs of spinners; from these plates the comb, by a rapid vibratory movement, draws out innumerable threads at once. The curled silk thus produced is used to strengthen the web, and also to make the egg-cocoon.

House spiders now and then eat parts of their own webs, and it is supposed that they do so when pressed by hunger.

Sometimes, however, a spider will merely chew its own web without swallowing any part of it.

XLI. ON A CHALK HILL.

At our feet is a tidal river a mile wide. Close behind us are low hills crowned with beechwoods, which disclose here and there the front, or it may be only the chimneys, of a large country-house. Autumn cornfields lie on the slopes between the plantations, and spread over the plain beneath. Neat hedges, trim parks, and the frequent towers of village churches tell us that this is a country of wealthy proprietors.

The river, like all great rivers, carries our thoughts far beyond the plain through which it flows. To the east we see low on the horizon the smoke of a great port. Slow barges and now and then a sea-going steamer tell of busy inland towns which find here one outlet for their wares. The mud of the ebbing tide of the Humber has been washed from the hills of Yorkshire, Lincolnshire, and half the midland counties, and it is not only water and sediment that are carried out to sea. The river bears along the products of many a thriving English town ; we can follow them far beyond the horizon to the mouths of great rivers across the sea, the Meuse, the Scheldt, the Elbe and the Weser, which stand open to receive what we send, or to send what we are glad to receive.

The hills about us are chalk hills, as an occasional quarry shows. Even without the quarries no eye familiar with the wolds and downs of chalkland could mistake such contours as these. Towards the west we look down upon a flat plain with interminable fields and hedges, a plain of sand, marl, clay and gravel, out of which starts a bold ridge, all but the very base formed of chalk.

The chalk is here 600 feet thick, and dips gently towards the east. If it were possible to sail southward in a balloon and survey the country stretched out beneath us, we should see the chalk wolds standing up as a great step or ridge. They begin in the sea-cliffs of Flamborough Head, curve southward, and in the course of a few miles reach the Humber. Where we now are the depth of the chalk is so great that the river makes only a trifling notch in it, and the chalk spreads without a break into Lincolnshire, slants across the county in a south-easterly direction, dipping beneath banks of sand, clay and shingle some miles before the Wash is reached. Beyond the Wash the chalk rises again, covers a great part of Norfolk, and continues towards the south-west through Cambridgeshire, Hertfordshire, Buckinghamshire, Berkshire, Wiltshire, Hampshire and Dorset. The tertiaries of the Hampshire basin, though on the map they seem to cut the chalk in two, merely overlie it. It continues all the way beneath the surface, and reappears on the south coast of the Isle of Wight. In Kent and Sussex it has been upheaved, and the lower formations of the Weald rise through it, the chalk sloping away on all sides like the rim of a crater except where the sea and the issuing rivers have worn it away. In the south-eastern counties it has therefore both an eastern and a western escarpment, each showing a very irregular outline on the map. Beneath the straits of Dover the beds continue without known break into France, whither we shall not follow them. The strait is so shallow, only 150 feet in the deepest part, that it does not nearly cut through the chalk, here about a thousand feet thick. To the east of the great chalk ridge of England come tertiary and other deposits, which are soft and incoherent, forming no bold features. These occupy the low countries, Southern Hanover, Brandenburg and most of the great North-German plain, so that an Englishman who stands on the Gogmagogs or the Wolds knows that there is no higher ground to the east between him and Russia.

Chalk is not a hard rock, but it stands out of the plain before us almost as if it were of marble. Its resistance to weathering may be largely due to its porosity. All the rainfall is sucked in, and there is little or no surface-flow. A bed of clay on the contrary admits no water, and all the rainfall upon its surface contributes towards its waste.

I do not know how those people feel who have been bred in a country of soft tertiary rocks, where the hills are mounds, and the streams slow and muddy. Those who are native to a sterner tract cannot easily be happy long together without gazing upon hills which have a structure of their own, a structure which is brought out and not effaced by weathering. They like their streams to be rapid and clear, untinged by the bed over which they flow. I once spent a holiday in Holstein, a land of gentle hills, lakes and beechwoods, with here and there an old château. The country was pleasant enough at first sight, and furnished plenty of occupation to the naturalist, but its charm did not last. Not even the buckets of crayfishes, which with salad furnish the chief holiday diversion of the Holsteiners, could allay the impatience with which my companion and I came to long for a land of firm rocks. Such rocks do not abound in the neighbourhood of the Baltic, but we made our way to the little island of Möen, and there found sea cliffs of hard chalk, rising in places to 400 feet above the beach. The complicated folding and contortion of the chalk and its overlying beds, the pinnacles, the sheer faces looking seaward, and the wooded ravines satisfied the longing which Holstein had been unable to appease.

Gilbert White found something "peculiar, sweet and amusing in the shapely figured aspect of chalk hills." His favourite forest-tree, the beech, thrives best on these same hills, and the chalk-downs of Hampshire with their hanging woods of beech are among the chief delights of Selborne. Box, juniper and yew are other chalk-loving trees. Nowhere is the turf closer, or the thyme more fragrant than on a chalk-down. Our Yorkshire chalk is not so thick nor so soft as the chalk of the southern counties, and the hill-forms differ a little. The prominences are not so evenly rounded, and the gullies not so sinuous.

What is chalk, and how was it made ? I do not venture to tell that story after Huxley's lecture on a Piece of Chalk, which is accessible to all readers. We know or can easily get to know that chalk is a calcareous paste, formed on the floor of an ancient sea, that it is very similar in microscopic character to the Atlantic ooze, which now overspreads the almost level ocean-floor between Ireland and America ; and that it consists, like the ooze, in great part of the shells of Foraminifera and minute calcareous seaweeds. The chalk is more purely calcareous than the Atlantic ooze, and was probably formed in shallower water.

How long is it since the chalk was formed ? We have no measure for such intervals of time, and all estimates are misleading. Some have measured the thickness of such a formation as the chalk, *guessed at* its rate of formation, and then by rule of three figured out the time required for its formation. Except by such methods we have no means of conjecturing when the chalk began to form, nor how long its formation was in progress. It will be more useful to apply a test of antiquity which attempts no arithmetical precision whatever. The chalk is the latest product of what may be called the mediæval period in geological history. The modern period, and especially the later divisions of the modern period, are marked by the occurrence of animals which are yet living. The fossils belonging to the latest of these divisions include many quadrupeds which still live ; going further back, the quadrupeds disappear, and are replaced by strange forms. The shells change much more slowly than the quadrupeds, but as we trace the life of successive periods and divisions, we find that the shells too change with some regularity. In the later tertiary formations a majority of the shells are recent; in the earlier tertiary deposits we find the proportion of recent shells gradually falling to 50 per cent., 10 per cent. and 3 per cent. But in the chalk all the mollusca are extinct, and we have to get very low down in the animal kingdom, to infusorians and Foraminifera, before we can find species identical with those which still survive.

The lapse of time since the chalk was laid down may be roughly estimated in another way. Europe has been reconstructed since the chalk-time. During the formation of the chalk a great sea stretched from east to west across what is now Central Europe, extending from the British Islands to Sweden, France, Germany and Russia. The Alps, Pyrenees and Carpathians did not as yet exist, for we know that a thick bed of limestone, younger than the chalk, runs through all these mountain-ranges. When we have said that the chalk is older than all existing species of animals except the very lowest, and that it is older than Europe, we have said all that can be demonstrated concerning its age.

What might we expect to have seen if we could have stood on some hill-side in these latitudes while the chalk was being laid down in the neighbouring seas? The reader must not look for any description such as Hugh Miller used to shape in his eloquent words when a good occasion offered; next to nothing is known of the land-life of the chalk-period. When we have said that there were flying reptiles, great reptiles that browsed upon foliage, toothed birds (in America if not in England), some insects, some conifers and some ferns, we are almost at the end of our information. Few indications of land-life are indeed to be expected in rocks deposited beneath the sea, and as the secondary formations are nearly all marine, it is not surprising that from the coal-measure time to the early tertiary period our knowledge of the course of life on the land should be almost a blank. Of the reptiles, fishes, shells, sea-urchins, starfishes and corals of the chalk-sea much is known, but the forests of the secondary age and the animals which inhabited them have not been revealed to us.

All men are now agreed that the matter of which these chalk-hills are composed was laid down at the bottom of the sea; that the fossil remains of the chalk belong to extinct species; and that the chalk-hills have taken their present form in consequence of the waste of rain and rivers. What long and bitter controversies these simple inferences from observed facts called forth, controversies which lasted down to our own time! Rather than accept such propositions, men could be found to maintain that the earth with all its rocks and fossils was formed at once, just as it stands; that the fossils are not the remains of real animals, but the result of a "formative tendency," whatever that may be; and that the chalk was raised into rounded hills by a kind of effervescence or fermentation. One is inclined to say strong things about those who, even when the facts were forced upon their notice, tried to escape from unwelcome truth by hypotheses so preposterous, but when we run over the names of the naturalists, physical philosophers and historians who proposed explanations like these, we see that it is prudent not to use harsh words. The history of scientific progress warns us that we too may be unconsciously entertaining delusions just as laughable. Let us abstain from reviling those whose delusions have been found out, and pray that when our turn of trial comes, we may not be so unlucky as to be obstinate on the wrong side.

Chalk, when free from surface-deposits, makes dry hills, yielding pasturage for sheep, and often nothing more. Much hygroscopic water, that is, water which is not free to flow, is nevertheless lodged in the capillary spaces of the surface-chalk, and this keeps the vegetation green. Scantiness of water is one chief reason why there are so few towns on the chalk, and why all the large ones have some means of subsistence other than agriculture, such as sea-bathing, a seaport, or a navigable river. The clays and gravels above the chalk, the upper greensand just below it, the impervious gault-clay, and in many places the lower greensand also, are better supplied with water, and are often very fertile. On these beds or close to them are situate most of the market towns which supply the chalk district.

London is encircled on nearly every side, and also underlain by chalk. To the south lie the Hog's Back and the North Downs, while far away, beyond the Weald of Surrey, Kent and Sussex, stretch the South Downs; all these are chalk hills. The beechwoods of the Chilterns slope upwards to the north-western escarpment of the chalk, and the rambler finds them so shady, still and lonely that he is startled when the milestones tell him how near is that vast city which he has been glad to forget a while. The chalk-land of the Chilterns is John Hampden's country; the chalk-land of Lincolnshire is Tennyson's country. Here on the chalk-hills of Yorkshire stood the palace of Edwin, here Paulinus preached, here the aged ealdorman spoke of human life and of the sparrow flitting from door to door through the warm house, and here Coifi profaned his own temple. Salisbury Plain, Shakespeare's cliff, the sea-worn pinnacles of the Needles, Beachy Head, and the low river-cliff on which Windsor Castle stands, all owe their existence to the chalk. In old days England was thought by foreigners to be a land of chalk. The merchant who landed in Kent, Sussex or Hampshire, and made his way to the capital, saw while yet far from shore our white cliffs, travelled on white roads through sheep-walks and cherry-gardens, and often returned home with the impression that all the rest of England was chalk too. Some modern travellers, like Taine, have gone everywhere by railway, and give their readers to suppose that a great part of the England of to-day is covered with cinders. The Englishman of course knows well that the chalk-downs are but a small part of his well-endowed island. We have a great tree-growing belt, once part of an unbroken forest, which extended from Dorsetshire to the Humber, broad cornlands, moorlands containing beneath their unpromising surface vast supplies of fuel and metal, and marshlands, which might be made as rich as Holland were they tilled with the same care. Britain, it has often been remarked, is an epitome of the geology of Europe, for it has a bit of everything, and abounds especially in all that makes man rich. Britain was first enriched by wool, then by corn and cloth, then by coal and iron. Besides all these gifts of nature, the sea makes a road for us to the remotest corners of the world. We occupy the centre of the land-hemisphere, and are yet so placed that we are invited to send forth our fleets upon the broad Atlantic. The seas are at once our defence and our highway. Beyond the ocean have arisen great nations which speak our language and inherit our institutions. No change of policy or fashion, no discoveries of science that we can foresee will neutralise the advantage of a position like this.

It is probable, almost certain, that when man first entered Britain it was still joined to the continent. There was then no Strait of Dover, and the Kentish downs made one range with the downs of Picardy. When and how was Britain cut off from the mainland ? As to the *when* we know some little ; it was later than the establishment of our present fauna and flora, which hardly differ except in their deficiencies from the fauna and flora of Europe. As to the *how* we need invoke no sudden operation of unknown forces. The sea, fretting the chalk cliffs both on the side of the North Sea and also on the side of the Channel, would make just such a shallow trench as now separates Dover from Calais. That shallow trench has controlled the whole political history of Britain. It made the permanent government of Britain by foreign nations impossible, and invasion so difficult that it has not been seriously attempted since the days of King John. While neighbouring nations were forced to sacrifice freedom and all else for the sake of military efficiency, we were able to keep our ancient parliaments, and put a much-needed check upon our kings. Let us not be over-proud of our virtues, for geological and geographical accidents have had much to do with the prosperous history of England.

XLII. FURNITURE-BEETLES, BOOK-WORMS AND DEATH-WATCHES.

In the days of timber-built houses much loss was caused by the borings of small beetles, which riddled the beams, floors and wainscots, and often spoiled the furniture as well. Now that we build with brick and plaster, and paint exposed surfaces of wood, the ravages of these insects have been lessened to such a degree that few houses contain the worm-eaten timber, which was formerly so common and so vexatious.

An attack of furniture-beetles is indicated by round holes in the wood, and little heaps of fine dust thrown out from them. The round holes lead to cylindrical burrows, which may run far beneath the surface, and in bad cases the strength of the wood is impaired. The hardest and driest wood is not safe, for boot-lasts, and the legs of chairs daily warmed before a fire have been attacked. It is the larva of the beetle which does the mischief. This is a whitish, soft-bodied grub, whose body is curved like that of a cockchafer-larva. Its head, jaws, and small legs are the only hard parts, and also the only parts which show a distinct colour.

Observation of other insects might enable us to predict that the growth of any larva which feeds upon dry wood will be slow. Hardly any poorer stuff for food can be found, but the supply is inexhaustible, and the larva runs no risks. A furniture-beetle has been known to pass three years in the larval stage. Contrast with this the history of a leaf-eating larva. Here the food is both more nutritious and easier of digestion; the time during which it can be procured is limited to the warm season, and many enemies await the larva. Its best policy is to feed without intermission, and get the dangerous growing period over as soon as possible. We have seen that the larval stage of a furniture-beetle lasts three years, and subterranean, root-eating larvæ, such as wire-worms, may go on feeding as long or even longer. But the leaf-eating larva of the turnip-beetle is full-fed in a week.

When the end of its protracted feeding-time draws near, the grub of the furniture-beetle prolongs its burrow nearly to the surface of the wood, and here it is said (I cannot vouch for the fact) to spin for itself a cocoon of silk interwoven with particles of wood. Then it pupates, and in due course the beetle emerges, the thin barrier of wood, which was left as a protective covering to the burrow, being easily broken down. The beetle is 3 or 4 mm. ($\frac{1}{8}$ to $\frac{1}{6}$ in.) long, and of a dull brown colour, varied on the sides of the body with greyish hairs. The head is bent downwards and sunk into the prothorax, which covers it like a hood; it does not appear when the insect is seen from above. The legs can be tucked under the body, so that it is a simple matter for the beetle, when alarmed, to sham dead, its rounded shape, inconspicuous colour and complete immobility allowing it to pass for a mere pellet.

The beetles often strike the wood of their galleries with their heads, and so produce a ticking sound, which is a call to the mate. The ticking is most frequent in the summer months, but in warmed rooms it may be heard at any time of the year. The commonest of our furniture-beetles is called Anobium domesticum (or striatum); this is the beetle whose dimensions were given above. Another species, which is nearly twice as long (Anobium tesselatum), has very similar habits, and is the beetle which has most frequently been heard to tick. In the dead of night this ticking sound, distinct but inexplicable, strikes the mind with a vague terror, like the sudden cracks of dry timber, or the dripping of unseen water, and what is really no more than the call of a minute beetle has come to be feared as a warning of death; hence the name of *death-watch*, given to the Anobiums and some other insects, which make a noise like that of a watch. The late Frederick Smith of the British Museum tells us that, having received two live examples of Anobium tesselatum from Mr. Doubleday, with full instructions, he tapped the table several times in rapid succession with a lead pencil, when the beetles raised themselves on their front legs, and bobbing their heads up and down, struck the bottom of the box in which they were kept with their mandibles. This performance he could set up almost at pleasure; the number of the taps was usually four or five.[1] In the state of nature the furniture-beetles excavate living or dead trees, usually running their galleries in the sap-wood.

"Notwithstanding the obscurity and retirement of their life, these wood-boring beetles have not managed to escape the attacks of parasites. Several species of ichneumon-flies and other allied insects prey upon them; and the delicate little gauzy-winged persecutors may sometimes be seen running about hither and thither over Anobium-infested wood, in maternal anxiety to find a suitable *nidus* for their brood. Some, too large to enter the burrows, are furnished with a long ovipositor with which to reach their victims, into whose bodies they insert their eggs. Others are small enough to enter the burrows bodily, and hunt their prey like a ferret after a rabbit. One of these latter, *Theocolax formiciformis*, superficially something like a minute ant, in consequence of the absence of wings, I have obtained in considerable numbers from a colony of *Anobium domesticum* which had established themselves in an old aquarium stand."[2]

[1] *Ent. Month. Mag.*, May, 1867.

[2] E. A. Butler, *Our Household Insects*, p. 11 (1893).

Anobium paniceum, one of the furniture-beetles, is also the weevil which devours ship's biscuit, it attacks all sorts of vegetable substances, wood, paper and drugs of various kinds. There is another furniture-beetle which now and then commits great ravages, especially in our southern counties; this is the Ptilinus pectinicornis. It is of the size of Anobium domesticum, and distinguished from it by the antennæ, which are long and plumose in the male, shorter and simpler in the female.

The grub of Anobium domesticum is not only a devourer of wood; it eats paper as well, and is one of the so-called "bookworms." Its burrows may extend from one neglected book to others on the same shelf, and Peignot has recorded an instance in which twenty-seven folio volumes placed side by side on the shelf were drilled by one larva, so that a string might be run through the hole and all the volumes raised by the string. It is rare to find so straight a gallery as this, but we may often find tortuous galleries several inches long. It is chiefly old books which are injured in this way. The general use of chlorine-bleached paper, though a cause of decay in other ways, and the substitution of cheaper materials for linen-rags, have probably checked the ravages of bookworms.

Several sorts of insects and a few animals of other classes deface or destroy books. Furniture-beetles bore into the covers, besides running their galleries through the piles of unreadable pages. Cockroaches nibble the binding, and now and then the edges of the leaves. Silver fishes gnaw the binding, and leave characteristic sinuous tracks. When the paper has been printed, they leave untouched the inked parts, so that a printed page becomes a tattered skeleton. A small mite (Cheyletus eruditus) has sometimes been found in numbers among books which have been stowed away in damp places, but it is really of carnivorous tastes, and feeds, not on the paper, but on small creatures which lurk in the books. A Chelifer, which may be briefly described as a minute tailless scorpion, is also to be found among neglected books, where it pursues its prey.

So many insects attack large collections of books, and so great is the damage done by them, that it is part of the professional education of the librarian to know the marks by which the different kinds are recognised, and the methods of extermination appropriate to each. Fifty or sixty book-destroying insects and mites have been catalogued, and books have been written to describe them, and explain how they are to be combated.[1]

Just as there are several different kinds of bookworms, there are several kinds of death-watches. Small insects (Atropos), belonging to the family of Psocidæ, and believed to be allied to White Ants, make a ticking very like that of Anobium. Two species of Atropos are common in our houses, frequenting dusty recesses, neglected straw, old papers, picture-frames, &c. They are often found on wall-paper. Both are so small as to require a lens to identify them. One kind (A. divinatoria) can be recognised by the vestiges of wings, which project as scales from the middle of the thorax; it has larger eyes than the other species, its length does not exceed 1 mm., and the legs of the third pair are much dilated at their bases. The second kind (A. pulsatoria) is larger (nearly 2 mm. long), devoid of wings, and its eyes are minute. It is this second kind of death-watch which makes such havoc in neglected collections of insects. Both divinatoria and pulsatoria produce a ticking sound, which is liable to be mistaken for the call of an Anobium. It has been said that Atropos has no structures in its body sufficiently hard to produce an audible sound, and that even when the ticking sound is heard and the Atropos discovered, it is really an unseen Anobium from which the sound proceeded. But the

[1] Blades on *The enemies of books* is a well-known English treatise. The latest study of bookworms is Dr. Houlbert's *Insectes ennemis des Livres*, Paris, 1903.

testimony in support of the ticking of Atropos is too strong to be overpowered by mere opinions as to what it can or cannot do. One of my friends, a very keen observer, traced the ticking sound on five different occasions to an Atropos, and in each case as soon as the insect was removed the sound ceased. If we are to retain the name of Death-watch at all, we must recognise that it has no scientific value. There are several species of ticking insects, and they belong to widely different groups.

It is not difficult to abate the attacks of these small insects, and to stop the destruction of furniture as well as the ticking sound. The infected object must first be discovered, and then an appropriate treatment can usually be devised. It is often most convenient to apply strong poisons in the form of vapour. If the infected object can be placed in a tightly closed case, together with a saucer of carbon disulphide or benzine, and left for a few days, the beetles and their larvæ will be killed. The eggs, however, are not necessarily destroyed, so that watchfulness is necessary to prevent a recurrence of the attack. In some cases it is possible to wash the object with benzine, or to plug the holes with furniture polish. Heat is very effectual, if it can be safely employed; a temperature of 80° C., maintained for some hours, destroys insects, larvæ, and eggs alike.

