

**LESSONS
IN
NATURE
STUDY**

**JENKINS
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LESSONS
IN
NATURE STUDY

BY

OLIVER P. JENKINS
AND
VERNON L. KELLOGG



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VERNON L. KELLOGG

PREFACE.

At a time when so many books are appearing in Nature Study, some sort of apology is due for proposing to add another to the list. There is some extenuation in the fact that the book was not premeditated as such. What is here presented began as a series of oral lessons by one of the authors given to classes of children. These lessons were afterwards put into manuscript form for the use of the Oakland (Cal.) schools, later they were used as leaflets printed by the Oakland School Department, and finally were included in the report of Supt. J. W. McClymonds. Finally, answering an apparent demand for a wider use of the lessons, both the authors revised and extended the lessons and had them illustrated by competent artists, and a part of the papers under the new form were published in the *Western Journal of Education*. Since the publication of the series in the *Journal* began, there has seemed to be a demand for the lessons that justified gathering them together in this more convenient form.

The selection of the particular topics here included is not to be interpreted as an opinion of the authors that they are the essential topics, or that they are the most important, since it is evident that a number of lists of equally important or interesting objects could be made. They have been selected as the result of long continued experimenting with children in different grades of the public schools. If merit attaches to this list, it is that the topics in it have been used as here treated with success, repeatedly, in the

actual work of the school. One of the authors has personally presented most of these lessons to classes of children in the schools ; and has observed the whole of this course as given by many teachers. At a time when there is so little of precedent in the way of nature study and so much that is still only in the form of proposal, anything which comes from actual experience must be of value from that very fact.

The authors are under the greatest obligation to Miss E. B. McFadden, Principal of Nature Study in the Oakland schools, who has for some years enthusiastically given and supervised giving these lessons in the various school grades. It is very largely thru the actual work of experimenting by the teachers of Oakland under the direction of Miss McFadden that the authors feel confident that the topics as given here can be used with success. The provisional course of study given in the Appendix is based on the Oakland experience.

No attempt has been made to outline actual lessons, nor, except as suggested in an appendix, to point out the portions to be assigned to the different grades, but rather to give only a simple treatment of the subject for the teacher's use with some suggestion as to methods. The lessons must be considered as simply suggestive and by no means as comprehensive. The Appendix already referred to suggests the allotment to the different grades.

The fragmentary treatment of the subjects and the lack of system in their arrangement is designedly carried out to illustrate the method which experience with children points out as the best method in which to proceed. Even at the risk of being monotonous it is stated now, and will be more than once repeated, that,

with the earlier grades at least, the lessons must be fragmentary, on one simple phenomenon at a time, without care for its relations, and the lessons should not be successive on one topic, but interspersed with those on different topics. Convenience of treatment for the teacher's use in the following lessons has led to a continuous account in some cases. In the school work, this should be broken up as suggested. It hardly need be added that the book is designed as an aid to teachers and parents or others directing Nature Study work and not as a Nature Study reader.

The chapters under the titles: The Mosquito, Rearing Insects in the School Room, Some Water Insects, How to make a Collection of Insects, About Spiders, How Insects Breathe, and Birds were written by Professor Kellogg, and Professor Jenkins is responsible for the remainder of the book.

The drawings, with the few exceptions noted at the proper places, were drawn from nature by Mr. W. S. Atkinson and Miss Mary Wellman.

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INTRODUCTION.

The conviction that nature study should form a part of the school course is growing stronger every year. Knowledge of nature as embodied in the sciences has grown to be a vast and important part of the sum of human knowledge. This knowledge completely dominates our material life, and profoundly influences our intellectual life. In the light of these facts it is not to be wondered at that there should be a demand that a study of nature should form a part of the education of the child. On the other hand, it is hard to understand why such study is still so widely neglected, or at best receives such small consideration. But the present widespread serious movement in this direction can never be completely checked, and it must be that there is in progress a real reform in school courses in this regard.

The question of the permanence of nature study in the school course seems to be settled, and it remains to prepare for the work of such a course. This is no easy task and all attempts for some time to come must be regarded as tentative rather than final solutions. To select from a vast body of knowledge those portions that both best represent that knowledge, and are at the same time best adapted to the powers of the pupils in a progressive educational course, would require greater wisdom and skill than exists. We are left to make the best selection possible, try it in our schools, and by means of our successes and failures with it correct from time to time our work. Thus there may grow up in time from extended experience, critically studied, a course in nature study approaching the ideal. However, there are certain matters in regard to such a course that seem clear, and in any suggested arrangement regard should be given them. Some of the most important are presented in the following paragraphs.

Nature study in some form should form part of the daily work of each grade. But little advance can be hoped from only occasional lessons, or lessons at long intervals, as once a week. Nature study should, as with the other principal subjects of the

school curriculum, be daily and continuous in order to work out the growth and development for which it is particularly adapted.

It should be carefully adapted to the nature and powers of grades where it is represented. In the lower grades nature study should not be carried on in the method of any of the formal sciences. This would insure failure. It is only with a wide experience with natural phenomena and a certain maturity of mind, that the organization of the accumulated facts into a science is to be accomplished with profit.

The work in the elementary grades should be with objects and experiments treated simply as phenomena. These furnish the material for exercises in accurate seeing and clear thinking. The phases of the phenomena should be within the child's interests and powers. The child's interest in nature cannot be that of an adult, and much less will it be that of one who has long been a student of nature. This fact makes it difficult for the adult, altho himself a student of nature, to select the work that can be most profitably used with children. We shall fail if we do not keep within the limits of the child's interests. We shall fail if we do not make use of that in nature which has real significance. The teacher should have a loving sympathy with the child, and at the same time a clear knowledge of the little bit of nature he makes use of in his work. He must attempt to understand the child's nature, its demands and its rights, and seek to meet those demands and respect the rights.

However, it is even more of an error to regard the child as less serious and less capable than he really is, as appears to be the case with some writers and teachers in nature study who attempt to "write down to children." This so-called writing down to children takes various disagreeable forms. Some teachers appear to think that nothing but a joke will interest a child. By them all nature is treated as a huge joke, but, it must be confessed, a rather poor one. Thru all their lessons there is a constant straining to be funny, with the usual success of trying to find a joke where there is none.

Others are impressed with the necessity of "being lively." Now liveliness is wholly to be commended when inspired by the subject and the class. In fact, it is hard to avoid a normal degree of it if one truly feels the situation. But "being lively"

for its own sake, is the hollowest kind of mockery. It leads to a disregard for the truth in the striving after sensational statements and bizarre comparisons. The constant beating of gongs and shaking of tambourines drowns out the sweetest voices of nature to which she alone can give tongue.

Still others seem to believe that nature's phenomena can not appeal to children unless the various agents are personified and made to march before the children in the form of kings, princes, fairies or other questionable shapes. This must always result in failure as far as nature study teaching is concerned, and on the other hand can not have the charm and good of true fairy stories. Ingenuously worked out battles between the marshaled hosts of the Frost King and the Heat Emperor or an account of the adventures of Fanny Violet and Billy June Bug have about as much in them for coming close to nature as would a marvelous account of how the Jolly little Fraction made trouble for the Sullen Giant Rule of Three for getting even a child's view of number relations. All these means are not only wholly unnecessary, but they defeat the purposes of nature study and prevent the accomplishment of just that special good which it can do. The child is as interested in the real facts and phenomena of nature when he can see them clearly, as he can possibly be in the array of any imaginary incongruities.

It is very important that not too much be attempted at a time. It is a common error to bring too much into a single lesson. One thing at a time seen clearly, should be the rule. Time must be given the pupil to see and enjoy. Progress in the power to deal with facts successfully is a matter of growth. Growth requires assimilation, and assimilation demands time. Hurrying over a a thing before the undrilled powers of the child have grasped what is before him, is losing a fine educational opportunity.

In the lower grades the lessons should be brief in addition to being simple.

Experience has clearly shown that it is better in the elementary grades to avoid keeping the lessons on the same group of phenomena for a very long time. The children soon become weary of a subject which is thus brought up day after day, and nothing is more inimical to success in teaching than such a feeling. The lessons must be fragmentary and the subject frequently changed.

While this method may seem a haphazard one, it need by no means be so. The order of presenting the facts need not interfere with good judgment in their selection and in the final grouping of the facts according to their relations.

Above all the nature study lessons should not be undertaken without the object. It is *nature* that is to help the child, and if the bit of nature on which the lesson is based is absent, nothing can make up for the loss.

Equally important with the presence of the object is the securing of the activity of child in relation to it. Indeed the success of the nature study teacher is complete, when the object and the child are brought together, and the child is awakened to work thoroly with this bit of nature. The skill to induce the normal activity of the child is the essence of teaching. Many a teacher makes the mistake of considering that what he says is of the utmost importance and can not be left out, and further, that no one but him can perform the little experiments just right. Consequently he teaches and does so much, and does it so long and so loudly, that the room is filled with him. Now the truth is, that what the teacher talks is of very little importance, but what he succeeds in getting the pupil to do and think is of the utmost importance. There is no work of the school so well adapted to bring out the activity of the child as nature study, and it would be a pity if the exceptional opportunities it offers for the best work of the school were lost by simply not giving the pupil the chance to do what he would do so willingly.