XLIII. PHASES OF SUMMER AND WINTER IN ENGLAND.

The months may be grouped in a variety of ways, each with advantages of its own. To the naturalist the most important primary division is into summer and winter, the leafy and the leafless seasons. If we seek to subdivide each of these, we shall find that bisection will not do; the solstitial periods cannot be halved. But a natural and useful division into three can be obtained. In this way we get six phases, which may be characterised as follows :—

EARLY SUMMER (April to June) is usually a time of light rainfall. Crowds of flowers of the same kind, such as bluebells, red campions and buttercups, bloom at once. Singing birds fill the air with their music. Flying insects are few, and cause little annoyance except near pools of water.

In MIDSUMMER (June to August) the heat and the rainfall on an average of years reach their maximum, though there is often a second maximum of rainfall in October. Flowers show their greatest variety; many trees put forth their July shoots. Songsters are very few. Insects of all kinds abound; this is the principal Aphis-time.

LATE SUMMER (August to October) begins about St. Bartholomew (Aug. 24), which, according to the proverb, brings the cold dew. Stationary, low-lying mists are common after sunset and before dawn. Calm, clear weather, with some haze, often prevails for weeks together. Many soft fruits and most of the small fruits ripen; thistle-down and other plumed fruits are dispersed. Nearly all the birds are mute. Flies, especially in a hot year, are abundant and troublesome. Gossamer may be seen more frequently than at any other time of year.

EARLY WINTER (October to December) is usually wet and foggy; cyclonic weather often prevails, and the rivers are in flood. Next year's buds are already fully-formed on the trees. Nuts and many hard fruits ripen and are dispersed. The summer migrants depart. Insects are few.

MIDWINTER (December to February) is the time for frost and snow. Vegetable and animal life is nearly at a standstill. Winter migrants arrive now or in early winter.

LATE WINTER (February to April) is usually a time of dry cold; the rainfall minimum is to be expected. The buds on the trees swell; catkins expand. Early spring-flowers bloom, being nourished by stores of food laid up in the preceding year. Summer migrants appear. Tadpoles are hatched. Humble-bees, with a few beetles and flies, are almost the only insects to be seen abroad.

Precision of date in the six phases is not to be expected. They begin approximately in the middle of April, June, August, October, December and February, lagging considerably behind the chief events of the astronomical year. Leafage comes about a month after the spring equinox; the maximum of vegetation and insect-life about a month after the summer solstice; defoliation about a month after the autumn equinox; while it is not till two months after the winter solstice that the annual cycle of growth can be said to be fairly set going again.

The traditional four seasons are convenient for most purposes, and it is only when a rather more precise subdivision is desired that six *phases* (so-called to prevent confusion) can be usefully distinguished.

XLIV. THE GARDEN SPIDER
(Epeira diadema).

Between the gorse bushes on a common, or the clumps of heather on a moor, or in the openings between the bushes in a garden, we often see a large and nearly vertical net with many radii, and what we may take at a first glance to be circles intersecting the radii. If there has been dew or fine rain, the net becomes much more conspicuous, because of the small drops which cling to it. In the centre of the pattern a large spider will probably be seen hanging head downwards. She is of chestnut or dark brown colour, speckled with whitish spots, and on the back of the abdomen a white cross is plainly to be seen. There are many species of Epeira, but only one shows the white cross.

A pocket-lens is sufficient to show the details of the garden spider's head. It is blended with the following division of the body (thorax), as in all spiders, and shows two sets of instruments, eyes to discern the prey, and jaws to grasp and devour it. The poison-fangs (cheliceræ) are two-jointed, and close up like a clasp-knife, each of the meeting edges being armed with sharp teeth; the duct of the poison-gland opens near the tip of the terminal joint. Behind the poison-fangs comes a second pair of jaws, which look more innocent, since they end in jointed and hairy palps; the base of each is shaped into a cutting blade opposable to its fellow, and useful in mastication.

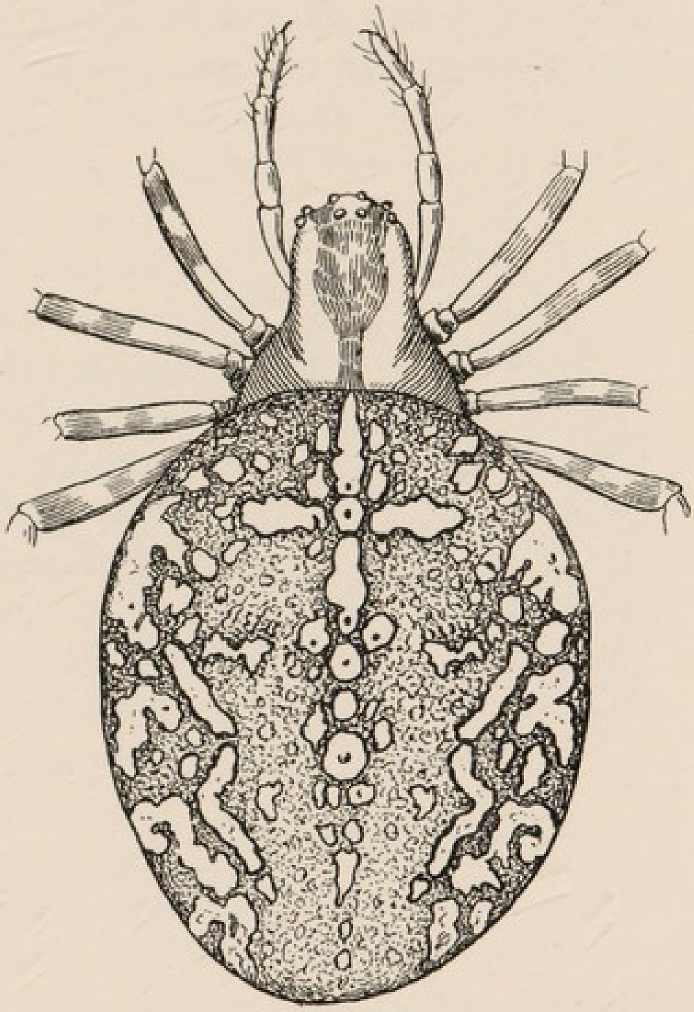

FIG. 49.—Dorsal surface of garden spider, showing the white cross. The legs are cut short.

Kirby and Spence in their Introduction to Entomology give an excellent description of the fabrication of a garden spider's net, and their description, supplemented where requisite by later observations, forms the basis of the following account. The first step in the formation of the net is the laying of the exterior lines, which pass in most cases from branch to branch, and are composed of several threads glued together. These are secured at many points by finer threads. Having thus completed the foundations of her snare, the spider proceeds to fill up the outline. Attaching a new thread to one of the boundary lines, she travels along the circumference, drawing out the thread as she proceeds, and guiding it with one of her hind feet, so that it may not touch surrounding objects of any kind. When the new thread has been carried half round the circle, she secures it to the boundary, stretching it diametrically across the centre of the space. A second thread is laid down in like manner, crossing the first at its centre, and after this the work proceeds rapidly, until twenty or thirty radii have been fixed. During these preliminary operations the spider sometimes rests, as though her plan required meditation, but no sooner are the marginal lines firmly stretched and the first radii spun, than she continues her labour rapidly and without pause. Proceeding to the centre, she pulls each thread with her feet to ascertain its strength, breaking any one that seems defective, and replacing it by a fresh one. When satisfied about this, she leads a spiral line from the centre to the margin of the net, the innermost turns being close together, but the outer ones much more open. This preliminary spiral is only a temporary scaffolding, to be replaced by a permanent spiral of different construction. Starting anew from the periphery, where the first spiral line ended, she draws a second spiral thread towards the centre, and glues it to all the radii as it crosses them. The thread is

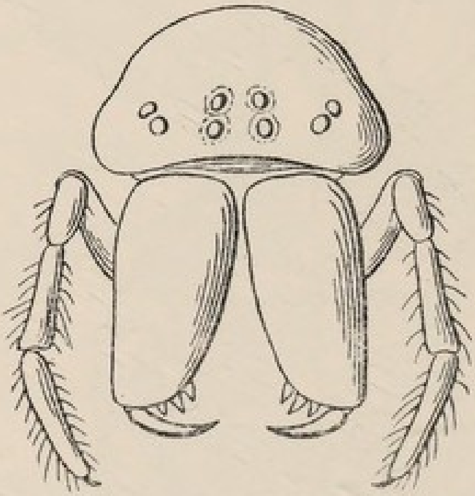

FIG. 50. — Head of garden spider, showing the eyes (four pairs), the poison-fangs and the jointed palps.

continued in gradually diminishing turns until the centre is almost reached.

Why, we may ask, should two spiral lines be laid down by the garden spider, one temporary and the other permanent? The answer is that in its final state the spiral line is meant to be adhesive, so as better to entangle flies, but a viscid thread is too slippery to give foothold even to the spider that lays it down, and moreover the viscid coating is injured whenever the spider steps upon it. Since the radii are too wide apart towards the circumference for the spider to step from one to another, she lays a non-viscid spiral line for her own use, and bites it away bit by bit when she passes over it for the last time.

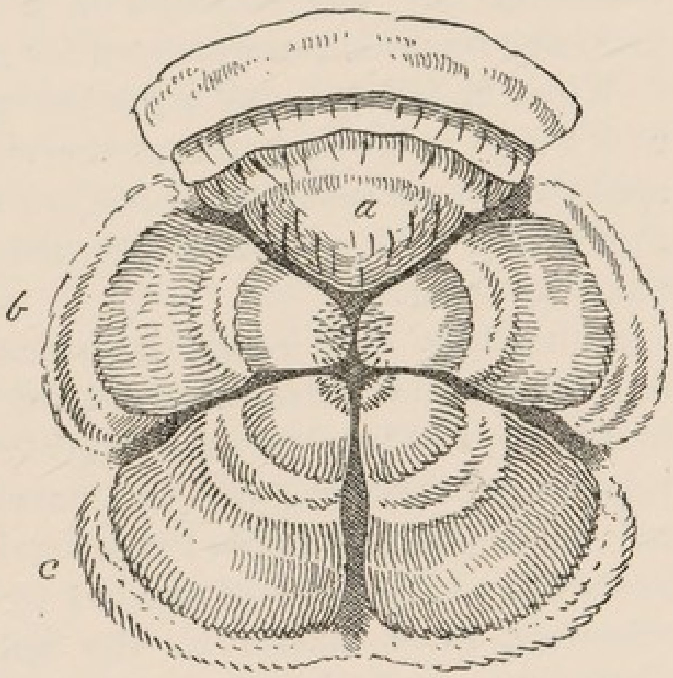

FIG. 51.—Extremity of abdomen (*a*) of garden spider, and two pairs of spinners (*b* and *c*). When these spinners are separated, another small pair is exposed.

The original spiral line is not completely removed. Towards the centre a few non-viscid threads are left, and these constitute the watching station of the spider. Here she hangs head downwards by the claws of her hind legs, waiting for a victim, which cannot fail to agitate one or more of the radii, and thus give her instant warning.

The permanent spiral thread is coated with a sticky film, as we see by its retaining dust, and adhering to the finger-tip when lightly touched. When fresh-spun, this thread has a uniform covering of fluid, poured out no doubt from special glands, though these have not been clearly identified. As soon as the thread is properly coated, the spider plucks each section like a harp-string, and the vibration thus set up resolves the fluid into countless drops, too small to be seen by the naked eye. The sticky globules must not be confused with the much larger dew-drops, which are often seen on the web of an autumn morning. When exposed to sun and wind, the adhesive coating soon dries up, but Blackwall found that when the net was enclosed in a glass jar, the adhesive property remained unimpaired for months.

When in full activity a garden spider makes a new net every day, or at least relays the viscid spiral thread. Old spiders are not able to secrete so much silk, and content themselves with repairing the net so long as it is in fair working order.

Somewhere in the neighbourhood of the net the spider has her special retreat, concealed usually by the leaves of a bush, and into this she drags her victims, sucking their juices and throwing out the carcases. A stout line of communication, composed of several threads glued together, leads from the centre of the net to this retreat, and by its vibration gives notice to the spider whenever a fresh victim is caught in the snare. The male spiders, which are much smaller than the females, are usually to be found near the retreat.

Blackwall describes the curious proceeding by which the garden spider and some other Epeiras envelope their prey. When too large and powerful to be safely approached, threads are cut away until the victim dangles; it is then made to rotate by a touch from one of the spider's legs, fine threads issuing from the spinners being first attached by means of a cautiously extended leg. As the object revolves, it is speedily wrapped up in a dense covering of silk, which makes even struggling impossible. In this way the garden spider deals with formidable insects, such as wasps.

Her eggs are laid in autumn in a cocoon, formed of a double sheet of yellow silk; there may be several hundred eggs in one cocoon. Leaves and other natural objects are often interwoven, to give it an unsuspicious appearance.

The garden spider often finds herself in a difficulty when seeking to run the first marginal threads of her net from point to point. The branches which she desires to connect may be high above the ground, and too far apart for her to make her way from one to the other by any ordinary method. One of the authors of the Introduction to Entomology relates the following observations, which are here slightly condensed:—"I placed a large field spider (Epeira diadema) upon a stick about a foot long set upright in a vessel containing water. After fastening its thread (as all spiders do before they move) to the top of the stick, it crept down the side until it felt the water with its fore-feet, which seem to serve as antennæ; it then immediately swung itself from the stick, and climbed up by the thread to the top. This it repeated perhaps a score of times. At length it let itself drop from the top of the stick, not by a single thread but by two, one finer than the other. When it had nearly reached the surface of the water, it broke off the finer thread, which, still adhering to the top of the stick, floated in the air, and was carried about by the slightest breath. On bringing a pencil to the loose end of this line it did not adhere. I therefore twisted it once or twice round the pencil, and then drew it tight. The spider, which had previously climbed to the top of the stick, immediately pulled at the thread with one of her feet, and finding it sufficiently tense, crept along it, strengthening it as she proceeded by another thread, and thus reached the pencil." Many spiders which wander in search of prey are able to emit threads by which they can support their bodies in the air when a breeze, even a gentle breeze, is blowing. The example just described shows that the snare-making spiders also may possess the power of throwing out a line, which, though it may not suffice to raise the spider in the air, enables her to pass to a point which would be entirely inaccessible otherwise.

The garden spider is guided in these operations entirely by her sense of touch. Blackwall tells us that he repeatedly confined garden spiders in glass jars placed in absolute darkness, and found that though unable to see they made nets of admirable workmanship.

What kind of feet does a spider require in order to run about on a network of fine silken threads? It is worth while to examine the foot of the garden spider or any other. You will find a pair of strong claws projecting from the upper surface of the last joint. Each claw is curved, and armed beneath with a row of teeth. A third and smaller claw is found beneath the pair, and on close examination several more claws, each with a row of pointed teeth, can be made out. We see that the comb-like teeth are suitable for clutching at a fine thread, but the difficulty is to explain why so many claws are required. On the hind legs, and on them only, are opposable claws, which can grasp the thread as well as hook on to it. When the spider dangles from its thread, it always holds on by the opposable claws of its hind feet. The harvestman makes no web, but follows its prey over stubble and the slender blades of grass. Here you will find that the foot consists of a long series of minute joints, each with its own set of outstanding hairs; the whole series may be half as long as the rest of the leg. The extraordinary length and flexibility of such a foot are obviously adapted to support on a yielding surface. The harvestman, one might almost say, runs about on flexible snow-shoes (see p. 114).

The silk of the garden spider is employed by opticians in one of the most delicate parts of their work, namely, the quartering of the field of a telescope or theodolite. The garden spider, which is easily identified by the white cross on its back, is always selected. When captured and set on a wire fork, she attaches her thread and lets herself drop. The fork is then turned round and round, so that the thread makes a number of separate turns round it. The prongs are next varnished to fix the thread at short lengths. A single thread can now be brought into its destined place, received into grooves cut for it, tightened and secured by a touch of varnish. Sometimes threads unwound from the cocoon of a spider are employed instead of fresh threads. In this case the cocoon is laid upon water till it untwists, then it is laid across the prongs of a fork, and secured as before.

The best part of this short account of the garden spider comes from Kirby and Spence, and I think that some of my readers, especially those who already know and value the Introduction to Entomology, may be glad to be told who Kirby and Spence were.

Kirby was a Suffolk clergyman, who before the Introduction had made him widely known, had won distinction in the narrow circle of professed zoologists by his history of British Bees (Monographia Apum Angliæ), and his investigations of the structure and habits of Stylops and Xenos, very remarkable insects, which are parasitic upon bees and wasps. So peculiar are they that Kirby with general approval made them into a separate order (Strepsiptera), which is still recognised, though it is generally believed that the Strepsiptera are beetles, which have become strangely modified to suit the exigencies of a parasitic life. It was a leading object with the authors of the Introduction to demonstrate the wisdom and beneficence of Providence as displayed in nature, and they were held to have succeeded so well that Kirby was afterwards selected to write one of the Bridgewater Treatises (1835).

The junior author, Spence, was a Hull drysalter. Before he published on insects he was well known as the writer of some spirited tracts on political and economic subjects, such as his "Britain independent of commerce," which was very widely read. Spence sought to convince people that Britain was more than a match for the whole power of Napoleon, that agriculture is the only basis of enduring national prosperity, and that British agriculture cannot flourish without the aid of corn-laws.

The Introduction was published in four separate volumes between 1815 and 1826. It proved so interesting to the public that seven editions were called for during the life-time of Spence, who outlasted his colleague by ten years. The authors owed much to earlier naturalists, especially to Réaumur, but they worked for themselves too, and described many contrivances which they were the first to discover. A reader of the Introduction will often find that Kirby and Spence furnish the most valuable part of some popular books on insects in which their names are barely mentioned. One would suppose from examination of their separate writings that Spence must have been the livelier writer of the two. When he was disabled by illness, Kirby wrote almost by himself the third and fourth volumes, and these are far less readable and less valuable than the first two. But the testimony of the authors does not allow us to give the credit of what is best in the Introduction to either author separately. They declared that it was in every sense a joint work, and that it was impossible to distinguish the part which each had contributed. Their friends remarked, notwithstanding this protest, that whenever a particular anecdote or description was praised, Kirby was inclined to say that it belonged to Spence, and Spence that it belonged to Kirby.

The Introduction is of permanent value ; it has helped to make many a naturalist already, and its virtue is not yet lost. Like the Natural History of Selborne, it shows how profitable as well as how interesting it is to study our animals *alive*.

XLV. A SCHOOL-COURSE ON THE STRUCTURE AND LIFE OF INSECTS.

METHODS OF DISPLAYING INSECT STRUCTURES TO MANY PEOPLE AT ONCE.

I wish to supply hints for a short school-course on insects. Besides supplying information on insects as a class, I propose to show how the structure of an insect can be made evident to a number of pupils at once, and this is the difficult part of my enterprise. The methods which I recommend will, I know, seem too laborious to most teachers. Yet they have all been carried out successfully in my own class-room, and I see no reason why they should not be practised in some of the better-equipped schools. An oxy-hydrogen, or better still, an electric lantern, is required. The teacher should be practised in the simpler methods of demonstrating and mounting insect-structures. The life-histories of a few common insects should also be rendered familiar by rearing the insects in breeding-cages. I do not recommend this subject to all teachers, nor to all amateur naturalists. Some knowledge, skill and experience are called for, and the study is better suited to a small class of elder pupils than to a large class of beginners.

Many of the characteristic features of an insect can be seen by the naked eye or a lens of low power, but this is not quite enough. It is sometimes indispensable to examine minute parts, such as jaws or air-tubes. We have found it a simple matter to fit a low microscope objective (2 in. or 1 in.) to the lantern, and this makes it possible to show to a whole class at once every detail which is likely to be profitable to young students. We may, I think, anticipate that the facilities which the optical lantern affords will soon be more widely turned to account, and that the higher elementary schools at least will before long be provided with the means of demonstrating to a number of pupils simultaneously the most necessary details of animal and plant structure.

An elementary knowledge of optics or a few trials are necessary to put the objective into its right place. The lantern-objective is removed, and the microscopic objective substituted for it. A stage carrying the object comes outside the objective, and all the parts are placed as in the compound microscope when arranged for work. The next point to be considered is how to absorb a large part of the heat-rays concentrated upon the object, which would soften the mounting medium or scorch the object itself. A glass tank filled with water was first used; this is liable to the objection that when the water grows warm, bubbles appear, and the water becomes more or less opaque to light. Glycerine was next tried, with far better results. My colleague, Dr. Stroud, suggested that the right liquid to employ is that which is used for mixing with the mounting medium. If, for instance, turpentine or wood spirit is employed to dilute the canada balsam of the preparation, turpentine or wood spirit must be put into the heat-absorbing tank. The rays which are most readily absorbed by the mounting medium will then be absorbed in advance. We have tried this plan with excellent results, and consider the heat-difficulty as disposed of. The tank should be made in one piece,[1] and the operator should remember that turpentine and wood spirit are very inflammable.[2]

The cockroach of the kitchen, which, like the frog or the crayfish, is one of the martyrs of science, may be taken for a first lesson on insect-structure. Distributing dead specimens to the class, we note the external features of an insect. The body is defended by an external armour,

[1] Our tanks were made by the York Glass Co.

[2] It is a pleasure to acknowledge the skill and kindness of my colleague, Dr. Stroud, who devised the simple but excellent lantern-microscope which we now use.

composed of a substance resembling horn in texture, but differing from horn in composition; this substance is called Chitin. It is one of the very few components of the bodies of animals which can resist the action of boiling alkalies, however strong. For the sake of flexibility the chitinous armour is divided into segments, and these segments are united by membranous junctions, where the chitinous covering, though not interrupted, becomes thin and flexible. The segments are grouped into three regions, head, thorax and abdomen. There are three pairs of legs, one pair to each segment of the thorax. The head is furnished with a pair of feelers, a pair of compound eyes, and biting jaws, which will be seen very indistinctly in the whole cockroach. Along the sides of the body, in the thin membranes which unite the segments, are the breathing-holes, or spiracles, but these cannot be well seen without special preparation.

We can next show by means of the lantern-microscope further details, which require enlargement. The head of a cockroach may be prepared for demonstration in this way. Cut it off, hold it between the finger and the thumb, pass a scalpel into the mouth, press the edge upwards and thus divide the head into a front and a back half. Boil these in a solution of caustic potash (10 per cent.) for a quarter of an hour or more, then soak in water, changing the water now and then until the potash is completely removed. Get rid of the water by soaking in methylated alcohol, afterwards in absolute alcohol, and lastly in turpentine. Mount in balsam, and the preparation is ready. Some days should however be allowed for hardening before any balsam preparation is put into the lantern. Watch-glasses may be used to hold costly fluids like absolute alcohol.

Put the front half of the head into the lantern. Observe the large compound eyes, made transparent by the potash, the long, many-jointed antennæ, the mandibles, with their strong, tooth-like prominences, and the labrum, a flap which covers in the front of the mouth. A close observer can tell by the details of the antenna whether the head so displayed is that of a male or of a female cockroach.

Next put the hind half of the head into the lantern. Point out that there are now seen two other pairs of jaws, called maxillæ. The fore pair of these are quite separate from one another; the hind pair are smaller and united at the base. Each of the four maxillæ bears a slender, jointed palp, which is used by the insect to examine its food. How does the palp differ in the two maxillæ? What are the most obvious differences between the feeding organs of a cockroach and those of a man, a snail, a crayfish, or any other animal known to the class?

One of the legs may be mounted in the same way, and shown by the lantern-microscope, or studied with a simple lens. Do not plague a class of children with Latin names for the joints of the legs, and do not name them at all unless you foresee that the names will be necessary, or at least convenient, in the present stage of your work.

Extend the wing-covers and wings, if your cockroach possesses them. In the common cockroach of the kitchen only the male has them well-developed. The large American cockroach, which is now supplied by many dealers, has the wings well-developed in both sexes. Note that the fore-wing (wing-cover) is attached to the mid-thorax, the hind-wing to the hind-thorax. The wing-covers, if well-developed, are stiff and cannot be folded; when at rest one overlies the other; the membranous wings are folded fan-wise. The female of the common cockroach has short and quite useless wing-covers, and instead of wings we find only a slight branched pattern, stamped, as it were, upon the back of the thorax.

The upper half of a cockroach abdomen, which has been cleared with potash, may be displayed in the lantern. Observe the segments, the flexible membranes by which they are united, and the pair of jointed tails which project behind. The tails have probably some real use, but it would be hard to explain what it is. Some have thought that they serve as feelers in the dark recesses where the cockroach lurks, and give warning of the approach of dangers from behind. In a cricket they look very like a hind pair of antennæ.

The breathing organs of an insect are more easily demonstrated in a caterpillar than in a cockroach. It is easy to prepare a piece of the integument of one side, which will, with the help of the lantern, display the spiracles with admirable clearness. The branched air-tubes may be exhibited either in the form of a microscopic preparation or a photograph from the same. The alimentary canal of a cockroach and a great part of its nerve-cord can, if desired, be mounted as lantern-slides.

The simple lens is an excellent aid to the study of insect structures. A lens, magnifying five or six diameters and suitably mounted, is not expensive,[1] but, where handicraft is practised, it is better to buy nothing but the glass lens, and make your own dissecting microscope in the school. (See Scherren's "Through a Pocket Lens.")

The study of enlarged preparations and of living insects may be accompanied or followed by some such remarks as follow.

WHAT IS AN INSECT?

An insect belongs to the large group of Arthropod animals, which all have the body defended by a jointed chitinous armour. Not only the body but the legs also are jointed, hence the name "Arthropod," which means "with jointed feet." Among the arthropods which are not insects come the crayfish and other crustaceans, the spiders and scorpions, the centipedes and millipedes. An insect is sufficiently defined as a six-legged, air-breathing arthropod.

[1] Leitz of Wetzlar makes a good one for 8s.

THE AIR-TUBES OF INSECTS.

All insects are air-breathers. It is true that some are so entirely aquatic during their early stages as to possess gills (the blood-worm is a common example), but every adult insect breathes by taking in gaseous air. The chief purpose of the winged stage in an insect is the dispersal of the eggs, and this purpose would usually be defeated altogether if the egg-laying insect could not range through the air. No insect breathes by taking in air through its mouth. The same thing is true of the greater part of animals; it is only vertebrates which breathe through their mouths. An insect has a row of holes along the sides of its body, through which air is admitted or expelled. The holes (spiracles) are defended by valves, and sometimes by an elaborate fringe of branched hairs, which not only exclude dust, but water. You may have observed that when an insect falls into water, it does not speedily drown. Its spiracles exclude the air sufficiently long to give it fair time to wriggle out. Have you ever seen an insect breathing? A bee or wasp moves the joints of its abdomen in and out, bending or straightening them at the same time. Some other insects raise or depress the upper surface of the abdomen. Whatever the action, it has the effect of alternately enlarging and contracting the cavity of the body. It is not enough to provide a series of holes; the air must be forcibly driven along through them, and along the air-tubes into which they lead. For this purpose it is necessary that the insect should be able to close the inlets tightly. Unless the air is put under pressure, it cannot be forced along narrow passages, and it cannot be put under pressure so long as it is free to escape. Just within the spiracle, the air-tube leading inwards is made to pass through a clip, and by means of the clip the air-tube can be throttled at pleasure. This is always done before the body-cavity contracts. The blood which fills the cavity transmits the pressure to the walls of the air-tubes, and drives the air into the ultimate recesses.

Examination of the tissues of an insect's body shows that they are traversed and overlaid by air-tubes, which branch continually, until they become extremely fine. A thread, wound spirally round every tube, acts like the iron wire often used to line a flexible gas-pipe. In both cases the spiral thread prevents the tube from "kinking" when sharply bent.

INSECT-TRANSFORMATIONS.

One of the best-known and most interesting peculiarities of insects is the transformation which so many of them undergo. Most of them pass the chief part of their lives as larvæ or grubs, and do all their feeding and growing in this stage. Then they turn to flies and lay their eggs. Many, but not all, pass through a resting-stage just before they acquire wings. Two questions call for consideration at this point. Why should so many insects get wings before they lay their eggs? Why does a resting-stage so often precede the winged stage?

Wings are necessary, I believe, to all insects which are very particular about the place where they lay their eggs. Suppose that a particular caterpillar will feed only on the leaves of buckthorn. If the female moth lays all her eggs on the tree where she herself was reared, that tree will soon be overstocked, while there may be plenty of other trees of the same species which are untouched. It would evidently be far safer, if many generations are to be reared in succession, that the eggs should be laid a few together on a number of trees. Now a creeping insect could not manage this; it would exhaust itself to no purpose in seeking fresh plants. But if the egg-laying moth can fly, and if it is furnished with acute senses, it can make its way to plant after plant, and distribute the eggs widely.

It will be a work of time to lay eggs in a number of different places, and the moth which undertakes the task must be able to feed for some days at least. It would never do for her to depend upon the coarse vegetable food on which she subsisted as a larva. That would weight her body and interfere with her flight, besides taking up too much of her time. The sweet and nutritious juices of flowers are much more suitable. They can be sipped rapidly, and the weight is insignificant. Change of food brings with it a change of mouth-parts; the insect discards the biting jaws of the caterpillar, and acquires a new sucking proboscis. The sucking proboscis leads to yet further complications, for there will be an interval during which the old mouth-parts are out of gear, while the new ones are not quite ready for use. Change of food leads therefore to a resting-stage.

But among the moths and other winged insects we find one here and there which does not require to scatter its eggs widely, and such insects as these sometimes lose their wings altogether. The female vapourer-moth is a well-known example. Here the caterpillar is not at all particular about its food; the leaves of most garden shrubs and trees suit its taste; moreover this caterpillar can run about very well. In this case, therefore, all the eggs may be safely laid in one place, and the female need not fly at all. Evidently her ancestors used to fly, for the stumps of wings can still be discerned on her back. The male vapourer flies very well, and both male and female still go through their resting-stage.

THE SIZE OF INSECTS.

Insects are small animals. A very large beetle may measure four and a half inches in length, but this includes a long horn. One of the longest stick-insects (so called because the body and legs resemble dry sticks) may be nearly a foot long, but the weight of such an insect is by no means great. Some dragon-flies are about six inches long, and there are some moths whose wings can expand to about a foot. None of these relatively enormous insects are found in this country. What the exact size of the smallest insect may be I cannot tell; I have seen a full-grown parasitic fly escape from an insect-egg, which was not distinctly visible to the naked eye.

The small size of insects throws some light upon their extreme ingenuity. Being unable to defend themselves or to attack other animals by main force, they have commonly to use artifice instead. The disguises of insects are innumerable; they escape notice by their resemblance to leaves, sticks, bird-droppings, and an infinity of other objects; they creep into crevices, or spin together particles of sand, wood, leaves and shells; many of them, when alarmed, sham dead. Though few insects are formidable to other animals by reason of their biting power, many can sting, injecting a poison into the minute wound which they make, a poison which is far more dreaded than the wound itself.

THE STRENGTH OF INSECTS.

There is a wide-spread but quite mistaken impression that, if fair allowance is made for their small size, insects will be found to be the very strongest of animals. Kirby and Spence tell us that a cockchafer, allowing for difference of size, is six times as strong as a horse, and they confirm the estimate of Linnæus that if the elephant were as strong in proportion as the stag-beetle, he would be able to level mountains. Such statements as these are based on the supposition that if one animal is ten times as long as another, it should be able to draw or lift ten times as much, but this is altogether fallacious. If the larger animal were identical in shape and build with the smaller one, it should be a hundred times as strong, while it would weigh a thousand times as much. The proportion of muscular strength to weight falls therefore as the size increases, and before long the animal would, as a mere consequence of increased size, become incapable of moving its body at all. It is only because the horse is expressly adapted to large size by its mechanical construction, and actuated by muscles of far greater power, that it compares so well as it does with an insect. If it resembled an insect in build and composition, we may safely predict that it could not even stand.

THE ABODES OF INSECTS.

The versatility of insects is very great, as a glance at their places of abode shows. There are insects which live in the earth, on trees, in ponds and streams, in torrents, in the sea, in brine-pits, on glaciers and snow-fields, in hot springs which scald the hand. A small beetle will live and multiply for years in a bottle of argol (crude potassium tartrate), drawing its whole nourishment from that uninviting substance. More than one insect finds its home and its food in the living colonies of the freshwater sponge. A leaf is not too thin for burrowing larvæ of many kinds (see p. 15). Many caterpillars and fly-larvæ run their tortuous galleries between the upper and lower epidermis of bramble-leaves, buttercup-leaves and many others, pupating in the excavated space, and emerging as moths or flies, having accomplished their whole growth at the expense of a small fraction of the living cells which are contained in a single leaf.

INSECTS AND HONEY.

Honey is a product worked out by insects and flowers for their mutual advantage. The flowers contribute more than the insects, for they can apparently make a little honey by themselves, but the co-operation of insects was necessary to the extensive and profitable natural industry, which has sprung from such unimportant beginnings.

Honey occurs in nature either as *bee-honey* or *flower-honey*. It is not known for certain that these two kinds differ in any material respect. The honey-bee collects sweet juices from flowers, stores them in its crop (an enlarged part of the gullet) and then disgorges them into a comb made ready for the purpose. One thing which makes us believe that the honey is not digested before being disgorged is that it differs so much according to the plants from which it has been obtained. Clover, heather, orange-blossoms, labiate flowers (mint, rosemary and the like) affect the taste, smell, colour and consistency of the honey; honey from poisonous flowers is sometimes itself poisonous. Such differences would not be likely to occur if the honey had been really digested.

How did plants come to make honey? The possibility of such a thing arose when green plants found out how to decompose carbonic acid in presence of sunlight. Sugar then appeared in the cells, and was ready to be excreted whenever a sufficient reason should exist. Various parts of green plants exude sugar (leaves, leaf-stalks, &c.), and the next step, viz. the exudation of sugar at the base of the floral leaves, is not a very great one. If insects, attracted to the flower by the hope of pollen, happened to find honey as well, that would be a powerful motive for coming again. The flowers which had secreted the honey would get their seeds fertilised more readily than others, and thus would be founded that alliance between flowers and insects, which is now so well established that many flowers cannot set their seeds at all if insects are kept off by a muslin net. It only remained to bring the mechanism to perfection. The honey became more abundant, exuded only at the time when the pollen was ready for transference, and was not only protected more and more carefully from rain and marauders, but placed just where it would ensure fertilisation. The perfume, which is so powerful an aid in attracting insects, is usually only the perfume of the honey itself.

The insects on their side acquired an increased appetite for honey and increased expertness in finding it; their crops enlarged; they learned how to make store-houses for their honey, using first of all, it may be, natural cavities, then cells of earth, clay, or impure pollen, and lastly cells of wax. The wax was no doubt at first very impure, and used very sparingly, as is still the case with the less expert insects. The most advanced bee-communities use it in large quantities, though always with the most scrupulous economy. The process of wax-making by hive-bees leaves no doubt that they make it out of honey —how I cannot tell. Some palms and other plants are also able to make wax out of sugar.

Upon the possibility of making wax and storing honey is founded the whole economy of the more complex bee-societies. Ants, though they are fond of honey, have not got so far as to make wax. They early took a line of their own, gave up the regular exercise of flight, most of them losing their wings altogether, and thus, while gaining greater facility in underground work, relinquished all the chief advantages of a close co-operation with flowering plants. Flies are often honey-seekers, and a few flies have powerfully affected the structure of certain flowers, but in general they are inexpert at this work, and seldom secure for themselves a monopoly of a particular source of honey, as bees and moths so often do.

INJURIES DONE BY INSECTS.

Long chapters have been written, among others by those excellent old naturalists, Kirby and Spence, on the injuries and benefits which we receive from insects. Nearly all our crops are injured by insects, and sometimes the injury amounts to destruction. We may see the gooseberry-bushes stripped of their leaves year after year; apples often fall half-grown to the ground, or are cankered at the core as the result of insect-attacks. Time would fail even to name the insects which prey upon the most useful of our plants. Let us just mention the locust, the wireworm, the turnip-fly, and the various sorts of beetles called weevils, as pernicious examples. Stores of grain, furs, skins, woollen fabrics and other valuable products are continually ravaged by insects. The white ants of tropical countries and our native clothes moths are notorious for the mischief which they do. Certain insects cause great damage by their attacks on cattle, sheep and horses, while a few are harmful or even deadly to man himself. It has been discovered of late years that malarial fevers are due to the bite of a gnat. When it pierces the skin to draw blood, the gnat introduces a microscopic parasite from its own salivary gland. In human blood the parasite multiplies prodigiously, and by penetrating the blood-corpuscles sets up the fever. Other gnats in turn become infected by drawing blood from malarious patients, and so the round is kept up. It is probable that several formidable diseases are propagated by different insects.

BENEFITS RECEIVED FROM INSECTS.

The list of benefits conferred by insects is not so long, but it includes some that we could ill spare. Insects are one great agent for the destruction of corrupting substances of many kinds. In visits to sewage-works I have been struck by remarking how much putrid matter is turned into small flies, and scattered harmlessly over the face of the country. Insects yield the favourite food of many birds and fishes which we prize as useful or agreeable. Insects yield honey, wax, cochineal, lac and silk. But I suppose that the chief benefit which we draw from the existence of insects springs from their activity in the fertilisation of flowers. Many useful and beautiful plants would cease to ripen seed at all, if it were not for the visits of insects.

THE NUMBERS OF INSECTS.

More insects have been described by naturalists than animals of all other kinds put together, and many sorts of insects are extremely plentiful, so that it is not unlikely that a majority of the animals now living on the surface of the globe are insects. The only doubt relates to microscopic creatures, far smaller even than insects, and nobody can at present even guess how many of these there may be.

INSECTS AND MAN.

The surface of the earth is a battle-field, on which a vast number of animals strive with one another for space and room. The advantage in this contest is by no means necessarily with the powerful. Numbers and artfulness have often prevailed over strength. It would seem as if the struggle was bound to remain for ever undecided, were it not that in the last ages an agent of mighty power has appeared before whom many of the combatants seem unable to make an effective stand. The great beasts of prey die out where he establishes himself; animals with hoofs and horns are enslaved by him, and made to do his work. All creatures that interfere with his purposes find in him a steady enemy, whose plans are handed down from generation to generation. This enemy is Man, who alone among animals can record his experience, and take counsel with kindred whom he has never seen. There is no chance for the biggest and fiercest animals in rivalry with man; it remains to be seen whether or not the most insignificant of animals can hold out against him by reason of their numbers and the ease with which they escape notice.

Somebody has lately been so bold as to propose that mankind should undertake the extermination of the whole race of insects, sparing, I suppose, the honey-bee and perhaps one or two others of undeniable utility. Whether it is desirable to extirpate the insects or not, I will not consider just now, but will content myself with remarking that their prodigious numbers, their powers of flight, and their wide distribution make the task of extermination infinitely more difficult than any enterprise which man has hitherto accomplished, or even undertaken.

I have sometimes thought that in an isolated country like Britain it might be possible to exterminate a particular farm-insect, at any rate for a time, by prohibiting for a whole year the growth of the crop on which it subsists. There are not many injurious insects which are absolutely restricted to one food-plant, but there appear to be some. The difficulty which I foresee in extirpating a single species of noxious insects makes me very indifferent to a project for the extirpation of insects in general throughout the world. We shall have plenty of time to weigh the consequences before it becomes a matter of practical business.

XLVI. VACATION RAMBLES.

The expansion of our towns and cities is ruining much that the naturalist loves. London has devoured many a pleasant wood and field. A little more than a hundred years ago Queen Square, hard by Southampton Row, was thought to be a delightful abode, because it commanded an unbroken view of Hampstead and Highgate. The naturalists of the first half of the nineteenth century looked upon Leystonstone, Tottenham, Highgate, Sydenham and Blackheath as unspoilt country, where nature could be explored without hindrance. Our busy provincial towns grow with almost equal rapidity. I know of a little valley near Leeds, where in my own boyhood rare marsh-plants and curious insects were to be found in undisturbed profusion. That valley is now crowded with forges, dyeworks, and back-to-back houses. Near Sunderland was once a delightful dene, where a bright stream flowed into rock-pools, which filled with sea-water at every tide. A singular mixture of marine and freshwater animals used to people these pools, but when I was taken to see them by their discoverer, great ironworks smothered the place with ashes and smoke. One could relate such experiences at wearisome length, and to the naturalist, as to some few others, these changes are pure loss. He cares little for "unexampled prosperity" and "increase of rateable value." The beauty and wholesomeness of human life, which he does care for, are not enhanced by such growths as these.

Even the industrial development of the nineteenth century, though it has brought upon us cruel losses, has its compensations, and it is the part of the philosopher to make the most of them. The compensation that I have now in mind is the vastly increased facility of locomotion which scientific discovery and commercial enterprise have placed at our command. As for the defacement of nature, if any words of mine could bring remorse upon the offenders, they should not be wanting, for I am persuaded that very much of this damage is needless. The Waesland, between Antwerp and Ghent, densely populated and busy with machinery, is much of it fruitful orchard. In Saxony only one per cent. of the soil is unused; the output of cotton, linen, leather and machinery is so large, that this little country is one of the chief manufacturing districts of Europe. Yet it is a pleasant land, a land of cornfields and fruit-trees. I maintain that the manufacturer has no more right to trample underfoot all that does not help him to make a profit than has the man who is in a hurry to catch a train to push rudely aside the people who stand in his path. A little thought, some faint preference for what is beautiful over what is ugly, would spare us many of the worst injuries that are being done to our country.

In the seventeenth and eighteenth centuries, besides those who travelled to earn money, only the wealthy, or those who had a passion for travel, visited any foreign land. There were plenty of young noblemen who made the grand tour with a tutor, visited France and Italy, and returned to show

> "How much a dunce that has been sent to roam,
> Excels a dunce that has been kept at home."

Here and there too there might be found such a singular example as that of Descartes, who, though only moderately wealthy and weak in health, contrived to visit every part of Europe which offered anything to a curious observer. Descartes wandered alone and almost furtively, for hardly more than a single friend knew where he was at any time. He particularly loved a pageant, and would travel far to see a coronation. It is very remarkable that a man of his tastes, who had lived abroad half his life, should nowhere speak of any detail of foreign life, nor of any city or building which he had visited. That he should make no mention of striking scenery, although he had crossed the Alps, and had occupied himself with the avalanches and other natural wonders of Switzerland, is less remarkable, when we consider what the readers of his day looked to find in any solid book. The descriptive traveller did not then exist, or used his talent only to gratify the curiosity of personal friends.

Naturalists were among the first to discover how much they might enlarge their knowledge by travel. John Ray and his pupil Willughby made many and long peregrinations both at home and abroad. Linnæus explored Lapland, resided long in Holland, and visited England. His pupils explored every land accessible to them. Sir Hans Sloane diligently collected the plants of Jamaica. Sir Joseph Banks, though a wealthy Lincolnshire squire, endured the hardships inevitable to a circumnavigation of the globe with Captain Cook. All these were men of exceptional energy or exceptional opportunities. The man who had his bread to earn was in the eighteenth century generally forced to remain at home round the year. Dr. Johnson saw the sea for the first time when he was fifty-six years old; his wife never saw it at all. George III. at thirty-four had never seen the sea, nor been thirty miles from London.[1] "I have described so much," said Richter, "yet I die without having seen Switzerland or the ocean."

Steam now makes it possible for many a busy man of small income to escape once a year from the cities which the love of gain has made unnecessarily sordid, and to

[1] Birkbeck Hill's *Johnsonian Miscellanies*, vol. i. p. 52 (*note*).

visit lands which our fathers knew only by report. It is now not difficult for any one who has a long vacation to visit every country of Europe. Sir Henry Holland did more than this. During a busy professional life (he was a West End physician in large practice) he contrived to visit every capital of Europe, most of them repeatedly, to make eight voyages to the United States and Canada, to visit the West Indies, to travel four times in the East, thrice in Algeria, twice in Russia, besides making journeys to Iceland, the Canaries, and many other places far from home. The wonder is a little explained when we are told that he lived to eighty-five, that he enjoyed a large income during nearly the whole of his life, and that he was able to leave London for two months every year, because nearly all his patients left London too. But the record, after all allowance has been made for favouring circumstances, is a remarkable proof of energy. Sir Henry had his reward. Foreign travel, joined to a hearty love of his kind, and a natural power of engaging the attention of noteworthy people, secured to him a kind of leadership in a very exacting society.