To sum up: The work in nature study should be daily; each lesson should cover only that small bit of observation that can be clearly seen and understood; the lesson should be brief with the lower grades; it must be fragmentary; the topics should be frequently changed; the lesson must always be adapted to the child's powers and interests; it should be with a real bit of nature; and above all, the great aim should be to induce the child to work for himself with hand, eye and mind with the bit of nature before him.

Making a Beginning.

AFTER one has decided to place Nature Study in the day's program the first question generally is, "Where shall I begin?" The answer "Begin anywhere," is a correct one but not a satisfactory one. Anywhere is a large country and one is soon lost in it. It is only fair that those who urge a beginning should point out a visible tangible point to start from. The only reason I would hesitate to select such a point is that it might be thought I considered that particular point an essential beginning. Let me indicate one way in which a beginning may be made. First, the teacher will look out over the field of Nature and consider, at least in a general way, what kind of facts he expects to make use of. These facts will be, of course, phenomena either of the life of plants, of the life of animals, or of inorganic nature. It will be hoped that in the course of time enough of the phenomena in each of these realms will be seen clearly enough to understand some of the larger relations of each, such as growth, development, adaptation, succession and the like.

With such conceptions in mind he will find on any day during any season, simple phenomena which just at that time may be used as a beginning in training in accurate seeing and clear thinking. These at the same time may serve as valuable facts which later will be, with other similar ones, an introduction to important generalizations.

Let me illustrate from the life of plants.

Thru the summer and fall various plants are busy distributing their seeds. They have manifold ways of doing this. Each method is an ingenious contrivance adapted to certain conditions. For example the large number of plants of California are so successful in this work that against multitudes of enemies and adverse circumstances they manage to hold their own year after year and many of them have done so for ages. The whole subject of plant distribution is a great one and is far reaching in its

relations. Now as you look out on the plant inhabitants of California you think of these questions and you are prepared to make your beginning with a simple lesson on the first plant you find distributing its seeds. That one of course might be any one of a great number that are at hand. To see what might happen to me in this line were I, to-day, to make a beginning, I have just taken a short walk. This has brought me across a lawn in which are growing a number of dandelions, some in bud, some in bloom, and some with erect stalks bearing the familiar downy globes ready to break up and sail away with the first puff of wind. This dandelion shall be the beginning lesson.

The Lesson—The Dandelion.

First: For yourself, on the lawn or wherever you find it, carefully observe all you can of the plant, how it grows, where the bud forms, and the different stages of growth of the different parts of the flowers, the unfolding of the bud to the formation of the ripened seeds.

While you may observe a number of interesting things in its study, make up your mind firmly to attempt in the one lesson one thing only, for example, the method by which the seed is distributed, and the growth of the apparatus by which it is carried. With the first three grades of pupils make two or three lessons even of this one small group of phenomena.

Provide abundant material so that each pupil may have enough to make out the points you wish him to see.

Don't "teach" but lead the pupil to see clearly: the seed in its place; the parts it flies with; how easily a current of air will carry it (experiment with a current of air made with the breath or with a fan).

Now further lead him to see how thru the bud to the ripened head the downy part grows to its mature form, how at first it is, on a single undeveloped seed, a minute bundle of soft down without a stem, how later the stem of the "umbrella" grows, how at first the umbrella is closed up tight, and opens only when its stem is grown and the seed is mature. Have him also see that at first when the flowers open they are raised up by the stalk. (If there has been no lessons on flowers previous to this do not go into the structure of the flower at this time, farther than to show that the dandelion blossom is a bunch or head of many small flowers.) Later as the seeds begin to mature and the downy part to develop the flowers close and the hollow stem of the head of flowers bends over and lies close to the ground hiding it until the seeds ripen. But just as the seeds mature the flower stalk becomes erect and grows in length raising the flower head high, which then opens and



Fig. 1. The Dandelion: a, bud; b, head of flowers; c, after flowering, head closed again, stalk bent over, stems of balloons growing, seeds ripening; d, seeds ripened, stalk erect and lengthened.

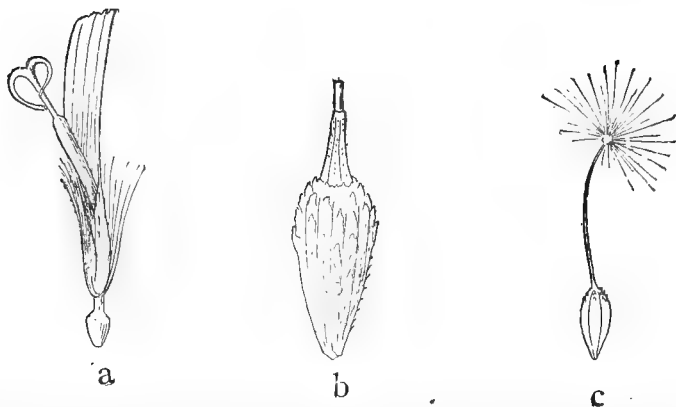


Fig. 2. The Dandelion; a, enlarged view of a single flower of dandelion, flower head showing at the bottom the down on short stem on the top of the seed; b, enlarged view of seed, balloon and its stalk cut away; c, ripened seed with balloon completed ready to fly.

as each umbrella opens out the seeds become very loosely attached, and all is very ready for a puff of wind to blow them away.

If all this is made out distinctly from material in hand, there will be one good example clearly seen of a plant putting forth a great deal of ingenious effort to scatter its seeds to the wind.

After first lessons on the dandelion, the pupils may be set to finding other seeds which have either similar or quite different means of distribution. Have them gather these themselves and explain from their own observation to the rest of the class the method each seed employs.

You will no doubt be surprised to see the number of different kinds that may thus be brought in, whether the school is in the country or in the city. A collection can be made and arranged for exhibition. But it is best that that disappear by the beginning of another year, so that the new classes may begin afresh.

Now, on your walk to seek a beginning lesson you may not find a dandelion, but you surely will find some plant which will serve as well. There are several that have downy umbrellas which

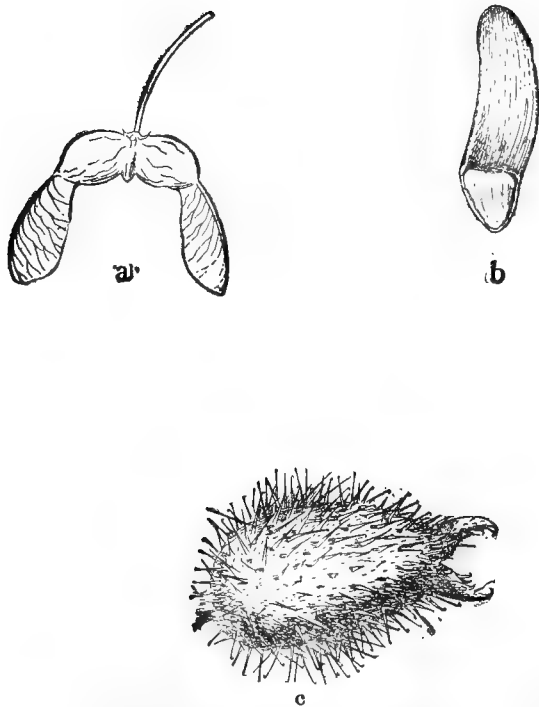


Fig. 3. Seeds; a, a pair of maple seeds with wings; b, a seed from a Monterey pine cone with a wing; c, a bur of the cockle-bur with a pair of jaws and many hooks.

act as balloons, others, as the maple, have wings, others as burs of various kinds, have hooks to fasten on clothing, and still others are carried by water.

For the first lesson choose a seed that is abundant and has some conspicuous, easily understood means of traveling and treat it something after the manner suggested with the dandelion. Do not be deterred in your choice because you do not know the name of the plant, as that has nothing to do with the lesson. Use the name the children use.

The beginning may be made, not with plants but with some animal. As plants and animals and inanimate things go thru their changes slowly it is best, even necessary, to have several things going at once that they may keep up a supply of lessons. For example, the gathering of the seeds may proceed while the eggs of a mosquito are hatching and the larvæ are growing.

The Mosquito.

Obtaining and Caring for Study Material.

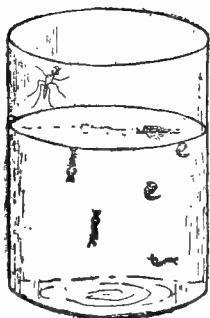


Fig. 4. Breeding jar for mosquitoes.

The mosquito is an always available and thoroly interesting object of nature study. At any time of the year, and in almost any small pool of stagnant water, the familiar "wigglers," which are the larvæ or first young stage, of the mosquito, can be found. "A ditch in a wood choked with fallen leaves is one of the best hunting grounds." Some of the material from which the following notes were made came from a watering trough in a pasture, and some of it came from a barrel of water containing considerable decaying matter. In many localities it is necessary only to expose an open pail or cask of water for a few days in order to get a thriving colony of mosquitoes. The mosquito larvæ (wigglers) are so distinctive in structure and manner that no trouble will be had thru mistaking other aquatic insect larva or other aquatic animals for them.