I am almost sorry to have mentioned Sir Henry Holland's long career of foreign travel, for the excursions which I want to stimulate are more particularly such as men of small means, uncertain leisure, and length of days not greatly exceeding threescore years and ten, can hope to enjoy. A man who accomplishes one-tenth of Sir Henry Holland's wanderings may be greatly exhilarated and enlightened by his foreign experiences. To break through the routine of home-life, to taste unaccustomed dishes, to hear unfamiliar tongues, and desperately, it may be, to attempt to express our views or our wishes under every disadvantage of vocabulary, grammar and accent, is one way of washing out the starch of respectability; it makes us more human, and gives us a brief chance of that independent activity which is too often impossible at home.

The traveller is lucky indeed whose attention has been called betimes to natural phenomena. Any kind of nature-knowledge will brighten a ramble abroad, but, according to my experience, geology and botany are best of all.

The geological structure of a new country can be in some measure appreciated, though of course it cannot be set down, during a rapid traverse. Much else turns upon geological structure, which governs not only the elevation of the land, its accessibility, the nature and position of the commanding points, but even in some degree the genius and temper of the inhabitants. History is largely affected by geography, and geography in turn by rock-structure. Geology abounds in the kind of questions to which the traveller can profitably bend his mind—questions not too special or minute for a man whose thoughtful hours are few and precarious, and who can carry few books along with him. A decent provision of maps, such local descriptions as can be picked up in the nearest city, a geological hammer, and if possible, a practised eye, are the chief requisites; they are all portable.

Let a man survey the Campagna from the windows of the Vatican, if he can get no nearer. He will wonder at the little towns, each perched upon its own steep and isolated hill, that start out of the sea-like plain. It is geological observation which tells him how these hills come to be there, and without some tincture of geology the hills themselves, the historical incidents which belong to them, and even the paintings of Italian masters, in which such hills are often delineated, may fail to impress themselves adequately upon our attention.

Or let a man visit Sweden, and observe the rounded knolls, great and small, which are not mere heaps of loose material, but bosses of solid rock, the perched boulders, the innumerable lakes, the long mounds of sand and gravel, and then ask himself why this kind of landscape, unknown in southern lands, should pervade large tracts of Sweden, Scotland, Ireland and New England. Geology answers the question, which else would remain totally dark. Why do we rarely find in a northern land splintery peaks like those of the Dolomites, or sand-worn cliffs like those of Arabia ? Here again it is only geology which can tell us.

Botany does more for the traveller than Zoology, partly because the range of plants depends more obviously than that of animals upon geological structure and soil, and also because plants affect the scenery in a way that animals can never do. An inquiring naturalist will raise deeply interesting questions of plant-distribution from very limited excursions, whereas it is only when studied on the continental scale that the geography of animals has proved instructive.

But all branches of natural history are good. The bird-man, the insect-man, the naturalist of any good sort (I mean any naturalist who inquires) will find in every foreign land abundant opportunity of carrying his studies farther, and giving them a wider scope.

The reader has very likely taken his own line, and knows perfectly well what he wants to work at the next time he has a chance of visiting an unfamiliar country. If so, I will wish him good luck, and hasten to stand out of his sunshine. There are other tourists who are eager but totally inexperienced, and here and there such an one may be glad of hints which his forerunners have found profitable.

To a young tourist with a taste for geology who is about to visit Switzerland for the first time, I would say : do not waste your leisure and strength by speeding over a great tract of country. Take one river-valley and work it well. There is none better than the Upper Aar valley for a first study. Begin at Meyringen, examine the Aar-schlucht as an example of what running water can do, work your way up to the Grimsel, and then photograph the glaciated rocks till you have learned something of what moving ice can do. The Obar Aar glacier will teach you nearly everything that one glacier can teach. Afterwards you can go on, if you are enough of a mountaineer, and cross the snowfields upon which the Schreckhorn and the Finsteraarhorn look down. That one valley will teach you more than all Switzerland could do, if you were to move over the ground as so many do at the rate of forty miles a day, in a personally conducted party. To find out your own way, to puzzle out your own problems, and to work at your own rate are the first elements of productive investigation, whether you are trying to master the scenery of Switzerland or a new science. Of course there are many people who find the only true method hopelessly slow. Switzerland in three weeks, chemistry in twenty lectures, is the programme for them. They will learn in time that lasting knowledge is not got by any such facile expedients. The rapid method is inviting enough at the outset. We go in a party because we love society. One of the party knows the way while the rest do not, what then can be more natural than that he should lead? One knows the elements of a science of which the rest are ignorant. What more natural than that he should speak while the others listen? The answer is in each case the same. Knowledge that we get without personal effort is knowledge in appearance only; it strikes no root, and soon withers.

Most of the people who visit Norway do just what the naturalist should avoid. They steam up one fjord after another, smoke twice as much as they do at home, eat heavy and frequent meals with no better intervals of exercise than are possible on an encumbered deck, vary the steamer only by driving from one hotel to another, and are guided all the way either by Baedeker or an experienced friend. This may be tolerable for the first week, but the second week is very like the first, and one fjord very like another. It is always somebody else, and not the tourist himself, who does whatever is done, manages the engine, manages the horses, cooks the dinner, chooses the route. A life like this has much in common with what I maintain to be the very poorest recreation that has yet been hit upon—watching a football match. To stand in a wet field on a winter day, and see men play a match, is an occupation that no man of any spirit could possibly endure. Let us do something or other, exercise either our brains or our muscles, and take our part in the fun.

If any naturalist wishes to break away from the relaxing and too commodious fjords, but does not know where to go, I can put him in the way. An excellent alternative, more practicable than others which I could name, is to visit Kongsvold. Kongsvold is nothing more than a post-house on the great north road leading from Christiania to Trondhjem. There, in sight of the Snehætta, he will find hills, wild gorges, and such botany as it is likely he has never enjoyed before. The first glance at Knudshö, a hill close at hand, tells us that we are in a new country. The rocks are of white quartz and black augite, the vegetation consists of patches of sulphur-yellow and a green so dark that at a little distance it looks black. When you come closer, you make out that the yellow indicates dense growths of lichens, the so-called reindeer and Iceland mosses, while the dark patches are clumps of dwarf willows, dwarf birches, juniper and Alpine bearberry. The delightful labours of the mountain-side are sweetened by the simple hospitality of the station, and by the friendly talk of the botanists, mostly Swedes, who assemble there every summer. I remember with special pleasure the conversation and help of the aged botanist, C. J. Lindeberg, whose latest visit to Kongsvold I happened to share. The difficulty of language is the only one that embarrasses the Englishman. I have been reduced at times to bringing out the Latin of my boyhood—such Latin! Who that has ever rambled over the Dovrefjeld would consent to go back to the coast-steamers and the stream of tourists which flows along the fjords like water in pipes!

Many of us are too busy to spend our holidays abroad.

There is plenty to see at home, and you can make all that you see profitable if you will only form the habit of putting and answering questions for yourself. When you visit a castle set on a ridge, such as Belvoir, Richmond, Beeston or Bamborough, ask yourself how the ridge comes to be there. When you visit the Roman wall, look out for the natural feature which determined the choice of that particular line, and possibly gave the first hint that a fortification might be easily made there and easily defended. Do not sterilise your geological or natural history rambles by mechanical occupations, such as aimless collecting, or the writing out of lists of species. Half a dozen questions answered—nay, half a dozen questions attempted—may be more to the purpose than note-books crowded with unproductive facts.

XLVII. GRASSES.

The characters of grasses. By what marks do we recognise grasses? I suppose that most of us would say that any plant is a grass which has long, narrow, pointed leaves, hollow stalks (haulms), and small, greenish flowers. So different are grasses from all other plants that we should have no hesitation in deciding whether a single leaf, a single haulm or a little cluster of flowers belonged to a grass or not. When we look closely it is easy to find further differences between grasses and other plants. The base of a grass-leaf forms a sheath around the haulm, which runs down the stem to the knot next below, and is nearly always split. Just at the place where the blade becomes free, there is a little colourless scale, which is in close contact with the haulm. The leaf is generally ridged on its upper surface, and if we cut it across and look at the cut edge with a lens, angular ridges will be seen. The hollow haulm, with knots at intervals, is almost equally distinctive. The flowers are usually very numerous and very small, so that it is not easy to make out all the details, but in a flowering grass we can see two things which are peculiar, lightly poised anthers, which hang out and dance in the wind, and long, slender, feathery styles.

The only plants which come so near to grasses that a doubt can arise as to whether they are grasses or not are certain sedges and rushes. In these the sheathing leaf-bases are either wanting or not split, and there is no colourless scale. The stalks are commonly filled with pith ; the anthers of the stamens are erect, and do not dangle as in grasses. The numbers of the flower-parts are also in many cases different from what we find in grasses, where there are nearly always three stamens and two styles.

There are many sorts of grasses, and about a hundred species grow wild in the British Isles. A very little attention will show that in every hayfield there are several distinct species with quite different flowers.

Any grass that we happen to examine will suggest a number of questions, and it may easily happen that among these will be some that we cannot answer to our satisfaction. It is a good practice, however, to put questions incessantly, for it is chiefly in this way that we make progress in the interpretation of natural objects.

Why are grass-haulms hollow and jointed, that is, with solid partitions at intervals? A hollow cylinder, like a grass-haulm, is better able to resist bending than a solid stem of the same weight for a given length. Take two lumps of plasticine or modelling clay of the same weight. Shape one into a solid cylinder ; spread out the other into a flat sheet, and roll it up till its edges meet. You can thus get two cylinders of the same length and the same weight, one solid and the other hollow. Lay each upon two supports, the distance between the supports being the same in each case. Then test the power of the two cylinders to resist bending. A tape, holding up a suitable weight, may be hung from the middle point of each cylinder. The result will leave no doubt as to the greater resistance to bending of the hollow cylinder.[1]

The hollow-grass haulm is light, strong and springy, yielding easily to wind, without being damaged by it, except indeed when the seeds are nearly ripe, and the top of the haulm is heavily loaded. Then wind and rain may lay the haulms flat, but even for such an accident a remedy is provided, as we shall shortly see.

Solid partitions or knots mark the places where the bases of the leaf-sheaths are attached to the haulm. Here the vessels pass out into the leaves, and it is chiefly the interwoven vessels which form the knot. The solid partitions stiffen the haulm, and hinder it from becoming flattened by pressure. But there is another and less obvious reason for the knots.

Take an entire grass-plant fresh from the ground, and a foot or more in height; plant it in a tray of wet earth or sand, not upright but horizontal, and see what will happen. A very top-heavy grass will not do. If the experiment is made with care and judgment, you will see in the course of a day or two that the haulm begins slowly to erect itself. Each segment between two neighbouring knots sets itself at a small angle to the segment next below, and as all the angles are bent towards the same side, the horizontal stem soon begins to rise. Before long it will be found to have completely erected itself, and perhaps to lean over a little to the opposite side. You can hardly fail to remark that all the bending necessary to erection is effected at the knots, and that the intervening parts of the stem are nearly straight all the time. There is evidently at each knot what we may call an organ of movement. (Compare clover and wood sorrel, pp. 125, 132.) If you mark one of the knots with horizontal Indian ink lines passing round it a small distance apart (say 1 mm.), you will see

[1] For the reason of the different resistance to bending of the two cylinders I may refer the reader to *Round the Year*, article "Hay-time."

that in a day or two the lines become a good deal wider apart on the side from which the haulm is bending. The organ of movement changes its form, swelling on one side, and either not swelling at all, or swelling to a less extent, on the other side. This power of swelling unequally according to circumstances is due to absorption of water. The knot, or some structure in communication with it, evidently possesses sensibility; it can feel, so to speak, when it is displaced, and absorb so much water as to bring the haulm back to the upright position.

Why do the bases of grass-leaves ensheathe the haulm? While the grass-haulm is still growing, the outer leaf-sheaths protect the inner ones, and the inner ones protect the haulm. As the haulm attains its full height, the inner parts are gradually withdrawn from the outer ones like the joints of a telescope, and the sheaths become free from one another. A young and soft shoot is stiffened, being made up of a nearly solid mass of sheaths, one within another, but an older and firmer shoot is hollow, light and springy, and needs no support from the leaf-sheaths. No better plan could be devised for the rapid lengthening of the flowering stalks. Something too is gained by carrying higher the base of the free leaf-blade, for to overtop its rivals is a leading feature in the policy of most grasses.

Why are the sheaths of grass-leaves split along one side? To permit of expansion without tearing as the parts within enlarge. The haulm within the sheath rapidly expands in diameter as it becomes older. Sometimes a growing ear or mass of flowers is lodged within a leaf-sheath, and needs room for its expansion.

Why are most grass-leaves ridged on the upper surface? The ridges when cut across are seen to be more or less triangular, and fit neatly together when the leaf is rolled up. Make a model of a grass-leaf by glueing triangular bars of wood to a strip of canvas, and see how neatly such a model can be rolled up or expanded, as circumstances require. Nearly all grass-leaves are rolled up in their early stages of growth, and even when full-grown they may require to be rolled up as a temporary protection against hot sun and dry air. Some of our native grasses, growing on dry pastures, such as Sesleria, can roll or unroll in a few minutes. It is enough to put a bell-glass over the growing plant to cause the leaf to open widely, as it always does when the air contains much moisture. If we remove the bell-glass and expose the plant thereby to the warm, dry air of an ordinary room, the leaf will roll up again, and expose a diminished evaporating surface. Some grasses, like the mat-grass of our moors (Nardus), or the sheep's fescue, grasses which inhabit places where there is no shelter from the sun and wind, are permanently inrolled. Others, which grow in damp meadows or shady woods, never roll up when they have once expanded. A few grass-leaves are flat, and have no ridges at all.

The stomates of a grass, that is the pores by which water-vapour is given off and air taken in, often lie only on the upper surface of the leaf, within the grooves between the ridges. Hence they are well protected from too dry air, especially when the leaf is wholly or partially rolled up. If the leaves are flat, the stomates are usually found on both surfaces.[1] In certain cases this concealed position of the stomates protects them against an opposite but equally dangerous accident, that of being choked by water, which would prevent gas or vapour from passing in or out. You have no doubt often seen the float-grass (Glyceria fluitans), rooted in the mud, and spreading out its leaves, which are sometimes yards long, upon the surface of a pond or a slow stream. The leaves of float-grass lying flat on the water could not, if they possessed the ordinary leaf-structure, drain off the rain, and if they happened to get splashed or drawn beneath the surface by a current, we might suppose that they would find it very hard to get dry again. But no such difficulty is met with. The

[1] Lewton-Brain in *Linn. Trans.*, 1904.

leaf of the float-grass, no matter what is the state of the weather, no matter how roughly the leaves have been treated, is always dry on its upper surface, and always wet on its under surface. The dryness of the upper surface is due to the deep furrows between the ridges. Into these the surface-film of the water cannot pass,[1] and the water above the surface-film is accordingly held up and prevented from entering. No accident to which the float-grass is exposed can fill the furrows with water, or drench the stomates which lie sunk in them. There is another Glyceria, almost equally common in watery places; in this second species (Glyceria aquatica) the leaves never float, and it is interesting to remark that they have no ridges on their upper surface.

It is probable that grass-leaves originally became ridged on their upper surfaces to facilitate rolling up lengthwise during seasons of drought, but float-grass has turned its leaf-ridges to account as a means of preventing the wetting of the stomate-bearing surface. A cross-section of the leaf reveals a number of enclosed air-spaces, which, one would think, must greatly increase the buoyancy of the floating leaves; however, in the second species of Glyceria (G. aquatica), whose leaves do not float, the air-spaces are much larger. They are not simple cavities, but are filled with stellate cells.[2]

What is the use of the colourless scale which is found inside the leaf-sheath, just where the blade becomes free? I have puzzled over this question for years without the least success. Some people think that the scale hinders water from making its way into the sheath. It is an objection to any such explanation that the surface-film

[1] Object-lessons from Nature, Pt. II., pp. 135–6.

[2] This was pointed out to me by Mr. Norman Walker in sections of G. fluitans. Mr. Lewton-Brain in *Linn. Trans.*, 1904, says that the "low ribs" of G. fluitans probably have no significance as an adaptive character. I suspect that he has not seen sections through *floating* leaves, where the ridges are as sharp and distinct as possible; in aerial leaves of the same species the ridges are much lower, especially in the neighbourhood of the midrib.

of water cannot pass into narrow spaces bounded by unwettable surfaces, so that a scale does not seem to be necessary to hinder it from passing in here. I took three common grasses, cut off the leaf-blades and their scales (ligules), and immersed them in water; no water made its way into the leaf-sheaths. The scale is very constant in true grasses, and peculiar to them.

Why do the anthers of grass flowers dangle? In order that the wind may shake the pollen out of them more easily. In hay-time the air carries everywhere the minute pollen-grains of grasses, and at this season the dust which settles in still places always contains grass-pollen. Grasses are wind-pollinated.

Why are the styles of grass-flowers long and feathered? In order that they may have a better chance of catching some of the pollen-grains which are wafted past by the wind.

Why are grass-flowers small, inconspicuous and greenish? Because the grass has no need of insects or other animals to pollinate its stigmas.

Remark the differences between a flower which is wind-pollinated and one which is insect-pollinated. We may take any common grass as an example of the first kind. Red clover, primrose, convolvulus, rhododendron and orchids are familiar examples of the other kind.

Wind-pollinated flowers	*Insect-pollinated flowers*
(1) are inconspicuous,	(1) are usually conspicuous,
(2) are scentless,	(2) are often scented,
(3) secrete no honey,	(3) usually secrete honey,
(4) produce much pollen, most of it being wasted,	(4) produce less pollen, comparatively little being wasted,
(5) often have feathered stigmas.	(5) usually have simple stigmas.

In certain states of the weather grass-leaves exude much water. There are fissures in them, by which drops of water can be passed out. It seems that a low temperature is particularly dangerous to green tissues which are laden with water. During a warm day when rain has saturated the earth, absorption of water goes on freely. Even after sundown the ground may still be warm enough to favour rapid absorption by the roots, but the air cools fast, and a temperature low enough to be dangerous to the softer tissues may obtain only a few inches above the warm soil. Under such circumstances grasses and other herbs pass out the water, which has become superfluous and even dangerous, in the form of big drops. Then people generally say that there has been a heavy dew, though it may be that the sky was overcast and that no dew whatever fell. Exuded water may be distinguished from real dew by attending to two points of difference. Dew never forms except under a clear sky; exudation takes place whenever plants gorged with water are exposed to cold air, whether the sky is clear or cloudy. Secondly, dew forms as minute, close-set drops, which on a surface not easily wetted may afterwards run together to form big drops; the drops exuded from the water-pores of leaves, on the other hand, are big and solitary from the first.

The exudation of drops from grass-leaves can be brought about at pleasure. Cut a sod, damp it, lay it on a glass plate, and cover it with a bell-jar. In a day or so the grass, kept at the temperature of an ordinary room, will exude abundantly from the leaf-tips.

XLVIII. THE WATER-SPIDER.

A very ingenious predatory animal, which makes use of the properties of the surface-film of water to construct for itself a home beneath the surface, is the water-spider (Argyroneta), of which Prof. Plateau has given a full and interesting account.[1] Like all spiders, this is an air-breathing animal. It dives below the surface, and spends

[1] Bull. Acad. Roy. de Belgique, 1867.

nearly its whole life submerged. In order to do this without interruption to its breathing, the spider carries down a bubble of air, which overspreads the whole abdomen as well as the under side of the thorax. These parts of the body are covered with branched hairs, so fine and close that the surface-film cannot pass between them. The spider swims on its back, and the air lodges in the neighbourhood of the respiratory openings, which are placed on that surface which floats uppermost. When the spider comes to the top, as it does from time to time to renew its supply of air, it pushes the abdomen out of the water, and we can then see that this part of the body is quite dry. When it sinks, the water closes in again at a little distance from the body, and the bubble forms once more.

It would be inconvenient to the water-spider to be obliged to come frequently to the surface for the purpose of breathing. A predatory animal on the watch for its victims must lie in ambush close to the spot where they are expected to appear, and the water-spider accordingly requires a lurking-place filled with air, beneath the surface of the water. It has its own way of supplying this want. Relying on the fact that the surface-film of water will not readily pass through small openings, the spider proceeds as follows. It begins by drawing together some water-weeds with a few threads, in such a way that they meet at one or more points. It then fetches from the surface a fresh supply of air, and squeezes part of it out by pressing together the bases of its last pair of legs. The bubble rises, but is detained by some of the threads previously spun across its path. Then the spider returns to the surface to fetch another bubble, and repeats the operation as often as may be necessary. Now and then she secures the growing bubble by additional threads, and before long has a bubble nearly as big as a walnut inclosed within a silken invisible net, which imprisons the air as effectually as a dome of glass would do. The spider takes care to conceal her home from observation, and before long the minute algæ, growing all the more vigorously because of the air brought to them, altogether hide the habitation. The mouth of the dome, which is of course beneath, is narrowed to a small circle, and then the spider constructs a cylindrical horizontal tube, seven to eight millimetres in diameter, by which she is able to enter or leave her home without being observed. The air within is renewed as required by the regular visits of the spider to the surface.

Besides this home, which is the ordinary lurking-place of the spider, another is required at the time when the young are to be hatched. The new-born spiders are devoid of the velvety covering of hairs, and would drown if placed in a nursery with a watery floor. The female spider therefore makes a special nest for this occasion, a strong, bell-shaped nest, which floats on the surface of the water and rises well out of it. The upper part is partitioned off, and contains the eggs. Beneath the floor of the nursery the mother takes her station, ready to defend her brood against predatory insects.