By reference to the figure of the larva (fig. 5) this characteristic appearance can be got acquainted with; in addition, the characteristic wriggling of the body when the creature is moving thru the water, and the hanging head downward from the surface when at rest, are manners which make the mosquito larvæ readily recognizable.

Besides the larvæ, there may be found both the eggs and the pupæ (second young stage). The eggs are in small masses which float on the surface of the water, resembling at careless glance nothing else so much as a largish bit of soot. These little, floating, sooty bits are composed of a single layer of slender, elongate eggs standing on end, and loosely fastened together to form a narrow, irregular, little raft, slightly concave on the upper surface. The pupa (fig. 6) is composed of a big bulbous head and a

short slender tail. It swims thru the water by making quick, violent jerks with the slender tail, and when at rest floats at the surface of the water with the back of the big head end uppermost and the slender tail hanging down.

The wrigglers and eggs and pupæ can be kept in wide mouthed glass jars (fruit jars, glasses, etc.) two-thirds filled with water. (fig. 4) The water should not be too good, or the wrigglers will lack food; water from the pool or ditch in which the

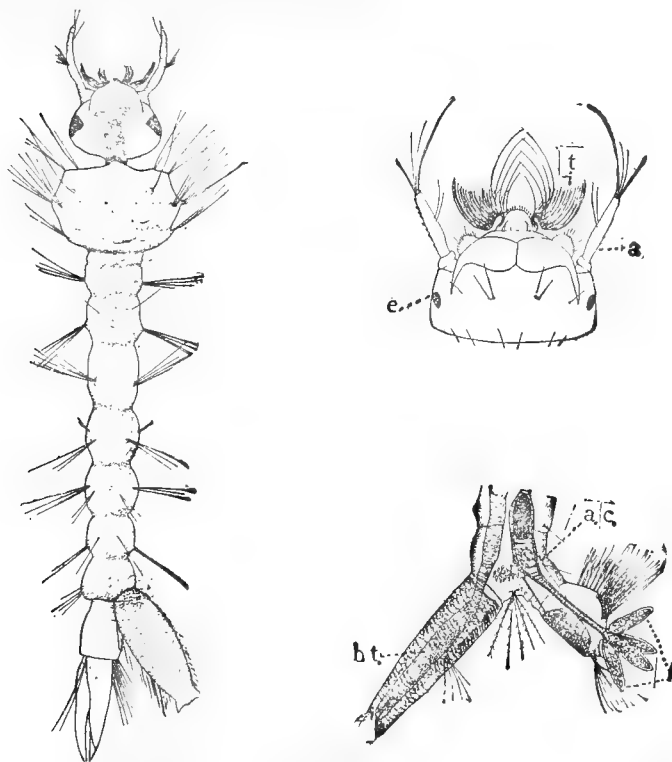


FIG. 5. Larva ("wiggler") of mosquito; a, antenna; t, tuft of hairs; e, eye; b t, breathing tube.

wrigglers were found is the best for the purpose. No special feeding is necessary; the organic matter in the stagnant water suffices. Do not put too many wrigglers into too small a jar of water. The mouth of the jar containing pupæ should be covered with cheesecloth, so as to prevent the escape of the winged mosquitoes which will emerge from the pupæ. With half a dozen jars of material, the life history and habits of the mosquito can be admirably observed. All of the changes of the mosquito from egg to adult are completed in three or four weeks.

Observing and Questioning.

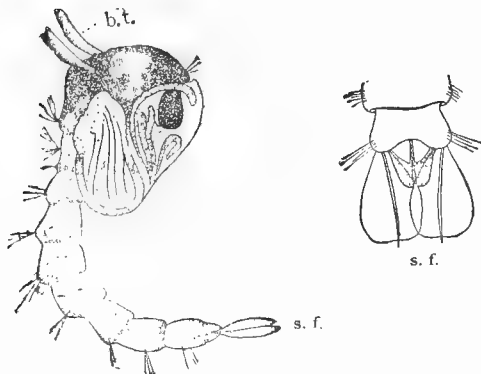


FIG. 56. The Pupa; b t, breathing tube; s f, swimming flaps at the tip of the body.

What is the wriggling of the wrigglers? Evidently simply the peculiar mode of swimming or moving thru the water. It is a violent lashing of the tail end of the body. The wrigglers move in any direction at will by means of this lashing. If a wriggler which is swimming thru the

water stops "wriggling" i. e. stops swimming, what happens? It slowly sinks. (If it touches the walls of the jar it may not sink because of the friction.) Why does it sink? And why so slowly? It is evidently heavier (denser) than water, but only slightly so.

There are, however, always many wrigglers hanging head downward just beneath the surface of the water; hanging down in fact from the surface of the water. What are they doing? Breathing.

You can see that a little stem-like process (fig. 5 b.t.) projects from very near the posterior tip of the body and the end of this process reaches the water's surface. This process is a breathing tube. (I shall describe it later, more in detail.) The mosquito does not breathe thru its mouth, nor thru any organs on its head, but thru this tube on the tail end of the body. It is necessary for the wriggler to come to the surface of the water to breathe. If the wriggler is prevented by any means from coming to the surface, it soon drowns. Many wrigglers too weak to swim to the top of the water drown.

But how can the wriggler remain thus at the surface without sinking if it is heavier than water and always sinks when it stops wriggling? It holds on to the tense surface film of the water. The tip of the breathing tube projects slightly above the surface when the wriggler comes up to breathe. The slightly expanded edges of the mouth of the tube are caught by the surface film, and the body of the wriggler supported at the surface. This tense surface film exists because the molecules of water which constitute the surface layer of the water are more strongly attracted laterally by each other and downward by the water molecules beneath than by the molecules of air which lie directly over them. It is easier, however, to prove the existence of this tense surface film than to explain it. If you carefully lay a clean needle on the surface of water it will not sink altho much denser than water, but will be supported by the surface film. If you fill a tumbler to its brim you can still add more water (doing it carefully) and so heap up the water above the level of the tumbler's brim. You can do this because the surface film extending over the water from edge to edge holds it in position. If you dip your finger into the water and lift it up all the water does not run off but a large drop will remain hanging to your finger. The tense surface film keeps this little mass of water together in the form of a drop. Many aquatic insects and other animals take advantage of the presence of this surface film on water. The water

spiders and little flies which run quickly about on the surface of quiet pools are supported by the surface film.

To follow the habits of our wriggler in relation to the surface film, we see that despite the fact that the wrigglers are heavier than water they are enabled to hold themselves without effort at the surface of the water to breathe. And yet, also without effort, they can rest on the bottom, feeding on the decaying matter to be found there. Indeed, because they are heavier than water when they are at the surface breathing they always hang with head down in the water, and thus can continue feeding on the organic particles that are floating everywhere in the foul water, at the same time that they are breathing. This is an important saving of time to the mosquito. When we have studied insects more we shall know that insects that go thru transformations like the mosquito—metamorphosis this transforming is called—do almost all of their feeding in their first young, or so-called larval stage. For example, the male mosquito eats almost nothing as a flying insect, (the female does take some food, as we are grievously aware), so the insect must not lose much time in its first young stage if it is to store up enough food (as fat) in this stage to suffice for its existence thru all of its other stages. And yet so active a creature as the wriggler must have a great deal of oxygen (taken from the breathed-in air) to keep its life fires burning. So you see how admirably arranged the wriggler is to take advantage of the natural conditions under which it lives.

Let us turn to the other kind of young mosquitoes, the big-headed ones, the pupæ (see fig 6). When they are below the surface and stop wriggling, what do they do? They rise to the surface. They must be lighter than water then. Are they not so well fitted for their life as the wrigglers? Or is there a difference in the habits of the mosquito in its two young stages? Yes, a great difference. The pupæ take no food. All they need is to be able to breathe, and to be able to swim quickly away from any ferocious pursuer.

Note that as they lie at the surface it is not the posterior tip of the body which touches the water, but the back or upper part of the bulbous head end. How do they breathe then? By means of two horn-like, hollow processes that project from the back of the head end. In this they differ from the wriggler, and we shall see later that they differ in many other details. As they do not feed there is no special need of having the breathing apparatus at one end of the body and the feeding apparatus at the other, or that the head should hang down in the water while the insect is breathing. But is there any special advantage in having the pupa float at the surface with the back of the large head end of the body uppermost? There is, indeed; it is more than an advantage; it is almost a necessity. It is from the pupa that the winged mosquito comes. Now the delicate wings of the mosquito are folded up in pads (which we shall later study) on the pupa. These wing pads are attached to the upper part or back of the big head end of the pupa, and when the mosquito is ready to emerge, this back of the big head end of the pupa, which is at the surface of the water splits longitudinally and the back of the mosquito with the delicate wings slips quickly out and above the surface of the water, without getting wetted. The delicate wings are immediately unfolded and in a moment or two the mosquito is ready to fly away. If the wings were drawn out of the pupal sheath in the water it is probable that few mosquitoes would ever be able to fly. Thus, you see, the second young stage of the mosquito, the pupa, altho very different from the first stage, the larva, is also admirably arranged for the successful living of the mosquito.