Where animals of a terrestrial, air-breathing stock become adapted to a submerged life, forms less perfectly equipped for aquatic conditions will usually be found among allied species. We know of insects so entirely aquatic in their early stages that they quickly perish when removed from the water, and many gradations can be found to lead from these to purely terrestrial forms. In the same way there are several spiders which connect the water-spider with ordinary hunting spiders. One of these is Dolomedes, which used to be found in our fen-country. The female is large, being 20 mm. ($\frac{4}{5}$ in.) long, and therefore much bigger than a house spider; the male is much smaller. They run about on the surface of standing water, and dive when pursued. But Dolomedes has not learned how to make herself a crystalline home beneath the water, a home whose walls consist of nothing more substantial than the surface-film which forms wherever air and water meet.

XLIX. THE INDUSTRIES OF WILD BEES.

(*a*) THE BURROWING BEE.

Almost any day in early summer I can amuse myself by watching the industry of a burrowing bee (Andræna) which abounds in my garden. It is a little smaller than a hive-bee, but so like it in general appearance that it might easily be taken for one. The observer's attention will probably be first roused by seeing the Andræna enter the

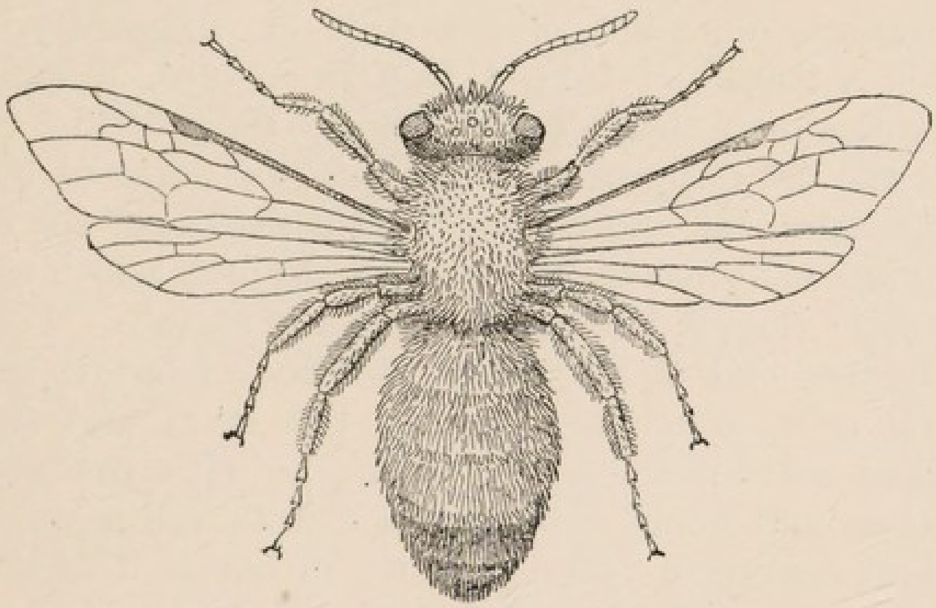

FIG. 52.—Burrowing bee (Andræna), magnified.

ground, or it may be by seeing the little heap of sandy earth which it throws out from its hole, for in early summer this bee is a great excavator, and throws out earth many times exceeding the weight of its own body in the course of a few hours. In dry, sunny April days the work gets on fast, and a mound of fresh earth and sand forms close to the hole, which is almost big enough to admit a lead pencil. The bees often leave their burrows and come back again. When they return, their hairy bodies, and especially the hind legs, are dusted all over with pollen, and the microscopic examination of this pollen shows that they have been visiting sallows, dandelions, gooseberries, and other early flowering plants. We cannot see how the burrowing bee combs off and collects the pollen; that is done in the dark. No lump of pollen, such as is conspicuous on the hind legs of a hive-bee or a humble-bee, is ever seen upon the Andræna. The pollen, mixed with honey pumped up from the crop, is stored within the burrow.

It is not difficult to explore the burrow, if plenty of time is allowed. A straw or other flexible stalk is useful as a guide. The narrow gallery bends this way or that to avoid stones, runs level or descends according to circumstances, branches occasionally or frequently,[1] and attains a length of from a foot to a yard, though not descending more than a few inches into the ground. Sometimes the bee happens to break into the deserted burrow of an earthworm, and follows it for a while, but the earthworm generally works too deep for the bee, which seldom gets more than a few inches from the surface. Towards the further end of its gallery the bee excavates one or several cells, which are nothing but short and slightly enlarged side-branches. In these she lays the burdens of pollen and honey brought back from the fields. One cell will contain a rounded pellet as big as a small pea, and upon this a single egg is laid, which quickly hatches and yields a white grub, whose whole store of food is the pellet provided by the mother. Neither the galleries nor the cells have any special lining. Male bees are now and then seen hovering about the entrance to the galleries, but it was long before I learnt to know the males of the species which is so common in my garden. They are smaller than the females and differently coloured, and seem to spend most of their time about the flowers, gathering honey or pollen, but storing none. Many Andrænas make their burrows near together, and a sloping bank or garden-walk will sometimes show scores or hundreds of

[1] The species differ in this respect. Andræna fulva, which I have chiefly observed, makes burrows which seldom branch.

holes within a few square feet. The bees seem now and then to enter the wrong holes, for they creep out again in a minute or less with the pollen still dusting their bodies. I do not however believe that they really make a mistake. The bee on entering finds an intruder in her burrow, a parasitic bee of which more will shortly be said, and being of peaceful disposition, she waits till the way is clear. There is no reason to suppose that several bees ever share the same burrow by mutual consent. When the cells are stored with honey and eggs, the bee shovels part of the earth back into the hole, makes up the mouth, and then probably sets about a fresh hole, as we may infer from the small numbers of eggs in one gallery, and also from the fact that the excavations are carried on for many weeks, while a single gallery can be excavated, stored, and closed in a few days.

FIG. 53.—Hind leg of Andræna, magnified.

The advantages of the burrow are obvious enough. The Andræna gets a tolerably dry place in which to store her honey and eggs, and some degree of protection from ants and other predatory insects, as well as from the innumerable insect-parasites, which are ever ready to appropriate either food or larvæ for the maintenance of their own young. The protection against parasites is, however, far from complete. When the mother-bee visits a flower, the hairs on her body are often grasped by the minute larvæ of Stylops, which lurk there for this very purpose. She unconsciously brings home an enemy, which will enter the body of one of her brood, and develop there, causing pain and distortion, though not necessarily death. Also there are cuckoo-bees, not unlike the burrowing bees in general build, which cannot dig, or collect pollen, or lay up stores of food. They find out the burrows, enter them and lay their own eggs in the cells. The larvæ hatched from these eggs get the start of the rightful owners, and it is not the offspring of the industrious burrowing bee but of the cuckoo-bee which ultimately enjoys the store of food. Though the cuckoo-bee is quite unlike an Andræna, it is allowed to enter the burrow without opposition, and the Andræna never learns the fate of the brood which she left to all appearance well provided for.

(*b*) THE LEAF-CUTTING BEE.

I will next describe the manœuvres of another solitary bee which I have lately had an opportunity of studying. We not unfrequently find that the leaves of trees and shrubs in our gardens have been mutilated in a singular way. Oval or circular pieces have been removed by clean cuts, which look as if they had been made with a pair of scissors. What creature cuts bits out of the leaves, and how is the cut made? A bright summer day given up to the inquiry will probably answer these questions. You will, if fortunate, see a bee, very like a hive-bee but rather stouter, hover about the tree, settle on a leaf, and cut a piece out with her jaws. While cutting, the bee clings to the piece which is to be detached; she cuts decisively and rapidly, doubling the fragment between her legs as she proceeds, and using her wings when the support begins to fail. Then she flies off, carrying the piece, which may be oval and half an inch long, or circular and a quarter of an inch in diameter. The bee will probably come back again and again, get more bits of leaf, and fly away with them. If your garden is of the modest dimensions common in cities, you will be probably unable to see where the pieces of leaf are taken to, but in a large garden you may find it possible to follow the bee and see her enter a hole, either in the ground, or in a wall, or in a tree-trunk. Then you will be able to learn something more. After many journeys, each resulting in the acquisition of a single bit of leaf, the bee changes her occupation, her journeys become longer, and she returns home with no load that you can see. After some days she will leave the spot altogether, and then curiosity will naturally lead you to examine the hole, and see what it contains.

Carefully exploring, you will find in the hole a cylinder, perhaps four inches long, made of bits of leaves wrapped one round another and pressed tight against the wall. If the tube is quite fresh, the bits of leaves will uncoil when removed, but if several days have passed since they were introduced, the tube will keep its shape. Gently unwrap part of it. You will find that it is carefully formed of several layers of leaves, and within are six, seven or more cells, arranged in a row, and filling the whole length of the tube. Each cell is thimble-shaped, and consists of leaf-fragments arranged in several layers. One end is a little narrower and rounded, the other end is wider, and closed by a neat lid composed of two or three circular leaf-fragments. Beyond this lid is a shallow open mouth, which receives the end of the next cell. The cells are all made separately, and though they fit the outer tube closely, they are not fastened to it. It is therefore possible to unroll the tube and leave all the cells intact. Within each cell is a mass of honey and pollen, with an egg or a larva on the top. Further study brings to light many more details. The leaf-cutting bees are of several species, and each has its own preferences. Some prefer one kind of hole, others another. Some prefer rose-leaves, others lilac-leaves, elm-leaves or horse-chestnut leaves. They have their favourite flowers too, which they visit for honey and pollen. The leaf-cutting bee which is most plentiful in London gardens finds or makes its burrows in the trunks of oak, elm, and mountain ash.[1] It generally lines the burrow with elm leaves, and gets its honey and pollen from thistles. The bee which cuts up the leaves of rose-trees generally makes its holes in brick walls or

[1] I have no proof that the leaf-cutting bee ever makes her own burrow.

in the ground. The leaf-fragments are not cut at hazard; each has a shape suited to the place which it is destined to occupy. The outer tube is more roughly shaped than the cells, which are beautifully exact. Every cell contains from nine to twelve separate pieces, sometimes many more, and though they are secured neither by stitches nor glue, they keep their shape perfectly. The fitting of the circular lids, each made up of three or four bits of leaf, into the mouth of the cell is an excellent piece of work. The bees often employ the disused burrows of earthworms, but are careful to stuff up the lower part of the tube with fragments of crumpled leaves, lest an enemy should enter from below. Some employ the holes excavated in tree-trunks by beetle-larvæ or wood-wasps. If the hole is wide, they will arrange their cells in two or three rows instead of a single row as usual. When all the cells are filled, the bee makes up the entrance with crumpled leaf-fragments, and comes back no more. The grub consumes its store of honey, and then enters upon its winter sleep, pupating in autumn or spring, but never emerging until the following summer.

I can only glance at a number of other contrivances employed by other solitary bees. Various species of Osmia utilise stacked reeds, burrows of other insects, and even snail-shells for their stores of food. Some bees employ the dead branches of blackberries, which are easily hollowed out because they are filled with soft pith; one species makes a collection of cells out of chewed leaves; another not only employs empty snail-shells, but conceals them in a dense mass of sticks and straws. Mason-bees build up tubes of small stones, which they fasten together with a secretion which sets hard like cement. Halictus makes a rude comb of cylindrical cells out of clay, and lines them with hardened saliva. The carder bee (Anthidium) strips off the woolly or cottony covering of certain herbs, and lines her burrows with it. Other carder-bees imitate that species of Osmia which chooses snail-shells for its nest, but subdivide the cavity by partitions of resin. Dasypoda improves on the methods of Andræna, and instead of leaving a conspicuous mound of loose sand and earth at the mouth of the burrow, disperses it with her feet, lest it should attract the notice of a spoiler.

(c) HUMBLE-BEES.

Let us next consider the economy of the humble-bees, which show a distinct advance upon the simple arts of the solitary bees.

In early summer we see big humble-bees flying abroad and at times exploring the holes in a stone wall or a bank of earth. The large black and yellow humble-bee is probably Bombus terrestris, which makes a subterranean nest. The moss-carding bee (B. muscorum) is much smaller, and has a reddish thorax and a yellowish abdomen. The fierce B. lapidarius, which makes its nest among loose stones, is about as large as B. terrestris, but has the end of the abdomen reddish-brown.

The moss-carding humble-bee (B. muscorum) does not usually burrow, but makes its nest on the top of the ground in meadows or among trees. Here they are often cut through by the scythe and picked up by the mowers. There is no readier way of getting to see these nests than to visit a meadow which has just been cut. A nest may be five or six inches in diameter, of low rounded form, with arched roof, and concealed by moss, ferns, grass or dead leaves, which are carefully arranged so as to give the outside as natural an appearance as possible. A narrow gallery, covered with moss or the like, and often several inches long, guards the entrance. The moss which covers the nest is never brought from a considerable distance, nor do the humble-bees ever carry it through the air. They push it backwards towards the nest with their legs, the head of the bee pointing away from the nest. With their legs also the bees card or teaze out moss or other vegetable tissues, reducing them to the condition of fine threads, which are employed to conceal or to line the nest. Several bees have been seen to work together in carding moss or passing it towards the nest. If the nest of the moss-carding humble-bee is dug up (which may be done safely, for this bee is very pacific), there will be found a lining of coarse wax no thicker than writing paper, and within this an irregular mass of egg-shaped cells, some open, others closed. They are of different sizes and of different shapes, and rather rudely fitted together. Some contain larvæ and pupæ in different stages of growth. A few contain honey only, and these are deeper and open at the top. Other cells will perhaps contain pollen saturated with honey, and lumps of the same substance often lie about the cells in a disorderly way. Schoolboys are often clever at digging out the nests of this and other humble-bees, and the taste of the wild honey, mixed perhaps with a good deal of earth, is to many of us a familiar recollection of our boyhood.

The nests of Bombus terrestris, one of the commonest of the burrowing humble-bees, are lodged in underground cavities. It is believed that the deserted burrows of small quadrupeds, such as voles, are taken advantage of, to save labour in excavation, but the humble-bees may often be seen working at their own holes, or shaping and trimming holes which they found ready-made. The red-hipped humble-bee (B. lapidarius) makes choice of a cavity in a loose heap of broken stone, or in a bank. The plan of construction adopted by Bombus terrestris is much like that of the moss-carding bee. The cavity, or some part of it, is lined by a thin layer of wax, which encloses the cells. These may be few, especially in early summer; when the nest is most populous a hundred or more may be counted. The early cells, made by the solitary queen, are comparatively rude, and consist of lumps of pollen, coated with wax, and enclosing many eggs or larvæ. The workers, when they appear, construct cup-shaped cells, as big as peas, in each of which the queen lays several eggs. Then the cell is stored with food (pollen moistened with honey) and closed. The grubs which issue from the eggs consume the store of food, and then require to be fed. The mother-bee, or at a later time one of the workers, bites a hole through the waxen wall, and passes food in from her own mouth. The common cell, shared by six or seven larvæ, steadily grows till it is as big as a walnut, and Pierre Huber ascertained that the grubs break through the wax from time to time, when the workers clap more wax on the spot and trim it neatly. As soon as the grubs are full-fed they spin egg-shaped cocoons of whitish silk; the silken threads are often intermingled, so that several cocoons loosely cohere. When they perceive that the cocoons are ready, the workers remove the outer shell of wax. After the short pupal stage is over, and the winged bees have emerged, the cocoons are seen to be truncated, a large, circular hole having been made towards the upper end. The empty cocoons are trimmed, coated with wax, and filled with honey by the workers, to serve as honey-pots. They are deepened, to increase their capacity, by a rim of wax added to the lip of the truncated cocoon; then the mouth is narrowed, but not sealed. Sometimes waxen honey-pots are made of wax throughout, with no cocoon as a foundation. As many as sixty honey-pots have been counted in one nest; most of these may be full, but when many larvæ are being fed, the store of honey runs low.

The humble-bees are much better equipped for pollen-collecting than any of the solitary bees. The first joint of the tarsus of the hind leg is dilated, as in a hive-bee, and its inner surface, the one turned towards the body, is closely set with short stiff bristles, which are very useful in combing the pollen from all parts of the body. Just above the tarsus, and on the outer side of the tibia, is a pollen-basket, enclosed on either side by long stiff curved bristles. Captured humble-bees will often be found to have a big lump of yellow pollen stored up in this basket. In one respect only is the collecting apparatus of the humble-bees distinctly inferior to that of the hive-bee. In the hive-bee the enlarged joint of the tarsus has the bristles set in regular transverse rows, and their efficiency in combing the hairs is thereby increased. In the humble-bees no such arrangement can be discovered.

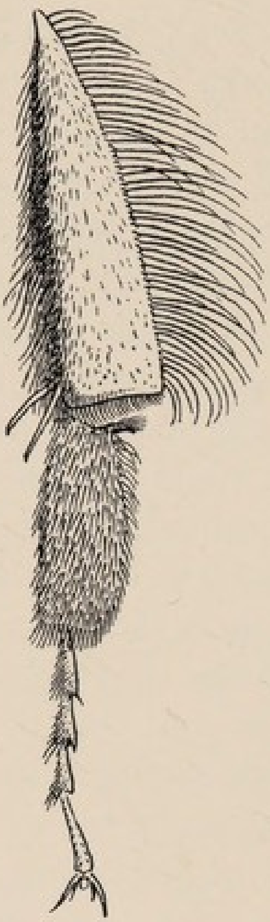

FIG. 54.—Right third leg of humble-bee, side next the body, magnified.

Humble-bees employ wax rather sparingly either to line the nest or in the construction of their cells, and often mix it with vegetable substances. Their wax is made in much the same way as in the hive-bee. The bee begins by taking a good meal of honey. Shortly afterwards wax begins to exude between the joints on the under side of the abdomen and also on the back. In the hive-bee the wax is secreted in the form of rather large thin plates, which can be detached by the nipper, a kind of forceps formed by the meeting of the tibia and tarsus of the hind leg. In a humble-bee the wax is much less coherent, and does not form plates but a kind of dust ; no nipper is therefore required to detach it. At the base of the tarsus of the hind leg we find, in place of the lower lip of the nipper, a short stiff brush, which is apparently employed to sweep out the granular wax as fast as it is formed. Réaumur was mistaken in saying that the wax of humble-bees is formed out of pollen, and that it cannot be melted by heat ; no doubt he mistook for wax the lumps of pollen moistened with honey which are so often found in the comb.

Three, perhaps four kinds of bees can be found within one nest in the height of summer. There are large females which may be called queens ; perhaps also smaller females whose unfertilised eggs regularly produce males ; workers, which rarely lay eggs at all, and males or drones.

The workers, unlike those of the hive-bee, are not distinguished by any external peculiarities of structure. The numbers of the family are far inferior to those of the hive-bee. A humble-bee's nest which contained three hundred individuals would be unusually populous.

In spring a queen which has survived the winter begins by herself to found a new community. Having chosen a spot to her taste, which may be either a hole in a bank or the bare surface of the ground, according to the habits of the species, she constructs a rude nest or shelter, lays a thin plate of wax, and deposits upon it a small heap of pollen mixed with honey. Upon this one egg is laid. She then builds up a low cylindrical wall of wax, joined to the basal plate; within this more pollen and honey are stored, and additional eggs laid. The sides of the cell are then carried a little higher, and at length the top is carefully sealed. Other cells may be added to the first, with which however they are only slightly connected. After some days the larvæ hatch out, and soon consume the food laid up for them. The queen then pierces a hole in the wall of the cell, passes her tongue in through the hole, and feeds the larvæ carefully, closing the hole when the operation is finished. The numbers of the family increase very slowly, for the whole of the labour has at first to be performed by a single individual, but the first brood which hatches out consists of workers, who relieve the mother of a great part of her work; after they appear the queen spends less time abroad, and lays eggs more frequently. The first cells are constructed as early as

FIG. 55.—Right third leg of humble-bee, external side, with pollen-basket, magnified.

February or March, and contain comparatively few larvæ. A few weeks later the number of eggs laid in a single cell becomes greater. The food-supply is then less adequate, and this may be one reason why the bees hatched in the height of summer are of smaller size. It has been said that the cells of late summer never contain any food, and that the grubs which they contain are fed exclusively from mouth to mouth. In autumn special provision is made for the perpetuation of the race. New queens and a great many drones are hatched out. Egg-laying has by this time ceased altogether, and the rearing of new generations no longer employs the workers, which remain idle in the nest, seldom going out even to procure honey. The community does not long survive the close of the fine season. The nest, which is then devoid of food and brood, is deserted, and a few fertile queens, scattered about in holes in the ground, are the only humble-bees which hibernate.

It has been found that the economy of the humble-bee is materially affected by climate. In the short summer of the arctic circle they are said to produce no workers. The nests are very small, and we might almost say that the social state has been lost, the bees having returned to the solitary condition. On the other hand, in Mediterranean countries the humble-bees often survive the winter in considerable numbers, and the nests appear to be tending to a permanent state, such as is more fully attained in the hive-bee.

It was long ago stated by the old naturalist Godard that in the early morning a sound is heard to issue from the nest of a humble-bee, which he supposed to be a call, rousing the inmates of the nest to work. This statement, after having been long regarded as a fable, has recently been confirmed by several observers. It is found that the humming noise is due to the rapid vibration of the wings, and that if the bee told off for this work should be removed, another at once takes its place. The purpose of the sound can only be guessed at.

Humble-bees have many enemies, which sometimes devour not only the honey but the bees as well. Among the number are ants, predatory flies (Conops), caterpillars, rats, field-mice and weasels, to say nothing of schoolboys and mowers. There are many parasites, too, which sponge upon the nest, the most curious being the cuckoo-bees, which, though unable by lack of special structures to collect pollen or make honey, are suffered by the humble-bees to dwell in the nest, and to take their share of the good things which have been stored up. Many solitary bees also are infested by their own species of cuckoo-bees (see p. 275).

The naturalist who has been able to acquaint himself with the habits of a solitary bee, such as Andræna, a humble-bee of any species, and the hive-bee, will find himself in a position to make some interesting comparisons, or even to trace what may be called the growing civilisation of social insects. He will see how bees may gradually associate themselves into permanent families, and families into little nations. He will see how the community, which in its simplest forms is short-lived, is gradually enabled to last through more than one season, while in the more complex societies provision is made for the storing of food, a regular succession of generations, and the occasional emigration of new swarms. He will see how bees which were solitary, and consisted of ordinary males and females only, developed a caste of small females, able to lay only unfertilised drone-eggs ; how these small females undertook more and more the rearing of the young broods, and became at last the workers and governors of the community. Social feeling, of which there could be none among the solitary bees, appears in all communities which include the offspring of more than one mother, and becomes intensified until in the hive we observe a division of labour, and a subordination of private interests to the general good, which can only be paralleled in ant-communities. Hardly less interesting is the steady improvement in the working implements of the bees, side by side with the growing complexity of their social state. Hairs, which are the only means which a solitary bee can employ to bring loose pollen to its burrow, become supplemented by pollen-combs and pollen-baskets. The mouth-parts become prolonged, so as better to explore the recesses of a flower, more efficient in suction, and more neatly folded when not in use. The rude materials employed for the constructions of solitary bees, such as sand, clay, or chewed leaves, become worked up with resin, vegetable wool, silk and wax, and at last replaced by them. With wax comes the possibility of an architecture economical of material, space and labour even to the theoretical limit.

Close and long-continued study of insect-communities is not work for young naturalists. It is more profitable for them to start many inquiries, and pursue each to the point at which the difficulties begin to be serious. The delight of pressing some one inquiry farther than it had hitherto been carried is not for them, but the future may have it in store for this or that individual. We should never forget that there may be a Réaumur or a Darwin among our pupils.

L. A SKELETON LESSON ON FURZE.

A. DIRECTIONS.

1. Draw a fresh branch of furze, about 3 in. long, of the natural size.

2. Make drawings on a larger scale of each distinct component of the same branch.

3. Cut thin sections of a young branch, and notice (*a*) the position of the stomates, (*b*) the arrangement and structure of the vascular bundles.

4. Examine the flowers, and make illustrative drawings.

5. Examine the pod, and draw it both entire and burst open.

6. On a hot, sunny August day study the dispersal of the seeds.

7. Collect a handful of the seeds in August, and sow them in a garden-border. Make a set of drawings at intervals to show the successive stages of growth.

B. QUESTIONS.

1. Classify the branches of furze, or what appear to be such.

2. How do branches of the year differ from older branches ?

3. What is the meaning of the grooves on the branches ?

4. Why is furze spiny ?

5. Where is carbon-assimilation effected in furze ?

6. Two species of furze (sometimes more) are often to be found growing together. Note such as are to be found in your own neighbourhood, and the marks by which they can be distinguished.

7. Xerophytes are plants specially adapted to dry situations. Mention all the xerophytes which you know by personal observation.

8. What features do you find to be shared by furze and the common rush ? What are shared by furze and ling ? Try to explain these resemblances.

9. What insects visit the flowers of furze ?

10. What evidence can you supply of the derivation of furze from a Leguminous plant of more ordinary type ?

LI. MUSEUMS AND THE TEACHING OF ELEMENTARY NATURAL HISTORY.

The museum is a time-honoured resource in the teaching of natural history. What can be more obvious than to preserve striking objects which are only met with at long intervals, arrange them methodically, and study them closely? What more obvious than to be guided in the choice of objects by experts, who give their whole time to natural history? The saving of time and thought is immense. The teacher takes his pupils to visit a great collection, selected with infinite pains and set out with professional skill; surely he will do more in this way than if he makes a fresh beginning, and tries to arrange a little collection of his own.

The great public museum is perhaps too distant for frequent visits, and then the school is fired with the ambition of setting up collections of its own. The very effort will be wholesome; surely every one will co-operate in building up a museum which shall be to the private collections of the boys what the national museum is to the little provincial museums.

These are our expectations, and we get to work in good spirits. It is easy to start a school-museum, and easy to carry it through the early stages of its development. Shells, fossils, birds' eggs and the like come in freely, many of the specimens being drawn from private collections which have ceased to fascinate, or have been bequeathed to uninterested persons. When gratifying progress has been made for some years, and a great array of named specimens has been set out in due order, disillusion sets in. It is discovered that the museum interests very few persons, and is put, even by those few, to uses which can hardly be called intellectual. Sometimes, for instance, it is valued only as a means of getting the right names put to the objects in a private collection without the labour of classification. Even then the school-museum may not have been entirely useless. Those who have worked at arranging and classifying will probably be the better for what they have done, but the school-generations which inherit their labours will find in time that there is little for them to do but admire, and admiration of other people's work soon ceases to stimulate.

Where then is the miscalculation? How is it that the method which seemed so obvious fails to answer expectation? It is, I think, because an important factor has not received due attention. We have considered what Zoology and Botany and Geology are, and how they can be logically cultivated, but we have not properly considered what the schoolboy is, and what instruction he will accept or refuse. The untrained boy has many individual peculiarities, but two or three things are true of untrained boys in general. They hate copious details, they hate Latin and Greek names, and they are not warmly interested in dead animals and plants protected from all interference by plate-glass. Not only schoolboys but people of all ages soon tire of being shown a multiplicity of objects of the same kind, all protected by glass.

Claparède, an eminent and productive zoologist, has declared that "les musées pèsent lourdement sur la science." I should not be easily persuaded that this is generally true, and that our Natural History Museum at South Kensington, the Museum of Natural History at Brussels, the Hope collection at Oxford and the Manchester Museum are incumbrances, of which science would be well rid. Such museums as these secure the progress which zoological science has already made, and train experts who will carry that progress yet further. Instead of admitting that great and well-arranged museums weigh heavily on science, I believe that they should be yet more numerous, more extensive and more completely systematic than in our day. But I am ready to admit that the nearer they approach to scientific completeness, the less fitted will they become for popular instruction.

It may be thought practicable to divide the objects in a great public museum into two sets, one arranged to suit the convenience of experts, and the other adapted for popular instruction. I have little doubt that such a separation of the collections in any great public museum is prohibited by the circumstance that the visitors are not divisible into two distinct groups; there are intermediate students of many grades, every one claiming recognition. All the worse for the great public museum as a place of elementary instruction!

In the school-museum this difficulty need not be felt, for only the wants of a limited and ready-classified set of pupils have to be considered. It would be easy in the school-museum to arrange long series of minerals, fossils, shells, birds' eggs, &c., in cabinets, and to display for elementary instruction only the things which can be made to tell their own tale effectively.

Few of our public museums are effective for the purpose of popular instruction. One notable example is, however, before us. Our great Natural History Museum contains many series of objects judiciously selected and skilfully disposed for this very end. Teachers and classes who are near enough to pay frequent visits to the museum may study with every advantage impressive and self-explanatory collections, which will admirably reinforce the comparatively rough preparations made in the school or at home. One caution is necessary. The great museum contains such a wealth of striking objects that the risk of distraction is unusually great. Many short visits would be far better than a few prolonged ones; the pupils should be encouraged to see only a very few things in one day, and these all closely and naturally connected.

Museum specimens are such things as skins, skeletons, models and fossils; they do not show the plant or animal in action. This does not mean that they are of no real utility or interest; but it shows that no museum can suffice for the purposes of Nature Study. It must be largely reinforced by outdoor lessons, experiments on seedlings, daily observations on nest-building birds, insects undergoing transformation, and the like.

There are instances, which I am glad to believe grow daily more numerous, of school-museums which are brought together and arranged by the pupils. These, though far less complete of course than the museum made and arranged by grown-up people, may be much more stimulating and more useful educationally. I can recommend also the temporary museum, made to illustrate a course of study actually in progress at the time. There need be no high standard of excellence for the admission of objects, and the naming and classification may be rough ; the great thing is to enlist the hearty co-operation of many pupils.

I do not expect great results from lectures delivered in front of the museum-cases, though they may be useful and stimulating at times. It has more than once happened to me to get a valuable lesson by accompanying a master of zoological science round a museum, and I recollect with keen pleasure a little lecture on Roman busts at the British Museum which I was fortunate enough to overhear. There is no method so poor but that it can be vivified by a powerful teacher.

The museum can be no substitute for the class-lesson, and its most costly treasures cannot replace the living plant or animal as the matter to be chiefly studied. If this is conceded, I have no further contention with the advocates of instruction in museums. We shall agree that the herbarium must not hinder us from studying the early purple orchis, growing in the pasture with its pollen-masses ready to be removed, that the cabinet of fossils must not take the place of the fossil fresh chipped out of the quarry, and studied together with the limestone in which it has lain so long.

In general, the museum meets the wants, not of young pupils who are about to receive first lessons in the observation and interpretation of nature, but of the few who have already carried their studies beyond the elementary stage. It is a place for the storage of exact and detailed knowledge.

I conclude therefore that while the usefulness of the museum in elementary instruction is limited, it is a most valuable and indispensable aid to the studies of the specialist. The usefulness of the museum as a means of popular instruction may be increased, but not indefinitely; it can never take the place of the class-lesson. Nature Study must rely on methods which work *by* the pupil, exercising his eyes, hands, judgment, independent observation, imagination and love of doing; rather than on the lecture and the museum, which work *for* him, and chiefly exercise his memory.

LII. BUTTERCUPS; A STUDY OF SPECIES[1]

Most of us think that we can tell a buttercup when we see it. If required to describe it from memory, we should probably say that it grows in pastures and meadows; that it has deeply cut leaves; and that its flower is a shallow cup composed of five glossy petals. Those of us who remember their school lessons in botany will be able to add that it has many stamens and many separate carpels. A good many different plants answer to this description, even when thus amended, and it is not easy to say which are to be reckoned true buttercups and which not.

Does the reader know the two spearworts, the greater and the less? They grow in marshy places, and the flowers are very like those of a true buttercup. But the leaves differ; they are not cut into segments, but undivided. When the flower of a spearwort is closely examined, we find that it resembles a buttercup not only in general structure, but even in details. Pull off a petal and examine its narrow base with a lens, you will find there a minute projection, which is a honey-gland serving to attract the visits of insects (see Fig. 57). A similar gland

[1] This discussion will be of interest only to those who have had some practice in classifying wild flowers, and desire to understand the reasons for the system which they find in their books.

is found just in the same place in every buttercup, and this fact strengthens the opinion that the spearworts, though they have peculiar leaves, may fairly be considered as particular kinds of buttercups.

In ponds and slow streams we often find growing in great abundance plants which have much resemblance to buttercups. The parts of the flower agree in every important respect, even to the gland at the base of the petal, but the petals are white instead of yellow. The leaves are usually of two kinds—floating leaves which are deeply cut ; and finely divided, submerged leaves, which look almost like leaf-skeletons. The old-fashioned name for these plants is water-crowfoot. If we were to go by the flowers, we might consider these too as peculiar kinds of buttercup, and call them water-buttercups.

Is the celandine which flowers so freely on shady banks in early spring a buttercup ? It has undivided, heart-shaped leaves. The sepals are usually not five but three, and there are always more than five petals ; but the celandine is of a bright yellow colour, while it has numerous stamens and carpels, and even a honey-gland and scale at the base of the petal, just as in a true buttercup.

These examples show that it is not quite a simple matter to say what a buttercup is. If we judge by the leaves, we should be inclined to say that the spearworts and the celandine are not buttercups. If we judge by the colour of the flowers, we should say that the water-crowfoot is not a buttercup, but that the spearworts and celandine are. If we go by the stamens, carpels and honey-glands, we should call all of them buttercups. Botanists have generally taken this last course, and have made them into a single group, which they call a *genus*. We might call it the Buttercup or Ranunculus genus.

We shall be obliged to alter our popular names a little, if we wish to bring all the species of this genus under a single English name. There is much practical convenience in doing so, and we must try to find a good common name for the water-crowfoot, the spearworts, the buttercups and the celandine. The Latin name *Ranunculus* is in general use; shall we translate this by *Buttercup*, and apply that name to all the Ranunculi? Then we may speak of the water-buttercup, the two spearwort-buttercups, the upright buttercup, the celandine-buttercup and so on. This will at least avoid confusion, though we may be sorry to spoil pretty and long-established popular names.

The Globe-flower (Trollius), which grows wild in some of our hilly districts, and is often seen in gardens, looks like a buttercup too. The sepals and petals have much of the general appearance of those of a buttercup, and the stamens are quite similar, but there are a great many petals, and the carpels are not like those of a buttercup. They are only five in number, and instead of each containing a single seed, they are many-seeded. If we look closely at the honey-gland, we find that it is not a prominence but a sunk space. Here the difference from the buttercups, especially in the structure of the carpels, is so considerable that we may well hesitate to consider a globe-flower a kind of buttercup. Hellebores have the same kind of carpels as the globe-flower, and must probably be associated with them.

Can a wood anemone be placed among the buttercups? Not without spoiling the definition of the genus, for the six white leaves of the flower have no honey-glands at their base. Indeed there is reason to believe that they are not petals at all, but sepals, and that the true petals have disappeared. At all events there is only one set of floral leaves. But since the anemones have numerous stamens and numerous one-seeded carpels, we must keep them near to the buttercups, if not in the same genus.

What about the marsh marigold (Caltha), which looks very like an exaggerated buttercup? This, too, has no petals, but only petal-like sepals. There are many carpels, but they are not one-seeded; when ripe, they burst lengthwise, and show a number of seeds within. Marsh marigold, too, would spoil the definition of the genus, if admitted, and by the structure of its carpels it is seen rather to belong to the hellebores, which have usually petal-like sepals, small petals, sometimes disappearing altogether, and many-seeded fruits, bursting lengthwise when ripe.

Thus we recognise by the comparison of a number of flowers that there are outside the buttercup genus several allied species, which cannot be included without spoiling the genus. Let us put them in separate genera, the most natural that we can discover, and then associate all in one large assemblage. We might give the name of Ranunculus *family* to the large assemblage, which includes several genera. Ranunculus will of course be one of these; clematis makes another distinct type, anemone a third, and hellebore or Caltha a fourth. All the British species of the buttercup family come near to one or other of these four types.

Diagram A.

RANUNCULUS FAMILY.

CLEMATIS.		ANEMONES.
	BUTTERCUPS.	
	HELLEBORES.	

It was only by degrees and after many failures that botanists came to recognise the Buttercup family as a natural assemblage. Two hundred years ago John Ray, the greatest naturalist of his age, put together the buttercups, the cinquefoils and the strawberries, all of them being what he called *polyspermous*, *i.e.* with many distinct carpels to one flower. Cinquefoils are often very like buttercups; they may have five sepals, five yellow petals, numerous stamens and numerous carpels. Was Ray justified in placing them in the same family with the buttercups? Linnæus turned them out again, and put them in the same family as the roses and brambles. When he set up his classes and orders, based largely upon the number of stamens and carpels, the cinquefoils would have come naturally, together with all the buttercups, into his Polyandria Polygynia, but to this he would not consent. Taking advantage of the circumstance that the stamens of the cinquefoils, roses, brambles, &c., spring *apparently* (not really) from the calyx, he made them into a separate class, which he called Icosandria. Had he any right to do so? Why was he bent upon keeping them apart from the buttercups? If we could have put these questions to him, he would have answered, "there are natural groups which we cannot make, but only recognise. Cinquefoils and buttercups belong to distinct natural groups. I see no close affinity between them, and have carefully framed my definitions so as to keep them apart."

This, you will say, is oracular, and gives us no intelligible reason why cinquefoils and buttercups are not to be associated. Linnæus had his reasons, but could not perfectly explain them, even to himself. Nevertheless they were sound reasons, as all the later history of botany shows. Many arrangements of flowering plants have been tried since his day, but perhaps no one of them has put the cinquefoils and buttercups together. The modern classifier pictures the families to which they belong as two large islands in an ocean with no land passage from one to the other. Nothing would induce him to represent the cinquefoils as belonging to the buttercup island.

If we are agreed as to our groups, it will be easy to find definitions for them. Plants belonging to the Ranunculus family have distinct petals, numerous stamens springing from the top of the flower-stalk, and separate carpels, whether few or many. Plants belonging to the Ranunculus or buttercup genus have a gland on the petal and many one-seeded carpels.

It will next be desirable to arrange the plants of the buttercup genus in the best order. One reason for doing this is that it is much easier to find the accepted name of any species if the descriptions are methodically arranged, but naturalists are not satisfied with an arrangement which is merely convenient for purposes of naming; they like to get what they would describe as a *natural* arrangement. It is not very difficult to divide the buttercups into small groups, which seem to be tolerably natural. We recognise:—(1) The water-buttercups, which grow in or close to water, and have nearly always both floating and submerged leaves, besides white petals; (2) the spearwort-buttercups, which have flowers both in form and colour almost precisely like those of ordinary buttercups, but undivided leaves; (3) buttercups with deeply cut leaves and yellow flowers; (4) the celandine-buttercup, with undivided leaves, and flowers like those of other buttercups, except that the sepals and petals are more numerous. The water-buttercup and the celandine-buttercup are the most peculiar of the four sets, and it will be convenient to put one at the beginning, the other at the end of the series, while the spearwort-buttercups and the ordinary buttercups may occupy a place in the middle (see Diagram B, p. 300).

Let us now for the sake of further practice see how we can arrange all the species of these groups in a natural sequence. The leaves, as we have seen, distinguish the two spearworts, for in these two they are undivided, whereas in most other buttercups they are much cut. The great spearwort-buttercup has large flowers, two inches across, and the leaves are not stalked. In the lesser spearwort the flowers are much smaller, and the leaves are borne on stalks.

There are several common buttercups which can be distinguished from one another. We might divide them according to the form of the leaves, for no two are quite alike in this respect. This arrangement would bring out the existence of a pretty regular gradation in the shape of the leaves, but the gradation is so gradual that the groups would be ill-defined. The carpels differ in the different species; in some they are rough, while in others they are smooth. The flower-stalks differ; in some they are furrowed, in others not furrowed. The sepals differ; in some they are bent back (reflexed) when the flower is open, in others they are spreading. Lastly there is a difference in the honey-gland; in some it is naked, while in others it is protected by a small scale. What organ shall we take as the basis of our primary division? Some botanists have said that the reproductive organs of the plant may be expected to yield more valuable characters than any other organs, and for the chief divisions of the buttercups they would prefer characters taken from the carpels or stamens to characters taken from flower-stalks or leaves. Some have said that convenience in naming is the chief or only consideration; others that it does not matter in the least where you get your characters, if they yield natural divisions. The success of the division, they would say, has to be judged altogether by the greater or less resemblance in many small details of the associated species.

FIG. 56. — Upright buttercup (Ranunculus acris). Flower with spreading sepals.

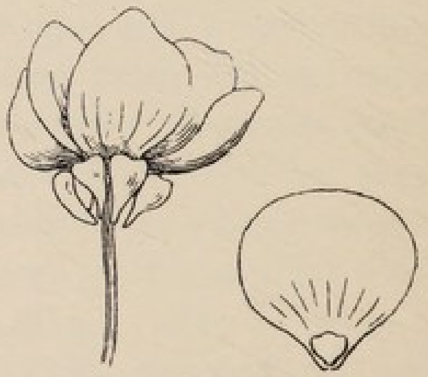

FIG. 57.—Bulbous buttercup (Ranunculus bulbosus). Flower with reflexed sepals. A detached petal, with gland and scale.

We may make a beginning by remarking that the celery-leaved buttercup (Ranunculus sceleratus) is tolerably distinct from most other buttercups, and may come at one end of the series, near to the water-buttercups and the spearworts, with which, however, it does not seem to be very closely related. The goldilocks buttercup will have to be placed close to the upright buttercup, and this again must not be widely separated from the creeping and the bulbous buttercups. There is a buttercup common in cornfields, which differs from the rest in its carpels and fruits, for they are few in number and covered with hooked spines. Another buttercup (the hairy buttercup), which is a very uncommon species, has its carpels roughened by tubercles, and the small-flowered buttercup has rough carpels too. This, like the hairy buttercup, is seldom met with.

FIG. 58.—Corn buttercup (Ranunculus arvensis). Carpel with hooked spines.

It is not difficult then to divide buttercups into such as have smooth carpels, and such as have rough or spiny carpels. Removing the buttercups with rough carpels from the rest, we have now left four species, which cannot very well be defined by any positive characters. There are some obvious differences among them. For example, in the golden and the upright buttercups the flower-stalk is not furrowed; in the creeping and bulbous buttercups it is. In the goldilocks buttercup, as well as in the upright and creeping species, the sepals spread horizontally, whereas in the bulbous buttercup and in the three species with rough carpels the sepals are reflexed, or bent down when the flower is expanded. We can now apply these distinctions to get a classification which complies with our notions of affinity. Of the four buttercups in question two (the goldilocks and the upright buttercup) have the

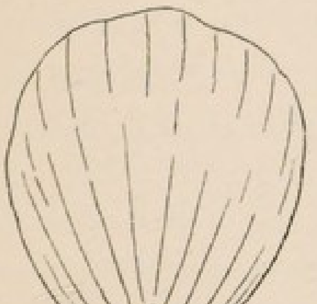

FIG. 59.—Petal of water buttercup, with exposed gland.

flower-stalk furrowed, and both have spreading sepals. The creeping and bulbous buttercups both have furrowed flower-stalks, but in the creeping buttercup the sepals are spreading, while in the bulbous buttercup they are reflexed. We have now only to distinguish the goldilocks buttercup from the upright buttercup, and this is not difficult. The honey-gland at the base of the petal is covered by a small scale in all buttercups except the water-buttercups, the goldilocks buttercup, and the celery-leaved buttercup. This distinction will separate the upright buttercup, which has the scale, from the goldilocks buttercup, which has none.

Small differences like these make it possible to arrange all the buttercups in such a table as is given in every modern manual of British flowering plants. But no linear series can show all the relations which the botanist traces between these species. It is possible to make a nearer approach to a natural arrangement by grouping the species map-fashion, as in Diagram B.

Diagram B.

THE BUTTERCUP GENUS.

	Water-buttercup.	
Celery-leaved buttercup.		Spearwort-buttercups.
	Goldilocks.	
	Upright buttercup.	
Creeping buttercup.		Bulbous buttercup.
Hairy buttercup.		
Small-flowered buttercup.		
Corn buttercup.		Celandine-buttercup.