I have constantly referred to these strange wriggling creatures inhabiting foul water as young mosquitoes. But they do not at all look like mosquitoes; they live in water, not in air; their habits are very different from those of the mosquito. How do I know, how do you know, that these curious wrigglers are young mosquitoes? Simply and sufficiently by watching one of these creatures thru its life.

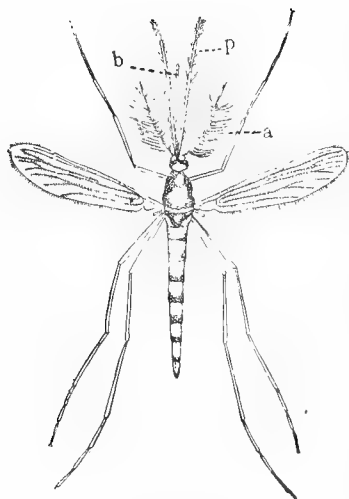


Fig 7 The Mosquito. a, antenna; b, beak; p, palpus.

If you put one of these little sooty masses of eggs, which we have found floating on the surface of the stagnant water in the leaf choked ditch or pool, or watering trough, or barrel, by itself, into a glass with some water, we shall find after a day or two that from each egg has come a tiny wriggler, that is, one of the creatures we have been calling mosquitoes in their first young or larval stage. (The time which elapses from the laying of the eggs to the hatching of the wrigglers varies with the species of mosquito and with the temperature.

In warm weather some mosquito species hatch in as few as twelve hours.) The tiny wrigglers wriggle, they go to the bottom to feed, they rise to the surface to breathe; they grow larger, and, what we have not before noticed, they shed their skin or moult. They shed their skin several times during their life as wrigglers. The duration of this first young stage is from one to several weeks. If the glass jars containing the eggs and wrigglers be kept in a warm, sunny window, the changes will probably be more readily made than if the jars are kept at a lower temperature. After eight or ten days, then, the wrigglers will change into the second young stage, the pupa, or the wrigglers with the big head end. The pupæ live for two or three days, most of the time floating motionless at the surface of the water. Then they transform into the winged mosquito. (fig. 7.)

Thus simply and certainly is proved that the sooty egg masses are mosquito eggs, that the slender wrigglers are the young mos-

quitoes as they are hatched from the egg, and that the wrigglers with the big head end are young mosquitoes in a stage following the first wriggler stage, and from which the winged mosquito comes. All these changes the children may see for themselves, and all in three or four weeks.

I have said that the larval wrigglers transform into the pupal wrigglers, and that the pupal wrigglers transform into winged mosquitoes. This is really true, but as seen from without, as seen by the children, one form will appear to *issue from* the next preceding form, i. e. the skin of the larval wriggler will split along the back and a pupal wriggler will come out, the split empty skin of the larva floating away on the water's surface. Then from the pupa similarly will come the winged mosquito, and the rent pupal skin will remain floating on the water. This last transformation ought to be watched carefully. From the splitting pupal skin will appear first the humped back of the mosquito, then slowly and carefully the head with its bushy feelers and long piercing beak, and, finally, the long slender legs. While all this is going on, the pupal skin serves as a raft upon which the soft-bodied, damp mosquito is safely supported until its wings and legs are unfolded and dried and hardened, and it is ready to fly away.

The winged mosquitoes may be kept some days in the hope that they will lay eggs, but this hope will probably not be realized. Only rarely do mosquitoes in confinement lay eggs. It is worth while however, to make the trial, altho the proof that the eggs and wrigglers are mosquitoes in egg, larval and pupal stages is complete without the actual observation of egg-laying.

All of the observations we have so far undertaken have been easily made. They have related to the habits and the life-history or development and growth of the mosquito. There are, however, some other interesting observations which we can make, but for which it will be necessary to have the aid of a microscope. These observations relate to the details of the structure of the

wrigglers and winged mosquitoes and are, of course, not well adapted for the younger children.

As the wrigglers hang head downward from the surface of the water there can be seen, with unassisted eye, two little tufts of hairs projecting from the head which are usually in rapid vibratory motion. What is the meaning of the movement of these hair tufts? If a wriggler be put into a watch-glass of water and be examined with a magnifier the head will be seen to have the appearance shown in figure 5. The two tufts of hairs, *t*, are situated at the sides of the mouth and their constant vibration is for the purpose of creating little currents in the water, which are directed towards the mouth and which carry food, i. e., tiny particles of organic matter, into the mouth. On the head may also be seen the eyes, *e*, and the feelers or antennæ, *a*. If the other end, the caudal extremity, of the wriggler be examined it will be found to present the appearance shown by the lower right hand portion of figure 5. In the finger-like breathing process may be seen the true breathing tube, *b. t.* This breathing process arises from the next to the last segment of the body. At the tip of the last segment may be seen four small leaf-like flaps whose use is not certainly known but which may act as a rudder for the body. The posterior opening of the alimentary canal, *a. c.*, is located in this segment.

Now examine a pupa (fig 6) under the magnifier. On the large head end of the body may be seen the pair of breathing tubes *b. t.*, previously referred to, and also the developing wings and legs of the mosquito. These wings and legs are all folded closely together and are covered with a thin membrane. At the tail end of the body may be seen the two large swimming flaps.

Kill a few winged mosquitoes and examine them with the magnifier. You will find two kinds, in general appearance very much alike but differing in some details; the most obvious difference is in the character of the antennæ. Some have antennæ which bear many long hairs (fig. 7, *a.*) The antennæ look bushy. These

are the males. The females have comparatively few hairs on the antennæ. It is believed that the mosquito hears by means of these antennal hairs. In addition to the antennæ, observe the long, slender, sucking beak, with which the female mosquito pierces the skin of animals to suck their blood. If mosquitoes cannot find animals then they live on the sap of plants. How many wings has the mosquito? How many pairs of legs? Most insects have four wings, but the mosquito has a pair of little knobbed projecting processes instead of hind wings. These knobbed processes are called balancers and they are believed to aid the mosquito in directing its flight.

The details of structure to which I have called attention are, perhaps, the ones of most interest; but the examination of the bodies of the wrigglers and winged mosquitoes will bring forth many questions on the part of the pupils, and the teacher can call attention to much of the general structural condition of the insect body.

Seeds.

As soon as the fall rains come we have sprouting on every side the many forms of seeds whose distribution has been studied. Consequently among the plant lessons the growing of seeds may well follow those on distribution of seeds. It is well at the very start for the teacher to have in mind something of the true meaning of the seed.

This will serve as the best guide to the use of the seed and its activities as lessons, even the most elementary. The full understanding of the significance of the seed would include, with other things, the knowledge of that part of its structure which points to the relationships of the seed-forming plants to those of lower forms. Such matters would obviously be out of place here

The view of the seed as a plant itself, being a phase in the existence of the plant's life adapted to certain conditions is the one to be kept in mind. These conditions are those connected with its distribution, including its ability to remain dormant a long time, its having the means of transportation as already studied in distribution, and its preparation for making a start in growth, in a favorable place, and continuing this growth until its organs for obtaining food from the air and the soil are well developed. This view will give us direction in the study of the structure of the seed, and in methods of observing the activities of the the growth of its parts.

Of the two lines of study of the seed, its structure and its action in growth, logically it might be considered that the lessons on structure should come first. It will be found, however, that there will be greater interest in the work if first we see the seed in action and then follow with the seeking out of the parts concerned in the action.

Growth of Seeds.

Do not confine the lessons to one form of seed as is sometimes

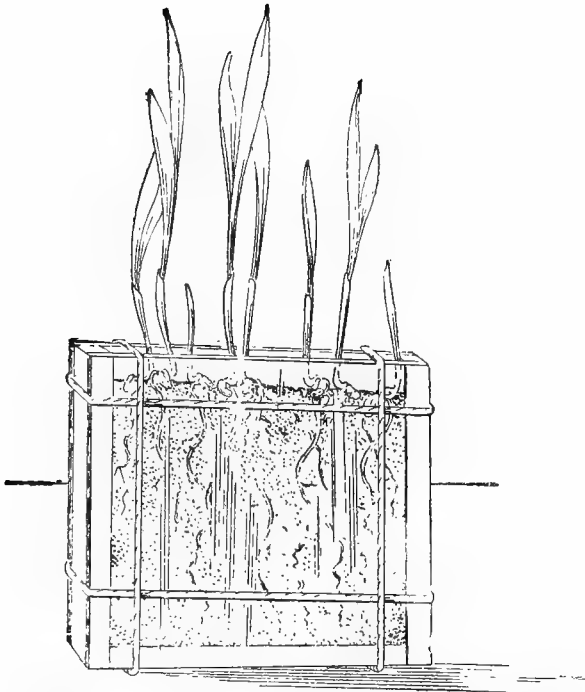


Fig. 8. Seeds growing between sheets of glass to show growth of root, root-hairs and root tips.

recommended, but have a number of forms planted. It would be well for the pupils to use many of the seeds gathered during the lessons on distribution of seeds, allowing them to select as they choose. Among the number it would be well to have squash or pumpkin, bean, pea, radish, wheat, corn, acorn and pine seeds. This list will insure having seeds of good size, and those which behave differently in germinating.