Our list of buttercups shows us that a number of closely allied species, very similar in structure and mode of life, may exist side by side. Indeed it is the rule, though not without its exceptions, that wherever we find a plant or an animal very abundant, it is accompanied by several nearly allied species. Chickweeds, clovers, cinquefoils, bedstraws, groundsels, thistles, hawkweeds, speedwells, docks, spurges, rushes, pondweeds and sedges are familiar examples of the rule. Among animals we might quote voles, warblers, owls, sandpipers, terns, gulls, house-flies, hover-flies, harlequin-flies, gnats, &c.

It is singular at first sight that many nearly allied species, all particularly numerous in individuals, should be able to exist in the same district. One would have thought that competition would speedily bring about a signal reduction of numbers, but such reduction is by no means inevitable. Human affairs, which have been more closely studied than the relations of animals and plants, show us why. Take any industry by which money has been made quickly and with apparent ease, such as the newspaper industry. We readily understand that where newspapers are profitable, newspapers will come to abound. Many will flourish side by side even in the same city. To an observer ignorant of the language in which the newspapers are printed they might seem very much alike. It will altogether escape his notice that the newspapers differ in price, in politics, and in the class of readers which they address, that one gives particularly good stock exchange news, that another has the confidence of farmers, and that a third describes football matches in language of uncommon vivacity. Our ignorance of the circumstances under which the buttercups compete with one another is almost total, but we may judge from their commonness that they enjoy special advantages over other plants. These advantages, whatever they may be, make it intelligible that several closely allied species should be able to flourish side by side. Moreover, our common buttercups, though very similar, are not quite alike even to the untrained eye. Sometimes we can assign no meaning to the differences which we observe. We do not know why some should have spreading, and some reflexed petals; some furrowed, and some smooth flower-stalks, but now and then we can see more or less distinctly the practical effect of a peculiar feature. We see that the upright buttercup with its tall erect stem will have the advantage in mowing grass; the creeping buttercup with its numerous runners the advantage in shallow, stony ground. Some buttercups are more acrid than others, and deter more effectually the bites of animals. The corn buttercup ripens its nuts with the corn, and these nuts are spinous and clinging, so that they are carried off with the sheaves, thrashed out with the grain, and sown with it next season. But how far are we from that kind of knowledge which would explain all the differences that we tabulate!

The more ordinary buttercups, such as the upright buttercup, show by the simplicity, distinctness and regularity of the parts of the flower that they are among the most primitive of flowering plants. Their very colour is primitive, for yellow seems to be, next to green, the most primitive of flower-colours; it is also, next to green, the most stable. The true buttercups do not deviate greatly from what we suppose to have been the original form of flower. The aquatic buttercups and the semi-aquatic celery-leaved buttercup have lost the scale to the honey-gland; the aquatic buttercups have almost completely changed the original yellow on the petals to white; the celandine-buttercup has reduced its sepals to three, and increased the number of its petals; the small-flowered buttercup has often fewer than the primitive number of petals. The stem and leaves show a greater variety of structure; the simple leaves of the celandine-buttercup, which are probably primitive, usually become more or less cut; the creeping buttercup throws out long runners; the bulbous buttercup has a starchy swelling at the base of the stem ; the celandine-buttercup produces detachable tubers and bulbils so freely that it has come to depend upon them for dispersal, and very rarely ripens its seeds.

When we get outside the buttercup genus (Ranunculus) and consider the far wider buttercup family (Ranunculaceæ), the modifications of the flower become more important. We find enlarged nectaries, loss of petals, stamens reduced to five, carpels reduced to one, the nearly uniform yellow of the flowers changing to red, purple and blue. The Ranunculaceæ show in epitome the modifications which flowers in general have undergone in compliance with the tastes and habits of flower-haunting insects, in this case mostly bees and flies. Time would fail even to mention the countless adaptations of leaves, stems and roots which are met with in the great buttercup family.

What is the main purpose of a classification of plants or animals ? The first systematists had very likely nothing in their minds beyond orderly arrangement. Even that excellent naturalist, Ray, could think of no better arrangement of plants at the time of his first treatises than an alphabetical one. Any orderly arrangement is of great service as a means of rapidly finding out what is known about a particular plant or animal.

The view long prevailed, and is evident in many old systems, that the best arrangement of animals or plants was that which brought together such as agreed in their mode of life. Hence animals were classed as animals with or without blood ; as hot-blooded or cold-blooded ; as walking, flying or swimming animals, and so on. Plants were divided into trees and herbs. Working naturalists came in time to perceive that it was bad classification to put bats near to birds, or whales near to fishes, or the crowberry near to the heaths, however striking the superficial resemblance might be. The principle of arrangement according to the organs of greatest physiological importance was defended long after it had been proved to be impossible in practice.

For nearly two centuries it has been admitted that plants and animals must be classified according to their natural affinities. Nobody however could be got to explain what he meant by *affinity*. They talked much about affinity, and they really recognised it, but they could not say what it was. Every fresh systematist proposed his arrangement, which was praised as natural or blamed as unnatural, and in time opinion became fixed as to the primary groups at least, although no logical basis of a natural classification had yet been discovered. In one important respect the accepted systems infringed a universally admitted logical rule. Every one agrees that whatever property is selected as the basis of an arrangement, it must be kept to throughout. In classifying books you may go upon subject, or size, or alphabetical order of authors' names, but if you begin with one of these and afterwards change to another, you will get into hopeless confusion. Now this was just what the naturalists did, or seemed to do. Indeed they discovered that the classifications which best satisfied their sense of affinity continually changed their basis. All classifications by characters taken from single organs, corolla, stamens, organs of circulation, organs of respiration, or whatever it might be, proved unsatisfactory. The increasing unanimity of naturalists on fundamental points showed, however, that whether they conformed to the rules of logic or not, they were in all probability making a nearer and nearer approach to scientific truth.

Such was the state of matters fifty years ago, when Darwin put forth his doctrine of the Origin of Species, which threw a flood of light upon the classification of plants and animals. Darwin gave reasons for believing that animals and plants now quite distinct from one another have often descended from a common ancestor. Affinity he interpreted literally, as the result of common descent; natural groups are collections of species whose likeness to one another is derived from common descent, and their unlikeness to other groups partly to the extinction of connecting forms which once existed, partly to gradual divergence. Divergence among species is a form of division of labour. One buttercup, for instance, becomes adapted to life among long grass, another to dry stony ground, a third to life in cornfields, which are regularly reaped and sown again. The more closely they become adapted each to its own sphere, the more will they diverge from one another.

We now regard the buttercups as plants which have diverged in comparatively recent times from one common ancestor, and this, if we could recover it, we should very likely pronounce to be a buttercup too. The gaps which separate the buttercups from one another, and the wider gaps between the buttercups and the anemones, or between the buttercups and the hellebores we attribute mainly to the disappearance of connecting forms. The gap between the buttercups and the cinquefoils we believe to be far wider, and their common ancestor must date immeasureably farther back than either the common ancestor of all the buttercups, or the common ancestor of all the cinquefoils.

Darwin's theory of the Origin of Species shows that the principle of a natural classification of plants or animals is descent, near or remote, from a common ancestor. It may restore our confidence in logical principles, or in natural classifications, whichever was shaken, to remark that the Darwinian explanation causes every natural classification of plants and animals, like every logical classification, to rest upon a single basis.

LIII. BIT BY BIT INVENTION: TEETH AND SCALES

Whenever we are able to study closely the conversion of structures to new uses, we find that the process is gradual. This is in general true of human inventions too, though the progress of man in the useful arts may far outstrip the slow and sure course of nature, but there are very few human inventions which are made suddenly, all at one time. Nearly always we find upon inquiry that they are founded upon ruder prototypes. A hastily-cut log is put beneath the big stone, which has to be moved by few hands ; a second log is added to lift the stone clear of the ground, and then a third, to shift to, while the first is being carried to the front ; this completes the first stage of the new invention. The next thing is to fix the rollers permanently to the slow and heavy cart, hitherto dragged by main force over the fields. Then the rollers are increased in diameter, and shortened in length. They become thin transverse slices of trees, or built-up solid wheels, such as may still be seen in some Eastern countries. The wheel with nave, spokes and rim is harder to make, but it does not crack so easily, and it weighs much less. A rim of brass or iron gives additional strength. Then comes the smooth iron bearing, and the tire shrunk on by cooling. In the end we get the locomotive wheel of compressed paper, with steel tire and self-acting lubricator, ready to run a thousand miles a day for years together.

This bit-by-bit discovery is just in the spirit of nature, though nature is slower than man, and her adaptations more exquisite. Every new idea is tested a thousand times over, and only adopted for good when approved by the most conclusive test, the practical superiority of those who have it over those who have it not. To try all things and hold fast that which is good is the essence of Natural Selection. Let us work out one example as a parallel to the chain of discoveries by which the locomotive-wheel has been attained.

The fishes of the sea long ago found out the advantage of a nail-studded hide, and were able to arm themselves with nails of suitable size and hardness, developed out of the tissues of the inner skin. These nails had a broad base of attachment, and a sharp point, generally pointing backwards towards the tail. The tip was often hardened by enamel, a contribution from the outer skin. Such nails made shark's skin very hard to bite, and the unpleasantness of trying to bite it may be estimated by the fact that one old form of file, still used by cabinet makers, is made by wrapping shark skin round a stick of wood. The usefulness of these defences led to further developments. In some cases the broad base was enlarged and enlarged until it became a shield, protecting the softer parts within. Such a development we see in the bony plates of the head and flanks of a sturgeon. To the same origin may be traced the scales of common fishes, and even the bones of the top of the skull, most of which are what are technically called membrane or skin bones. The parietal and frontal bones, which protect the brain of man, can be derived by a long series of steps, from nails in the skin of a fish hard pressed by greedy enemies. But the nails in the skin have given rise to another structure of quite different uses. On the lips, where the outer skin passes into the mouth, the nails changed their shape, and grew long, dropping by degrees the wide plate at the base, and becoming lodged in the jaws instead. At first the gums bore several rows of these altered scales, but the number gradually lessened as the size grew, and at last we see what slow and gradual change can effect. The teeth of a quadruped, large, strong, and tipped with enamel, are simply one extreme form of the primitive nails in the shark's skin. By leaving out the central prong and developing the base, membrane-bones have been attained; by leaving out the basal plate and developing the prong, teeth have been formed.

When the invention of teeth became a practical success, it was perfected in a thousand different ways according to the various needs of toothed animals. We now find conical, pointed teeth; bayonet-shaped teeth; saw-edged teeth, which enlarge the wound and avoid jamming; chisel-shaped teeth, which by means of the unequal hardness of their constituents, keep always sharp; teeth with rounded studs for crowns; pavement-teeth; and folded teeth, with ridges and hollows of unequal hardness, so that they never wear smooth. The angler-fish has hinged teeth, which bend inwards easily, but cannot be forced outwards, and detain the struggling prey as in a trap. The pike has the whole mouth and gullet crowded with teeth. The male narwhal has only one functional tooth, but this is several feet long—half the length of the body.

Not less various are the situations in which teeth are developed. The edges of the jaws are the places usually chosen, but the roof of the mouth is often armed with teeth also. Some fishes, which swallow their prey whole, have backward-pointing teeth, projecting from all parts of the mouth. Even the gill-arches, bony and jointed hoops, primarily intended to spread out the gill-filaments, are made to bear teeth, and the last gill-arch in many fishes loses its respiratory character altogether, becoming transformed to a single or double tooth-bearing plate which underlies the gullet. The upper parts of other gill-arches may also expand into broad tooth-bearing plates steadied by attachment to the skull. In some fishes the lower plate plays upon the upper one, and forms together with it a pharyngeal mill, able to grind up the food. Where a highly peculiar instinct calls for the development of teeth in a quite unexpected place, the adaptation of some structure originally intended for a different purpose may be of startling singularity. Wherever there is epiderm, or its equivalent, enamel can be developed; wherever there is derm (inner skin) or its equivalent, dentine can be developed, and these two things are the ordinary components of teeth. But the tooth must also have a supporting base, and it is here that the greatest ingenuity is displayed.

A certain African snake, the Dasypeltis, or "egg-eater" of the Cape Colony, lives upon eggs. This food is no doubt both wholesome and agreeable, but it is not without its difficulties. If the snake breaks the egg before eating it, what becomes of the yolk? If it eats the egg before breaking it, what becomes of the shell? Dasypeltis calls to its aid the outstanding processes of its neck-vertebræ. These were primarily intended to serve for the attachment of muscles, but now they are made to change their directions, and to stand forward through the muscles into the throat. They become tipped with enamel, like true teeth. Dasypeltis swallows the egg whole, breaks it in the gullet by its vertebral teeth, and when the contents are swallowed, discards the shell.

Human invention has this great advantage over what we are compelled to call the invention of Nature, that it can readily take short cuts. When man has once laid hold of a real improvement, all the steps by which that improvement was attained become a mere matter of antiquarian curiosity. When the light wheel, built up of nave, spokes, and tire, has once been got, we give up cutting sections of tree-trunks. But Nature goes back to the beginning time after time. Stages of development, long superseded, may be abbreviated or disguised, but they are not quickly lost. The higher animals begin their individual lives as simple cells, very like, at least superficially, to Amœbæ, or to the cells which compose the colonies of the lowest Protozoa. In the further course of their development they may reproduce as transitory structures organs which they have never actually used since the time when the Silurian rocks were forming.

Fresh organs are nearly always made by giving a new shape to old ones. Hence the patient ingenuity of Nature is fettered by a load of tradition, and not a few structures which we perceive to be exquisitely fitted for their place were originally meant for something else. The development of every animal is a condensed history of adaptations.

LIV. GREAT EXAMPLES.

If any of us were called upon to name the greatest biologists of the nineteenth century, we should not go far wrong if we chose Charles Darwin and Louis Pasteur. For the work of these two men has profoundly affected both thought and practice; many days can hardly pass without the biologist or physician, to say nothing of the chemist, having to recall some investigation by Darwin or Pasteur, relating it may be to the cross-fertilisation of flowers, the movements of plants, climbing plants, the descent of man, the supposed spontaneous generation of living things, the nature of fermentations, the rôle of minute organisms in disease, or the prevention of diseases caused by minute organisms. The labours of Cuvier, Humboldt, Robert Brown, Johannes Müller, Baer, Bernard and Owen are for ever memorable, but even these men did not, like Darwin and Pasteur, act powerfully upon the whole generation of scientific workers among whom they lived.

It is remarkable that neither the one nor the other was a professed biologist. After returning from the voyage of the *Beagle*, Darwin must have considered himself a working geologist; after the monograph on the Cirripedes, he must have considered himself a working zoologist; and after the treatises on orchids, climbing plants and insectivorous plants he must have considered himself a working botanist, but always with considerable reserves. In his own eyes Darwin ranked as a self-taught, half-trained man, needing at every turn the advice and help of regular students. Pasteur, though he had the courage to discuss disease among physicians and to set the physicians right, though he identified many obscure organisms and investigated their mode of life, had always to disclaim the attainments of the biological specialist. Neither Darwin with his pass-degree, nor Pasteur with his purely chemical and physical education, would have had early in his career a chance in any biological competition. Biological text-books, lectures and museums had little or no share in making them what they were.

Both were eminent observers and experimenters. Both, I imagine, if interrogated as to the secret of their productiveness, would have attributed it mainly to the habit of independent observation, reflection and verification by experiment.

Genius, we may be told, is an exception to all rules. I for one do not admit this as an axiom ; genius conforms to certain generalisations from ordinary human experience. Their ancestry and their associates helped to make Darwin and Pasteur what they were. Nor, though they stood out higher by the head and shoulders than the other eminent biologists of the century, did they fail to show the qualities which bring success to smaller men. Perseverance, candour and trust in scientific inquiry are among the ordinary virtues of all deserving men of science ; in Darwin and Pasteur these virtues were carried to the heroic point. I do not quite believe that Darwins and Pasteurs come among us like lightning from heaven ; there are surely reasons why they should appear in some ages, and some nations, and some families, but not in others. Whether we can by taking thought make such men more frequent is not adequately proved, but since the lower degrees of their qualities are clearly beneficial and to some extent capable of cultivation, it would be wise to encourage these lower grades wherever they show themselves. Among the lower and ordinary manifestations of those qualifications for biological discovery which became illustrious in Darwin and Pasteur, I should reckon curiosity, the habit of observation and the habit of experiment. We shall certainly not spoil any unrecognised Darwin or Pasteur by giving opportunity for the exercise of these propensities, and we may possibly favour the production of genius.

Nature Study seeks above all things to develop the earliest rudiments of the scientific discoverer. It does not aim at making zoologists, or botanists, or professors, or honour-men, but would strengthen if it could curiosity about nature, the habit of observation and the habit of experiment.

INDEX

Printed by BALLANTYNE, HANSON & Co.
At the Ballantyne Press

Telegrams:
'Scholarly, London.'

41 and 43 Maddox Street,
Bond Street, London, W.
March, 1905.

Mr. Edward Arnold's List of New Books.

THE EAST AFRICA PROTECTORATE

By SIR CHARLES ELIOT, K.C.M.G.,

LATE H.M. COMMISSIONER FOR THE PROTECTORATE.
AUTHOR OF 'TURKEY IN EUROPE' (BY 'ODYSSEUS').

Demy 8vo. With Illustrations and Maps. **15s. net.**

Sir Charles Eliot, whose authorship of the important work on the Near East, 'Turkey in Europe,' is now an open secret, had been, until his recent resignation, for three and a half years His Majesty's Commissioner for the British East Africa Protectorate. In this book he gives a very complete account of the country, its history and its peoples, and discusses with great fulness its prospects as a field for European colonization. He describes the present system of administration in the Protectorate, and makes a number of interesting suggestions for the future. There are chapters on the Uganda Railway, Trade, Slavery, Missions, a Journey down the Nile, and Animals, the whole forming a comprehensive and valuable account of one of the most remarkable and, to the ordinary Englishman, least familiar possessions of the British Empire.

'A book of singular interest and of permanent value, which is not only much the best account that has yet appeared of the Protectorate, but an invaluable contribution to the problem of the administration of Equatorial Africa.'—*Morning Post.*

'His style is admirably simple, and throughout there is a pleasing vein of humour, which relieves the book of any suspicion of heaviness.'—*Standard.*

ALESSANDRO SCARLATTI: HIS LIFE AND WORKS.

By EDWARD J. DENT,

FELLOW OF KING'S COLLEGE, CAMBRIDGE.

Royal 8vo. With Portrait and numerous examples. **12s. 6d. net.**

For this biography special researches have been made in the principal libraries of Europe, and much new material has come to light.

'When one remembers the extraordinary fecundity displayed by Scarlatti it is evident that to examine the compositions which are extant requires no ordinary application and knowledge. The monograph is no mere biography; Scarlatti's career is indeed very fully treated, but no less attention is paid to his works, of which a critical account is given, accompanied by copious musical quotations. Mr. Dent deserves hearty thanks for shedding light upon the life and works of one so nearly forgotten by the world as Alessandro Scarlatti, "the father of classical music."'—*Musical News*.

'We very heartily recommend lovers of music, especially those who care for old Italian music, to obtain and enjoy this book, which, besides being a valuable contribution to the history of music, is very delightful reading.'—*Cambridge Review*.

THE UNVEILING OF LHASA.

By EDMUND CANDLER.

Demy 8vo. With Illustrations and Map. **15s. net.**

Fourth Impression.

'Mr. Candler's account of his experiences in Tibet is as breezy and suggestive as is the excellent sketch which stands on the frontispiece. There is no attempt at a learned disquisition on the mysteries of Buddhism, no laboured effort to explain the intricacies of Indian diplomacy, but just a clear and impartial narrative of the toils and difficulties of the Tibetan Mission. "The Unveiling of Lhasa" is precisely the kind of book which the ordinary reader wants.'—*The Times*.

THE BURDEN OF BABYLONDON;

or, The Social Incubus, and other Vers de Société.

By HUGH E. M. STUTFIELD.

Crown 8vo. **2s. 6d.**

In this book of verse the author, who is better known as a traveller and sportsman than as a nimble poet, satirizes in a style equally genial and pungent the foibles of the 'Smart Set' and other curious phenomena of modern society.

THE BURDEN OF THE BALKANS.

By M. EDITH DURHAM,

AUTHOR OF 'THROUGH THE LANDS OF THE SERB.'

Demy 8vo. With Illustrations and Map. **14s. net.**

In this story of her sixth visit to the Balkan Peninsula, Miss Durham, after an historical survey of the causes of the present state of affairs, gives a most interesting account of her work as relief agent for the Balkan Committee, and finally describes Albania and the Albanian, 'the root of all the Balkan difficulties.' She endeavours to look at the situation from the point of view of each nationality in turn, combining with a keen sense of humour and the picturesque a discerning eye for all kinds of imposture. The book contains a number of striking illustrations from sketches by the author.

'Miss Durham has the adventurous traveller's liking for fighting races, and, on the whole, her sympathies appear to be with the Christian Montenegrins and the Mohammedan Albanians; but the book is an armoury of facts for the use of all the races against one another.'—*Athenæum.*

'Miss Durham's pencil made her friends in several parts of the country, and the illustrations from her hand add much to the interest of a lively volume."—*Glasgow Herald.*

STUDIES IN COLONIAL NATIONALISM.

By RICHARD JEBB.

Demy 8vo. **12s. 6d. net.**

Mr. Jebb believes—and in this book he makes out a most interesting case for his belief—that the view commonly held in this country of the future development of the British Empire is obsolete, being based on conditions and ideas which have very largely altered in the course of the last six years. He finds that, so far from welcoming the federation dreamed of by official Imperialism, the colonies, each in its peculiar and diverse way, are tending in the direction of nationalism. This means the substitution of alliance for federation, Imperial reciprocity for Imperial free trade, commercial treaties for the Zollverein compact. There is much in the book to make the reader think, and a good deal to make him uncomfortable.

FISCAL BALLADS.

By CAPT. HARRY GRAHAM ('COL. D. STREAMER').

AUTHOR OF 'RUTHLESS RHYMES FOR HEARTLESS HOMES,' ETC.

Foolscap 8vo. **1s. net.**

This little volume of poetry is a most amusing contribution to the literature of the Fiscal controversy, and may be cordially recommended to Free Trade politicians for electioneering purposes.