Explain how the seeds are to be planted in boxes or pots of

rich mellow earth and to be kept properly watered, and in a warm place, but have the pupils do all the work of preparation, planting and care of the boxes. It will be of great advantage to have a large number of the forms planted you expect to work most with, such as squash, bean and corn. The seeds planted in boxes will give ample means for observing how the seed starts to grow, how it gets out of the seed leaves, and how the stem and leaves develop from these.

But to see the equally interesting and instructive development of the root with its branches, root hairs and root cap, some other method of planting is necessary, since digging up the root

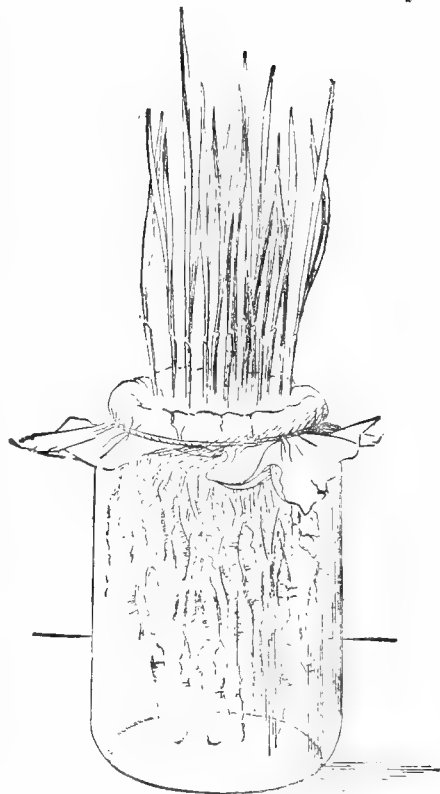


Fig. 9. Seeds grown on netting just touching water in the jar, showing root, root-hairs and root cap.

destroys some of the very things necessary to be seen. For study of the growth of the root, plant a few seeds in earth confined between two sheets of glass about seven by eight inches, or larger. The sheets of glass are kept apart by thin strips of wood, as thick as a lead pencil, and are clamped together by pieces of bent tin or tied with strings. The sheets of glass might also be held

in place by means of wooden frames with grooves sawed in for slipping in the glass. The two sides are to be kept dark with a cloth or board covering except when observing the roots, which may well be seen thru the glass.

Another means for seeing the growth of root is by planting the seeds on a piece of netting tied over the mouth of a jar filled with water sufficiently to bring the water just in contact with the seeds. Seeds planted between layers of cloth or blotting paper kept moist will grow roots of considerable size and allow the examination of root hairs and root cap.

With many seeds planted in the various ways indicated, and a supply of seeds for successive planting to study out phases that were missed in the first observation, or to settle questions of doubt, the teacher has abundant and rich material for many lessons, which, interspersed with those on animals and minerals, will extend over a long period.

Now what is to be looked for in this material? First is to be noted just how the different seeds "come up." Each kind of seed has the problems to solve of getting its parts out of the seed coats, its first root started downward and fixed in its position and its young stem started upward. Have the pupils note carefully each step in the above mentioned process. How the seed coats are moistened; the contents swollen with the imbibed water; the seed coats split and pried open, and the seed leaves with the young stem and the minute new leaves withdrawn from the coats in some seeds; in others the seed leaves are not withdrawn but remain in the seed coat and the ground, the root and stem escaping however. Find out also how these steps are taken with corn, wheat and onion seeds. In brief, keeping in mind that the growing seed is a living thing very active, and active too with purposes, have the pupils over and over again on different seeds watch the series of actions of a germinating seed and, as far as may be discovered, the purpose of each action.

The Structure of the Seed.

For making out the parts of the seed make use both of dry seeds and of those that have been soaked in water for some hours. It is best to begin with the larger forms such as beans, peas, or pumpkin seeds.

Have the pupils see that the seed is a small plant ready to grow, but wrapped up tightly in a covering. The covering has a small opening at one point. The contained plant can be clearly seen to have a stem bearing leaves, and a point that is the beginning of the root. The leaves are (in the bean, pea or pumpkin) first two large thick white leaves filling the main part of the covering, and then the pair of minute ones which are to be the first pair above the seed leaves. Grains of corn and wheat or a pine seed will show a different arrangement of the seed leaves, the first having only one, the last having five. The seed contains stored up nutrition. Often, as in the bean, this nutrition is stored in the thick seed leaves, but in others as in the morning glory it is deposited around the seed leaves.

The parts of the seed as known in botany are, as illustrated in the bean, for example: The covering, the *seed coats*; the two thick seed leaves, the *cotyledons*; the small stem, the *caulicle*; the part above the cotyledons bearing the minute leaves, the *plumule*, the point at the opposite end of the caulicle is the root point. The whole minute plant as it lies in the seed is called the *emb. yo.*

Have the pupils hunt out the seed leaves in many forms of seeds, including some in which they are not so evident as in the bean and squash, such for example, as the acorn, walnut, pecan, chestnut, buckeye, wild cucumber. The germination of each of these nuts is very interesting. The methods used by the buckeye and wild cucumber of this coast are apparently so widely different from those of the squash and bean that they present quite attractive puzzles. Who in the schools this winter will solve them?

Each kind of seed has a habit of germination peculiar to itself. To discover these individual ways of plants is to become personally acquainted with the plants, which can not fail to beget not only an interest but even a love for these earnest members of Nature's community. This interest and love will not cease with the lessons in the school, but will be a source of wholesome pleasure at every recurring spring time thruout life.

The embryo plant well out of the seedling state, leading now an independent existence, presents us with other lessons inexhaustible for our school work. Some of these we shall select to form a part of this course to be treated subsequently.

Most of these lessons will be taken from the adult plants as we shall find them in gardens, woods and fields. There are some important matters which may be noted as the young seedlings are growing in the boxes, etc.

Each plant on leaving the seed, each in its own way, immediately begins to establish its stem with its peculiar system of branches, and its root and root system. As has been pointed out, the former is to explore the air for carbonic acid and sunlight, and the latter to explore the ground for water and certain substances dissolved in the water.

Each plant arranges its stems with its branches and the leaves on them, in such a way as to present its leaves to the sunlight and air to very good advantage and with little interference with each other. The ways in which the many forms of plants have worked this out are very numerous and are represented in the varied habits of plants which we know as characteristic of them. This subject we shall take up in later lessons.

The root systems of the plants are as important and as well planned as the stem systems. However, less is known about them since they are hidden and hard to get at. Still the early stages of the formation of the root system can be observed in the growth of the seeds between the glass plates and in the jar of water.

Growing plants of various kinds may be carefully dug up

the roots washed off and thus much be learned in regard to the root systems. If caving banks, washouts, railroad cuts or other excavations allow the observation of the roots of larger plants at greater or less depths under ground, the teacher of course will take advantage of them. Professor Hilgard has published in a bulletin of the Department of Agriculture of California, the photographs of excavations showing the extensive root system of fruit trees as they are disposed in California to meet the requirements of its peculiar seasons.

Two objects of great importance can easily be observed in the growth of the plants between the glass sheets and in the water jars—they are the *root hairs* and the root tip with its *root cap*.

The root hairs are the parts that absorb the water and hence their importance. The main purpose of the root system is to extend the parts that bear the root hairs into every cubic inch of soil where moisture can be obtained within reach of the plant.

The root hairs form a fine down of minute hairs as thin as filaments of cotton which cover each small rootlet a short distance back of the growing tip of the rootlet. They are so delicate that they usually break off when a plant is pulled up by the roots. They can be seen with the naked eye, but, of course, a lens shows them better.

The *root tip* is also a very important organ of the plant since it is by the root tips that the roots are planned out and each carried to the place where it comes finally to lie. That is, the root tip is the growing end of the root. It is very sensitive to contact, to moisture and also must be to other influences. It is, in consequence, able to find its way to the parts of the soil where it should go and in doing this is able to avoid the various obstacles which it meets. At its very tip it is covered with a minute cap called the root cap which affords the extreme end some protection.

Have the pupils see thru the glass sheets how the root tips avoid the obstructions and find their way in different directions. Root tips avoid light, while stem tips seek it. Root tips

usually grow downward and stem tips grow upwards, but both may grow horizontally.

Here are opportunities for some instructive, tho simple, experiments which will reveal more of the life of plants, but these must be reserved for future lessons.

How to Make a Collection of Insects.

Though the nature study class will find most of its interest and most of its work in observing the habits of animals and plants, there is a certain interest and use in collecting and preserving specimens, in "making a collection." Among animals none are more readily collected and preserved than insects. They are abundant both in species and in individuals; they are to be found at all seasons of the year, and under all conditions of surroundings. They live on the surface of the ground, in the soil, in water, on and in all kinds of plants, in decaying matter, in short, they have adapted themselves to almost all of the conditions under which it is at all possible for animals to live. Coupled with this abundance of individuals and variety of habitat, they are readily collected and easily preserved. No elaborate collecting equipment is required, nor any expensive and room filling cabinets. Thus insects present themselves as specially fit objects for the beginnings of a nature study collection.

Not only are the full grown flying insects themselves to be collected, but also their immature stages; the eggs, the caterpillars and other larvæ, the cocoons and chrysalides and various pupal forms, and finally their nests and the various products of their handiwork, all should be collected and properly arranged and displayed for reference. In the following directions for making and caring for, as simply as possible, an insect collection, some account of the collecting and preserving of all these various kinds of specimens is included.

For collecting insects there is necessary a collecting net and a collecting or killing bottle. The net bag should be about 12 or 13 inches in diameter at its mouth, about 24 inches deep, and should taper from its mouth to a diameter of about 6 inches at the rounding bottom. It should be made of cheese cloth or strong bobinet, and should be bordered at its mouth by sheeting which should be firmly sewu over a wire net-ring fastened to a

light wooden or cane handle three and a half feet long. Any ingenious boy can make the net-handle and ring.

For the collecting and killing bottle (fig. 10) put into the bottom of a wide-mouthed bottle (a 4-oz or 6-oz quinine bottle) a tablespoonful of cyanide of potassium which has been broken into small pieces (as large as peas) and cover this with a layer,



Fig. 10. Killing bottle; cyanide of potassium at bottom, covered with plaster of Paris.

half an inch thick, of plaster of Paris mixed with water to form a thick paste. After the plaster has set (letting the bottle stand uncorked), put into the bottle a small crumpled bit of tissue paper (to prevent the shaking about of the insects and to absorb moisture) and the killing bottle is ready for use. It should be kept tightly corked. Insects caught with the net or with the hands have simply to be dropped into the killing bottle and the deadly hydrocyanic gas which fills the bottle will kill them almost im-

mediately. The insects may be left in the bottle until the school-room is reached, when they should be taken out and pinned up as described later. The cyanide of potassium used in the killing bottle is a deadly poison and the utmost care should be shown in its use. Perhaps it will be advisable to have a druggist make the bottles according to the above directions. Each bottle should be marked "Poison," and the pupils warned not to inhale the gas when the cork is removed.

With collecting net and killing bottle, and a few small boxes for live specimens, nests, etc., the insect collector is outfitted. In collecting, visit flowers, turn over stones and old logs, go into

orchards where fruit is falling, explore the bark of tree trunks, work along the banks of streams or ponds. For insects which live in the water, a special water net will be necessary; one with wider meshes so that it may be drawn readily thru the water. A special kind of collecting is that called "sweeping." In a meadow or pasture, especially if many flowers are in bloom, whip the net quickly back and forth over the tops of the weeds and grasses. You will be sure to catch a host of small insects and spiders in this way. Do not collect the flying insects alone, but collect larvæ, caterpillars, cocoons, chrysalides, nests, leaves and twigs bearing galls or showing the effects of insect attack, and all other specimens which illustrate the life of insects.

The preservation of the collected specimens is simple, and easily learned. The insects are to be pinned up, i. e., each insect is to be mounted by thrusting a special kind of slender pin (called an insect pin) thru the middle of that part of the body called the thorax, the part of the body from which the wings arise. Beetles, only, are not pinned thru the middle of the thorax, but thru the right wing-cover close to the median line of the body. These insect pins must be bought of a dealer in nat-



Fig. 11. "Pinned-up" insect

uralists' supplies, and can be had in various sizes. The sizes most commonly used are numbers 1 and 3 of the kind of pins called Klaeger pins. (The dealer may not have the Klaeger pins, but a kind called Karlsbader; numbers 3 and 5 are the size to buy of this kind.) These pins cost 12 or 15 cents a hundred. The insects should be pushed up on the pin so that only one-third of the pin projects above the back of the specimen (fig. 11).

Most insects need no further care than this simple pinning

up. But some large-winged kinds, as butterflies, moths, dragonflies, etc., should have their wings spread. To accomplish this, there is necessary a setting-board (figs. 12 and 13), consisting of a block or frame arranged so that a groove runs between two flat strips of board. Under the groove cork is fastened. The body of the pinned insect is placed in the groove, the pin being thrust into the cork below far enough to bring the back of the insect just even with the surface of the strips of the board at the sides. The wings are spread out and held flat against the surface by pinned-down strips of paper.

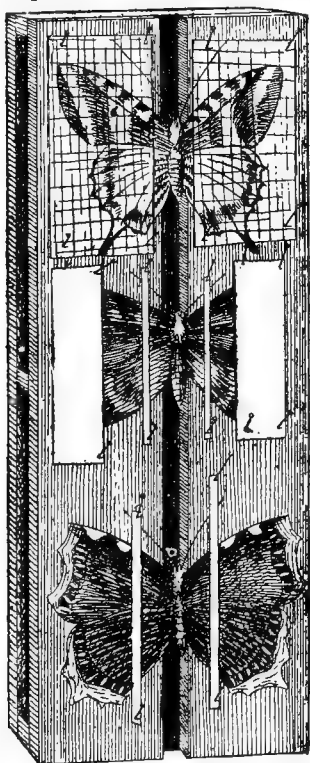


Fig. 12. Setting-board. (After Comstock). e., all the beetles together, all the

strips of paper. Insects should be left on the setting or spreading boards for a week or more, when they may be removed, the wings having dried in this outspread position.

Caterpillars, spiders and some very soft bodied insects should not be pinned up but should be put into alcohol in vials for preservation. Cocoons and chrysalides may be mounted on pins or put into alcohol. The pinned specimens must be kept in "insect cases;" the best insect cases for the beginning collection are cigar boxes with the bottom covered inside with sheet cork or with any soft pith such as the flowering stem of the century plant (pita-wood) or of the stalks of field corn (corn-pith). The pinned insects can be arranged in these cigar boxes according to kind; i.

moths and butterflies together, all the bees and wasps together, all the flies together, etc. If some little expenditure of money can be made (the cigar boxes cost practically nothing), have a good carpenter make a number of shallow glass topped cases according to the following directions: Make a shallow box 12 or 15 inches (inside) by 2 inches deep (inside) with tight joints, and with a cover 1 inch deep, which fit together tightly by means of groove and tongue; all joints should be as close as possible. (There are certain small insects, so-called museum pests, which feed on dried specimens, and the tight covers and perfect joints of the insect case are necessary if these pests are to be kept out.) Cover the bottom of the case with sheet cork or pith, and it is ready for use. This kind of a case not only preserves the collection from the attack of museum pests, but allows the specimens to be attractively displayed.

All specimens should bear a small label—the label should be borne on the pin under the specimen—give the locality and date of capture. If most of the collecting is to be done in a single locality small printed labels bearing the name of the locality and with a blank space for writing in the date, are convenient.

Collecting net, killing bottle, insect pins, setting board, insect cases, and vials of alcohol, these are the apparatus necessary for collecting and preserving insects for making an insect collection. An expenditure of one dollar will suffice (if cigar boxes are used for insect cases), to make a good beginning in the making of a school room insect collection.

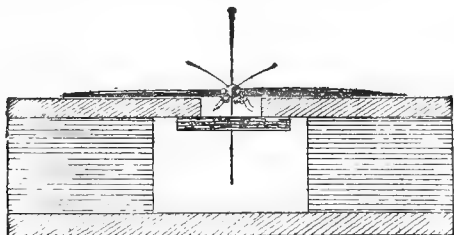


Fig. 13. Cross-section of setting-board. (After Comstock).

FUNGI.

After the first rains come and thruout the season of rains the mushrooms and many other forms of fungi spring up on every hand.

The great majority of this company of plants are quite modest in their behavior. They are, too, mostly short-lived, coming in the night, and passing away during the next day, or extending their stay but a few days at the most. Their methods of gaining their nutrition, of reproducing themselves, and of distributing themselves over the earth are hidden from the casual observer. In short their mode of life is a puzzle and mystery to most people. This has led the whole group to be much neglected in the pursuance of the more conspicuous phenomena of plant life as presented by the showy flowering plants.

From time out of mind, many members of the group have been looked upon with downright fear as being intimate with all sorts of uncanny existences, and being in league with them to work evil on mankind. But these quiet little plants, like all other plants, both big and small, are hard at work at food gathering, reproduction and distribution. Each one from the microscopic bacterium to the great puff ball represents in their varied forms and sizes, special adaptations to conditions which each has found favorable to its life.

They offer many a delightful lesson to him who will hunt out their homes in pasture, woods or cañon.