FACTS AND IDEAS.

By PHILIP GIBBS,

AUTHOR OF 'KNOWLEDGE IS POWER.'

Crown 8vo. **3s. 6d.**

As in the case of the author's previous book, the intention of these short studies of life, literature, philosophy, religion, history, and art, is to suggest ideas, subjects for investigation, and the like, connected with some of the great intellectual problems and achievements of civilization.

ECONOMIC METHOD AND ECONOMIC FALLACIES.

By WILLIAM WARRAND CARLILE, M.A.,

AUTHOR OF 'THE EVOLUTION OF MODERN MONEY,' ETC.

Demy 8vo. Cloth, **10s. 6d. net.**

'Mr. Carlile is a hard hitter and an acute thinker. The dominant economical doctrines have had no more trenchant assailant for a long time.'—*The Times.*

COMMONSENSE COOKERY.

Based on Modern English and Continental Principles worked out in Detail.

By COLONEL KENNEY HERBERT.

Large Crown 8vo. **7s. 6d.**

THE RUSSO-JAPANESE WAR:

From the Outbreak of Hostilities to the Battle of Liaoyang.

By T. COWEN.

Demy 8vo. With numerous Illustrations, Plans, and Maps. **15s. net.**

'Mr. Cowen's analysis of the events which led to the war is excellent. He puts things which we have all understood rather vaguely in a telling and direct fashion. He has evidently taken the greatest care to collate his facts, and the consequence is that we have a most enthralling and connected narrative of the naval operations round Port Arthur, enriched with small but convincing details such as could only have been related by eye-witnesses. Mr. Cowen's description of the Yalu battle is spirited, and his accounts of Kin-chow and Nanshan are quite the best we have seen.'—*Morning Post.*

THE REMINISCENCES OF SIR HENRY HAWKINS

(Baron Brampton).

Edited by RICHARD HARRIS, K.C.,

AUTHOR OF 'ILLUSTRATIONS OF ADVOCACY,' 'AULD ACQUAINTANCE,' ETC.

Two Volumes. Demy 8vo. With Portraits. **30s. net.**
Second Impression.

'A delightful budget of miscellaneous reading. The Reminiscences are light reading of a very easy and attractive kind; but underlying them is the revelation of a strong and genial character, forcing its way to recognition by sheer merit alone. They are delightful, not alone by their wealth of anecdote, but also by their unconscious revelation of a strong and yet lovable personality.'—*Standard.*

POLITICAL CARICATURES, 1904.

By F. CARRUTHERS GOULD.

Super royal 4to. **6s. net.**

Also an Edition de Luxe of 100 *large-paper copies, numbered and signed,* **£2 2s. net.**

'One looks twice before he is quite sure that the price of "Political Caricatures" is only 6s. Where else for 6s., in a book or out of it, can we find so much good humour and so much hearty laughter? "F.C.G." is still our one cartoonist, and his is the only brush which pictures the real history of our time in caricature.'—*Daily Mail.*

EDWARD AND PAMELA FITZ-GERALD.

Being some Account of their Lives Compiled from the Letters of Those who Knew Them.

By GERALD CAMPBELL.

Demy 8vo. With numerous Portraits. **12s. 6d. net.**

'No one interested in the '98 rebellion, in the gay and chivalrous and hapless Lord Edward, or in eighteenth-century folk and manners, can afford to miss this delightful volume.'—*World.*

'The frankness of the correspondence of Lord Edward's aunts and sisters makes Mr. Campbell's volume more entertaining than most novels.'—*Speaker.*

JERUSALEM UNDER THE HIGH PRIESTS.

Five Lectures on the Period between Nehemiah and the New Testament.

By EDWYN BEVAN,

AUTHOR OF 'THE HOUSE OF SELEUCUS.'

Demy 8vo. **7s. 6d.**

'These lectures deserve careful study by everyone interested in the history of how Hellenism and Judaism first came into contact.'—*Cambridge Review.*

STUDIES IN VIRGIL.

By TERROT REAVELEY GLOVER,

FELLOW AND CLASSICAL LECTURER OF ST. JOHN'S COLLEGE, CAMBRIDGE,
AUTHOR OF 'LIFE AND LETTERS IN THE FOURTH CENTURY.'

Demy 8vo. **10s. 6d. net.**

'Mr. Glover has achieved a real triumph; he sends his readers away longing to take up their Virgil again.'—*St. James's Gazette.*

THE WHITE MAN IN NIGERIA.

By GEORGE DOUGLAS HAZZLEDINE.

Demy 8vo. With numerous Illustrations and a Map. **10s. 6d. net.**

The author of this graphic account of life in Northern Nigeria was for some time Private Secretary to Sir Frederick Lugard, the High Commissioner, and was thus in a position to learn the truth about the country and its problems.

'The author supplies some admirable pictures of the incidents which have led to the British occupation of Northern Nigeria. His theories are sane and wholesome, his descriptions graphic and informing. One would like every responsible tax-paying British subject to read them.'—*Athenæum.*

'A really fascinating book, which, while stirring and picturesque, vivid and human throughout, is as full of facts of the rarer and more valuable sort as the driest and most scientific treatise could be. The book is certain to be read in France and Germany. By every law of common-sense it should be read, well and carefully read, in England. We hope it may be.'—*Pall Mall Gazette.*

SUNSHINE AND SENTIMENT IN PORTUGAL.

By GILBERT WATSON,

AUTHOR OF 'THREE ROLLING STONES IN JAPAN.'

Demy 8vo. With numerous Illustrations. **12s. 6d. net**

'Mr. Watson has written a book which may be fittingly placed on the bookshelf between Sterne's "Sentimental Journey" and Robert Louis Stevenson's "Travels with a Donkey in the Cevennes."'—*Scotsman.*

ENGLAND IN EGYPT.

By VISCOUNT MILNER,

HIGH COMMISSIONER FOR SOUTH AFRICA.

Eleventh Edition. With additions summarizing the course of events to the year 1904. *Crown 8vo.* **6s.**

The great and far-reaching change in England's position in Egypt effected by the signature of the Anglo-French agreement has rendered necessary a further addition to Lord Milner's work, tracing the course of events from 1898, when the book was brought up to date by a chapter by Sir Clinton Dawkins, to the present time. This important task has been carried out by Sir Eldon Gorst, K.C.B., late Financial Adviser to the Egyptian Government, who describes in a masterly chapter the recent results of British rule in Egypt and the Soudan, and the hopeful possibilities of the future.

ENGLISH ESTATE FORESTRY.

By A. C. FORBES.

Demy 8vo. With Illustrations. **12s. 6d. net.**

Forestry is a subject the importance of which is by no means adequately recognised in this country. It is, indeed, seldom that one finds an owner of woodlands who has a competent knowledge of the scientific theory and practical possibilities of timber-planting. Mr. Forbes's book will be found a valuable corrective of the prevailing happy-go-lucky methods.

'Mr. Forbes has produced a most excellent work, which should be on the shelves of all estate agents and owners of woodland property.'—*Saturday Review.*

'Perhaps the soundest and most useful book on forestry yet written by an Englishman for the ordinary reader.'—*Estate Magazine.*

GHOST STORIES OF AN ANTIQUARY.

By MONTAGUE RHODES JAMES, Litt.D.,

FELLOW AND LATE TUTOR OF KING'S COLLEGE, CAMBRIDGE.

Crown 8vo. With Illustrations by the late James McBryde. **6s.**

Second Impression.

'We do not hesitate to say that these are among the best ghost stories we have ever read; they rank with that greatest of all ghost stories, Lord Lytton's "The Haunted and the Haunters."'—*Guardian.*

OUTLINES OF THE SYNOPTIC RECORD.

By the REV. BERNARD HUGH BOSANQUET,

VICAR OF THAMES DITTON;

And R. A. WENHAM.

Crown 8vo. **6s.**

'There is at the present moment a place for some such work as this, which, at once scholarly and popular, reverent, yet pervaded with the modern spirit, will put young students of theology and the educated laity in possession of the results of recent "higher" or literary criticism of the Gospels.'—*Scotsman.*

MY SPORTING HOLIDAYS.

By Sir HENRY SETON-KARR, C.M.G., M.P.

Demy 8vo. With numerous Illustrations. **12s. 6d. net.**

'The book which, like "Scolopax's" delightful gossip, informs the reader's mind without ever taxing his patience grows yearly rarer. Sir Henry Seton-Karr's volume is a very pleasing specimen of this class, the notebook of one who has wandered far afield in search of sport, and can write of his doings without egotism or vain repetitions. His sketches of Western society are very vivid pictures, full of insight and good humour.'—*Spectator.*

'This lively volume, which will be read with a great deal of pleasure by every sportsman who can get hold of it, records the author's adventures in search of sport during the last two-and-thirty years.'—*Illustrated Sporting and Dramatic News.*

PAGES FROM A COUNTRY DIARY.

By PERCIVAL SOMERS.

Large Crown 8vo. With Photogravure Illustrations. **7s. 6d.**

'It is not often nowadays that a writer on indoor and outdoor life in the country appears with a knowledge so matured and a style so mellow as that of Mr. Percival Somers. In fact, we do not believe that there could be a book which would better reflect the attitude of a country gentleman towards men and animals and affairs. His inimitable, genial manner is so effective that the reader is continually delighted, whether he is reading of a local steeplechase or how the author basketed some fine trout with the help of a phantom minnow when he was out with a party of dry-fly fishermen.'—*World.*

HOUSE, GARDEN, AND FIELD.

A Collection of Short Nature Studies.

By L. C. MIALL, F.R.S.,

PROFESSOR OF BIOLOGY IN THE UNIVERSITY OF LEEDS, AND FULLERIAN PROFESSOR OF PHYSIOLOGY IN THE ROYAL INSTITUTION.

Crown 8vo. With numerous Illustrations. **6s.**

Second Impression.

'Quite the best things of the kind that have appeared since nature study became a subject in the schools.'—*Field.*

'This admirable little work appears to be by far the best aid to the proper teaching of nature study that has hitherto come under our notice.'—*Nature.*

NEW FICTION.

Crown 8vo. 6s. each.

THE SEETHING POT.

By GEORGE A. BIRMINGHAM.

'A very brilliant and detached study of Ireland of yesterday and to-day.'—*Spectator.*

THE RAMBLING RECTOR.

By ELEANOR ALEXANDER,

AUTHOR OF 'LADY ANNE'S WALK.'

Second Impression.

'In "The Rambling Rector" one finds the same delicate humour, imagination, and sentiment which distinguished "Lady Anne's Walk."'—*Manchester Guardian.*

'Miss Alexander has the goodly heritage of an admirable literary style combined with a sympathetic comprehension of the Irish people and a keen sense of humour.'—*Athenæum.*

PETER'S PEDIGREE.

By DOROTHEA CONYERS,

AUTHOR OF 'THE BOY, SOME HORSES, AND A GIRL.'

With Illustrations by Nora K. Shelley.

Third Impression.

'The story is very clever and amusing, brimful of real Irish fun and humour, and adorned with illustrations quite up to its own mark.'—*World.*

'This is one of the funniest books we have had the pleasure of reading for a long time, and is full of genuine humour.'—*Illustrated Sporting and Dramatic News.*

SCENES OF JEWISH LIFE.

By Mrs. ALFRED SIDGWICK,

AUTHOR OF 'CYNTHIA'S WAY,' 'THE THOUSAND EUGENIAS, AND OTHER STORIES,' 'THE BERYL STONES,' ETC.

Second Impression.

'Mrs. Sidgwick's bright manner of telling her stories, her delicate humour, and quick realization of the subtle pathos that is threaded through all Jewish life, appear on every page, and make the book both interesting and enjoyable reading.'—*Westminster Gazette.*

'A volume from the pen of Mrs. Alfred Sidgwick is always welcome, so alert is her intelligence, so keen her observation, so crisp and clear-cut her style. Altogether, this is an extremely vivacious and instructive volume.'—*Spectator.*

NEW FICTION.—Continued.

THE CELESTIAL SURGEON.

By F. F. MONTRESOR,

AUTHOR OF 'WORTH WHILE,' 'INTO THE HIGHWAYS AND HEDGES,' ETC.

Third Impression.

'In "The Celestial Surgeon," Miss Montresor is at her best. The character drawing, as is usual with the writer, is excellent; the characters are all living human beings, neither too good nor too bad for everyday life. The book is not one for girls just out of the schoolroom, but their elders will be glad to have it.' —*Guardian*.

'An immensely clever study of a group of temperaments, with the added advantage of a capitally constructed plot.'—*St. James's Gazette.*

THE SHADOW ON THE WALL.

By MARY E. COLERIDGE,

AUTHOR OF 'THE KING WITH TWO FACES,' 'THE FIERY DAWN,' ETC

Second Impression.

'A new novel from the pen of Miss Coleridge is an event the pleasure of which is enhanced by the comparative rarity of its occurrence. All who are able to emancipate themselves sufficiently from the tyranny of circumstance can hardly fail to recognise the charm of this delicately fantastic melodrama.'—*Spectator*.

THE REAPER.

By EDITH RICKERT.

'A simple yet strange story of a mind at once simple and strange; and throughout it the author would seem to have been guided by a delicate-unerring instinct for the central, the captain thought or word or expression.'—*The Times.*

'A novel the scene of which lies beyond the beaten track, and which will repay you amply for the reading.'—*Review of Reviews.*

CHECKMATE.

By ETTA COURTNEY.

'Miss Courtney has written an able novel, and one that will interest the reader from the first page to the last.'—*Sheffield Daily Independent.*

'The story is very interesting, and is told throughout with great cleverness and skill.'—*Outlook.*

THE EVOLUTION THEORY.

By Dr. AUGUST WEISMANN,

Professor of Zoology in the University of Freiburg.

Translated by J. ARTHUR THOMSON,

Regius Professor of Natural History in the University of Aberdeen,

And MARGARET THOMSON.

Two volumes, Royal 8vo. With many Illustrations. **32s. net.**

The importance of this work is twofold. In the first place, it sums up the teaching of one of Darwin's greatest successors, who has been for many years a leader in biological progress. As Professor Weismann has from time to time during the last quarter of a century frankly altered some of his positions, this deliberate summing up of his mature conclusions is very valuable. In the second place, as the volumes discuss all the chief problems of organic evolution, they form a trustworthy guide to the whole subject, and may be regarded as furnishing—what is much needed—a Text-book of Evolution Theory. The book takes the form of lectures, which are so graduated that no one who follows their course can fail to understand the most abstruse chapters. The translation has been revised by the author.

LECTURES ON DISEASES OF CHILDREN.

By ROBERT HUTCHISON, M.D. Edin., F.R.C.P.,

Assistant Physician to the London Hospital and to the Hospital for Sick Children, Great Ormond Street;

Author of 'Food and the Principles of Dietetics.'

Crown 8vo. **8s. 6d. net.**

'It is difficult to praise this little volume too highly. It deals with one of the most attractive and satisfactory subjects in medicine, the treatment of children's diseases; the style is excellent, and the illustrations, which, with one or two exceptions, are taken from photographs of the author's cases, are unusually good.'—*Nature.*

'Dr. Hutchison says in his preface that he does not intend to compete with the many excellent text-books on Children's Diseases, but we feel sure no student should be without this book, as, unable to spare time for the larger treatises, he will here learn many things which otherwise practice alone in after-life will teach him.'—*Guy's Hospital Gazette.*

ASTRONOMICAL DISCOVERY.

By HERBERT HALL TURNER, D.Sc., F.R.S.,

SAVILIAN PROFESSOR OF ASTRONOMY IN THE UNIVERSITY OF OXFORD.

Demy 8vo. With Diagrams. **10s. 6d. net.**

In these lectures, written for delivery before the University of Chicago, Professor Turner traces the history of modern Astronomical Discovery, first showing by what an immense amount of labour and patience most discoveries have been made, and then describing in detail many of the more important ones. Among his topics are Uranus, Eros, and Neptune, Bradley's discoveries of the aberration of light and the nutation of the earth's axis, the photographic measurement of the heavens, Schwabe's work on the sunspot period, and Mr. Chandler's discoveries in connection with the Variation of Latitude.

'A volume of unusual interest. In its fascinating chapters the story of some half-dozen discoveries is developed in an exceedingly attractive manner.'—*Westminster Gazette.*

THE BECQUEREL RAYS AND THE PROPERTIES OF RADIUM.

By the HON. R. J. STRUTT,

FELLOW OF TRINITY COLLEGE, CAMBRIDGE.

Demy 8vo. With Diagrams. **8s. 6d. net.**

'The author possesses to a remarkable degree the faculty of stating difficult questions in a simple way, and of expressing the answers in a language which is easily understood.'—*Nature.*

'The book may be confidently recommended to the general reader as a comprehensible and attractive account of the latest developments of scientific thought on the structure of matter.'—*Cambridge Review.*

AN INTRODUCTION TO

THE THEORY OF OPTICS.

By ARTHUR SCHUSTER, Ph.D., Sc.D., F.R.S.,

PROFESSOR OF PHYSICS AT THE UNIVERSITY OF MANCHESTER.

Demy 8vo. With numerous Diagrams. **15s. net**

This volume is intended to serve as an introduction to the study of the higher branches of the Theory of Light. In the first part of the book those portions of the subject are treated which are independent of any particular form of the undulatory theory. The author has endeavoured, by means of elementary mathematical reasoning, to give an accurate account of the study of vibrations, and has laid special stress on the theory of optical instruments. In the second part mathematical analysis is more freely used. The study of luminous vibrations is introduced through the treatment of waves propagated in elastic media, and only after the student has become familiar with the older forms of the elastic solid theory are the equations of the electro-magnetic theory adopted. The advantage of these equations, more especially in the treatment of double refraction, is explained, and the theory of ionic charges is adopted in the discussion of dispersion and metallic reflexion.

THE ELECTRIC FURNACE.

By HENRI MOISSAN,

PROFESSOR OF CHEMISTRY AT THE SORBONNE; MEMBRE DE L'INSTITUT.

Authorized English Edition.

Translated by A. T. DE MOUILPIED, M.Sc., Ph.D.,

ASSISTANT LECTURER IN THE LIVERPOOL UNIVERSITY.

Demy 8vo. With numerous Illustrations. **10s. 6d. net.**

This work embodies the original French Edition, together with the new matter incorporated in the German Edition. Moreover, Professor Moissan has written, specially for this edition, a chapter dealing with the most recent work. The book, while dealing largely with Professor Moissan's own researches, gives a general survey of the experimental work accomplished by means of the electric furnace up to the present time. The bearings of this work on technical processes are frequently discussed.

THE CHEMICAL SYNTHESIS OF VITAL PRODUCTS

AND THE INTER-RELATIONS BETWEEN ORGANIC COMPOUNDS.

By PROFESSOR RAPHAEL MELDOLA, F.R.S.,

OF THE CITY AND GUILDS OF LONDON TECHNICAL COLLEGE, FINSBURY.

Super Royal 8vo. **21s. net.**

The great achievements of modern Organic Chemistry in the domain of the synthesis or artificial production of compounds which are known to be formed as the result of the vital activities of plants and animals have not of late years been systematically recorded.

The object of the present book, upon which the author has been engaged for some years, is to set forth a statement as complete as possible of the present state of knowledge in this most interesting and important branch of science. The book will consist of two volumes, of which the first will be ready very shortly. The treatment is calculated to make the volume a work of reference which will be found indispensable for teachers, students, and investigators, whether in the fields of pure Chemistry, of Chemical Physiology, or of Chemical Technology.

HUMAN EMBRYOLOGY AND MORPHOLOGY.

By ARTHUR KEITH, M.D. Aberd., F.R.C.S. Eng.,

LECTURER ON ANATOMY, LONDON HOSPITAL MEDICAL COLLEGE.

A New Edition. Greatly enlarged. Demy 8vo. **12s. 6d. net.**

The greater part of the work has been rewritten, many of the old illustrations have been replaced, and a large number of new figures introduced. The alterations have been rendered necessary owing to the advances which have been made in our knowledge of the early phases of development of the human embryo, of the implantation of the ovum and formation of the placenta, and of the development of the heart, lungs and nervous system.

THE WALLET SERIES OF HANDBOOKS.

Mr. Edward Arnold has pleasure in announcing the publication of a series of handbooks, ranging over a wide field, which are intended to be practical guides to beginners in the subjects with which they deal. The first five volumes, of which descriptions are given below, may be regarded as typical of the scope and treatment of the whole series, which is published at 1s. net per volume, paper, and 2s. net cloth.

ON COLLECTING ENGRAVINGS, POTTERY, PORCELAIN, GLASS, AND SILVER.

By ROBERT ELWARD.

'Really very interesting and constitutes in brief an admirable historical and artistic sketch. It forms an excellent handbook for the guidance of amateurs.'—*Scotsman.*

DRESS OUTFITS FOR ABROAD.

By ARDERN HOLT.

'To take more clothes than wanted is almost worse than not to have enough; . . . A perusal of this little volume, which is sensibly written, should enable any traveller, man or woman, to journey abroad suitably equipped.'—*Sheffield Independent.*

ELECTRIC LIGHTING FOR THE INEXPERIENCED.

By HUBERT WALTER.

'We really are delighted to meet with it; common-sense, practical knowledge, and no small share of humour are marked characteristics of the work. . . . As a guide to the plain man, who wants to know how to set about getting his house wired and fitted . . . this is the best work we have seen, and we have pleasure in recommending it as such.'—*Electrical Review.*

HOCKEY AS A GAME FOR WOMEN.

By EDITH THOMPSON.

'Miss Thompson's book may be recommended to beginners as the very best that has yet appeared of its kind. It has the great merit of being quite practical throughout.'—*Queen.*

WATER-COLOUR PAINTING.

By MARY L. BREAKELL ('Penumbra')

'Miss Breakell's work is the product of knowledge and sympathy. She shows a thorough acquaintance with her subject, and is always able to illustrate her teaching by reference to the practice of great masters—past and present. The arrangement of the work is excellent.'—*Manchester Courier.*

LONDON: EDWARD ARNOLD, 41 & 43 MADDOX STREET, W.