The sizes and forms of fungi are as variable as could be imagined. They include the mushrooms or toad-stools, the puff-balls, the moulds, the blights, the mildews, the smuts, the rusts, the bacteria, and many other forms whose names are not so familiar.



Fig. 14—The common edible mushroom.

Many are harmless to man, many are indifferently good or bad, many are delicious and nutritious food, many are destructive enemies to man's buildings, his clothing, and especially his food, others attack the plants he nurtures for their fruits and grains, and some are deadly enemies to his own body, being poisonous like some of the poisonous mushrooms, or, as with some forms of bacteria, being the cause of the most dreaded diseases. Their abundance and importance as well as their interesting mode of life, are sufficient reasons for their introduction into a course of nature study lessons, for which a few of the more common and conspicuous forms may serve as an introduction.

As the terms mushroom and toad-stool will come up immediately for consideration, it may be said that the usage shows both terms applied indiscriminately to the same species. Toad-stool is applied by some to those forms only which they consider poisonous, while mushroom is reserved for those considered edible. But the general usage among botanists is to make the term mushroom serve as the common general name of all the forms to which the names mushroom, toad-stool and puff-ball are commonly applied.

It may be stated also that it is not the object of this lesson to point out any methods of distinguishing the edible from the non-edible mushrooms. While it is very desirable that a better understanding of the wholesome and nutritious value of many of the common forms be extended and thus save great waste of ex-

cellent food that goes on every year in our fields and woods, the teacher should not undertake the responsibility of giving this information without an accurate knowledge of the good and bad forms.

Our lessons are to be with the life of the plant. Some form of the umbrella shaped mushroom is good for the first lesson.

The common edible mushroom is shown in Fig. 14. If this or some similar form can be obtained in sufficient abundance, allow each pupil to have a specimen. Have him examine all its parts carefully. The stalk is called the *stem*; the expanded portions is the *cap*; the ragged fringe running around the stem a short distance below the cap is the *ring*; the thin plates underneath this cap radiating from the stem are the *gills*. These in the younger specimens of the common edible form are pink, turning brown and later black with age. Have the pupils slice the mushroom through cap and stem to see the connection between them.

The stages of growth from their first appearance as small white balls to the adult form should be observed. It will then be seen that a curtain covers the cap and gills, and it is the breaking of this by growth of the containing parts which makes the ring.

Direct the pupils to cut the stems of several close to the caps, and place these caps, gill side down on sheets of white paper, and place them where they will not be in currents of air. After some hours or the next day the paper will show a beautiful deposit of very fine powder neatly outlining the shape of the gills. This powder is made of the *spores* which have been discharged from the gills and the picture thus made is sometimes called a *spore print*. As the spores of different species are of different colors they may be taken on a sheet of glass and this placed over dark or light colored paper to give the proper background for displaying the spores to the best advantage.

This brings us to make a brief survey of the course of the life of the plant. The spore is to this plant what the seed is to higher plants being the part from which the plant starts to grow.

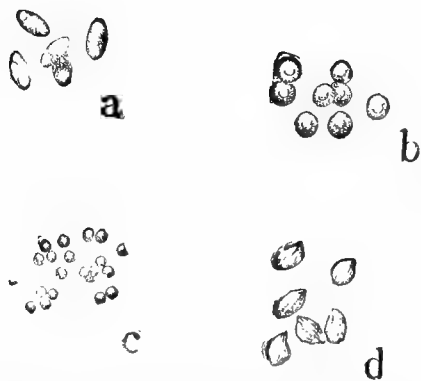


Fig. 15—Spores of fungi, highly magnified; a, of Fig. 16; b, of Fig. 14; c, of Fig. 18; d, of Fig. 22.

The shape of the spores of each kind of mushroom is peculiar to it. Fig. 15 shows four forms of spores.

The mushroom discharges countless numbers of these minute spores, which are borne on the wind over great areas of the earth. The spore that lodges in a place just suitable, as far as moisture, heat and food are concerned, begins to grow by sprouting out a minute and delicate thread. This absorbs food and water, grows further and then sends off minute thread-like branches. The branches continue the same method of growth and branching until the soil, the rotting stump or whatever the mushrooms flourishes upon is penetrated by a great mass of these fine threads. If we could get them out they would look just like the white ectony mass, which, in the form of mould sometimes is seen upon bread or on the top of fruit in jars. It is so delicate that it is impossible to extricate it from the soil entire, but we can see at the bottom of the mushroom stem, the large white cords looking like roots, which are made up of great numbers of these threads running into the stem. These white threads are called the *mycelium* or *spawn*. When one buys of the seedman spawn of mushroom for propagating them for the table, what he obtains is a block of

The spore, however, is not a true seed. It does not have the structure of a seed. It has no seed coats, no cotyledons, and no embryo. It is very minute and consists of a single cell, while a seed of a flowering plant may have millions of cells in it. A single spore is very small and requires a good microscope to see it well.

rich earth which has fine threads of mycelium all thru it, but of course not to be seen in the mass, which will continue to grow in similar rich earth. Fig. 21 represents the mycelium of a mould that grows upon bread, and illustrates well the mycelium of the mushrooms.

After the mycelium has grown for sometime and accumulated a great amount of nutrition it is ready to form spores. Then it pushes up rapidly the toad stool, puff ball, or what ever other spore bearing apparatus it may possess. The conspicuous forms that we see above the ground or on the rotting log are simply the spore bearing part of the plant, tho they grow sometimes with such remarkable rapidity as to make "mushroom growth" an often used comparison. We must remember that the forming of the conspicuous spore bearing portions of the mushroom is but an incident in the life of the plant, and that it may have taken months of hard work to get ready for the important incident.



Fig. 16—A common form of the genus *Boletus*. In this the spores come from tubes, which are shown on under surface of the cap.

Briefly the life of a fungus consists of: The sprouting of a minute thread from a spore; the growth of this thread into a tangled felt of mycelium which penetrates the substance it grows upon; then the forming a spore bearing apparatus which produces the spores from which the cycle begins again.

The work of the nature study class may

begin by gathering the different forms that may be found and determining where the spore bearing surface is in each. As has already been seen in Fig. 14, the spore bearing surface of the common edible mushroom is on the gills on the under side of the cap. There are many forms like this from which spore prints can be obtained.

Another large group of mushrooms bears the spores on the surface of small tubes which are in the part under the cap, or under the shelving masses growing on the sides of stumps or logs. Fig. 16 is a very common form found in lawns, in the woods under pine trees and in other situations. It is known as *Boletus* and there are many species of this genus: The illustration shows the tubes on the under surface of the cap.

Fig. 17 represents a spore print of this *Boletus*, taken by cutting off the cap and placing it bottom side down on a sheet of paper and allowing it to remain for some hours when it discharges its spores down the tubes thus outlining the underside of the fungus.

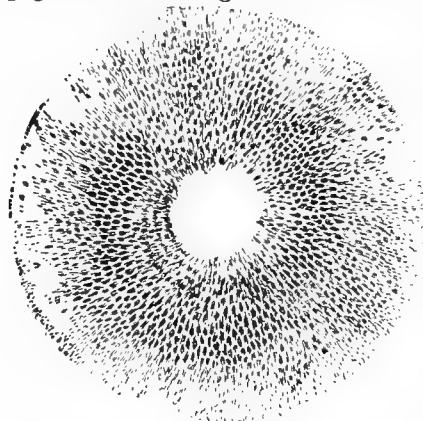


Fig. 17—Spore print of the *Boletus* of Fig. 16.

Some of the puff-balls in California grow to the enormous size of a foot in diameter. These when growing, while still white are excellent food, many thousands of pounds of which go to waste every year.



Fig. 18—A very common form of small puff-ball. The one at the right hand is discharging its spores.



Fig 19—A Geaster with its collar turned up.

What a vast number of spores one of these sends out!

There is one very curious form of puff-ball that always interests the class very much.

It is known as the Geaster (earth star.) It is a puff-ball with a great collar around its neck. When it is dry the rays

of this collar curl up tightly over the ball. (Fig. 19.) When moistened the rays of the collar swell up and turn out first, then down against the ground and raise the ball up as in Fig. 20. A dry Geaster placed in a dish of water will quickly take the form in Fig. 20, and may soon be given the form in Fig. 19 by drying. This process may be repeated many times on the same individual.

Moulds lead the same life as do the mushrooms. As the whole course of their life can easily be observed the study of a mould is very interesting and makes the conception of the life history of the large fungi clearer.

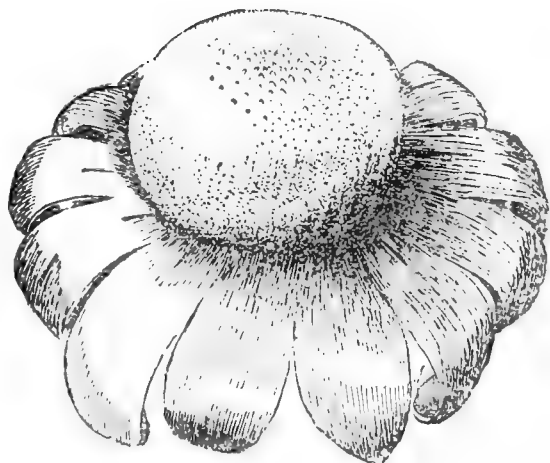


Fig. 20 - A Geaster with its collar turned down.

scattered everywhere so that the cleanest bread has some. In two

A good growth of a large kind of a mould is generally easily obtained by placing a piece of bread slightly moistened in a closed fruit jar, kept closed that the air around the bread may remain moist. In some manner the spores of this mould are

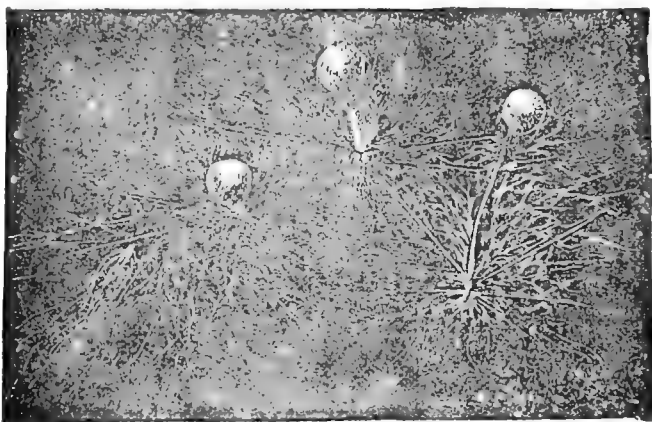


Fig. 21—The mould *Mucor* grown on bread. The network is the mycelium; the knobs are the spore bearing parts. Magnified.

or three days the bread will become covered with a cotton-like felt of threads. This is the mycelium. Later there rise up from this mass many minute stalks which develop at their summits little black beads. The black beads are the spore bearing surface and each furnishes an immense number of spores. Those who understand the use of the microscope will know how to inclose some of these spores in a glass "moist cell" and watch their growth and thus

demonstrate the whole course of the life of a fungus. The spores may be sown on other pieces of bread and a new crop raised. The name of this particular kind of mould is *Mucor*.

There are many other kinds of moulds which the pupils may find and bring for comparison. There are several species which will follow the *Mucor* on the same piece of bread on which it grew. Some of these may be of bright colors.

The blights, mildews, smuts and rusts possess more or less the habits of life of the moulds. Many of them live on living plants.

As none of the fungi have chlorophyll (the green coloring matter in the leaves of higher plants. See lessons on leaves) they cannot feed upon

carbonic acid and water. They, every one, feed upon organic substances. Either decaying plants or animals or living plants or animals furnish them their food. Indeed it is they that produce the processes we include under the term decaying.

It will readily be seen that as they must find their food in the substances of plants and animals either living or dead, they



Fig. 22. A single plant of the mould *Mucor*. One knob is discharging spores. Magnified.

become in some cases scavengers clearing away dead timber or dead animals, or may attack all substances made of wood or other plant products or of animal products, that means our food and clothing, or may attack living plants or animals. The preservation of food, clothing, the protection of garden and orchard plants from certain diseases and the treatment of many of the diseases of the human body are problems of dealing with forms of fungi, mostly of the minute forms.

The collection of a few of the common forms of mushrooms will easily recommend them to the teacher as excellent objects for drawing. Their graceful forms and beautiful colors have been most attractively portrayed by Gibson in his "Toad-stools and Mushrooms."

Rearing Insects in the School-room.

For the study of the habits and life-history of the mosquito, as described in one of the first of these nature study lessons, it was found to be necessary to keep the young mosquitoes alive under conditions approximating the natural conditions of mosquito life. Many other insects lend themselves to similar more or less nearly complete observation of their habits and transformations under those favorable conditions for seeing obtained when the insects live and grow and transform in the school-room. A building or room in which insects are reared and kept alive under conditions approximating natural out-of-doors conditions is called an insectary, and may be an extensive and costly affair; but any school-room can with little trouble and less expense be made to serve as a modest insectary, sufficient for the needs of the nature study class.

The necessary equipment comprises a few flower-pots, a few glass lamp chimneys, or better, lantern chimneys, a few small boxes, and a few glass fruit jars.

The insects to be reared are those whose habits and life-history may happen to be specially described in the course of these nature study lessons, and in addition any others which can be readily obtained, kept successfully in confinement, and whose food can be easily supplied. Many insects can be kept in the school-room for part of their life; and certain particular phases of their life-history observed. Thus the cocoons or chrysalides of moths and butterflies may be collected and brought into the school-room and kept until the issuance of the imago (adult insect). Or caterpillars, whose food plant is known and is readily obtainable, may be reared, and their moultings, their transformations into pupæ, and finally the issuing of the moths or butterflies from the pupæ, all may be observed.



Fig. 23. Lamp chimney and flower-pot breeding cage.

“Breeding cages” can be made in various ways. One of the most generally useful consists of a flower-pot in which the food plant of the insect to be bred is growing. The plant should be inclosed by a lantern globe or wide lamp chimney whose top is covered over with mosquito netting (fig. 23). If the food plant cannot be grown in the pot (if for example it is some shrub or tree) the flower-pot may be filled with wet sand, or better, a wide-mouthed bottle filled with the wet sand and sunk into the soil in the flower-pot, and leaf-covered branches be stuck into the sand. The food should be renewed as often as necessary.

Professor Comstock recommends a cage made by fitting a pane of glass into one side of an empty soap-box. A board, three or four inches wide, should be fastened below the glass so that a layer of soil may be placed in the lower part of the cage, and the glass should be fitted so that it may slide and thus serve as a door (fig. 24).

Many caterpillars when ready to pupate burrow into the soil, and transform underground. For this reason it is necessary to have a layer of soil in the flower-pot cage or the boxcage if such caterpillars or other larvæ of similar habit are being bred. After the caterpillars have gone into the soil to pupate, they may be dug for and the pupæ found and examined. The pupæ should be buried again, and the issuance of the moth or butterfly (or other insect) be awaited.

Cocoons may be kept suspended by strings in wooden boxes. The interior of the box should contain a little soil which should

be occasionally wet so that the cocoons may be kept in a not too dry atmosphere. Pupæ which are found underground must be kept buried in soil or moss. This soil should not be allowed to become too dry, nor yet should it be kept too moist.

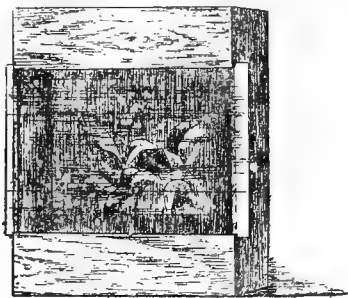


Fig. 24. Soap-box breeding cage.

Insects which feed on dried or decaying organic matter may be put, together with a supply of their food, into a glass fruit jar, over the top of which mosquito netting is tied.

From some of the cocoons or chrysalides will issue, not moths or butterflies, but smaller wasp-like or fly-like insects. These are, if four-winged, ichneumon-flies, or if two-winged, true flies, which

are parasites of the moth or butterfly species whose pupa you have. The adult ichneumon fly or other parasitic fly lays its eggs on the skin of the caterpillar; the young parasites soon hatch and burrow into the body of the unfortunate caterpillar and live in the body feeding on the body tissues. The caterpillar usually has strength left to transform into the pupa, but the continued attacks of the internal parasites kill the pupa, and from it issue finally the full-grown ichneumon flies.

Directions for the special care and treatment necessary for rearing those insects whose life-history is described in this series of nature study lessons are given in the case of each insect studied. Thus, with these few general directions for rearing insects, our consideration of the school-room insectary might be closed, if it were not that we have omitted all reference to the caring for those insects which live in water. For the rearing and observation of these water insects aquaria are necessary. The

making and care of aquaria for the school-room is discussed in the lesson, "School-room Aquaria," but the following brief notes are inserted here because of their special bearing on the rearing of aquatic insects.

To construct and maintain an aquarium has the sounding of something difficult and large to undertake: to put a layer of sand, some water, and a few water plants and animals into a fruit jar and let it, the aquarium, take care of itself, is no such prodigious undertaking. The fruit jar aquarium may be made an object of lively interest and a great help in nature study work.

Miss Mary Farrand Rogers, who has written an interesting and informing account(*) of life in an aquarium, for the series of teachers' leaflets prepared by the nature study bureau of Cornell University, tells so well what a schoolroom aquarium should be and how to contrive to have it what it should be, that my first suggestion to you in regard to schoolroom aquaria is to get, if you can, a copy of this leaflet.

Aquaria are of two kinds, (1) running water aquaria, and (2) quiet or stagnant water aquaria. The quiet water aquaria are so much the simpler to care for and more likely to be possible in the ordinary schoolroom that we may put aside any thought of attempting the other sort. If, however, there is a tap of spring or brook water in the schoolroom a running water aquarium can be maintained. The water can be allowed to flow constantly from the tap into the aquarium and out of it by means of a "constant level siphon" (devised by Professor Comstock), which differs from an ordinary siphon in being bent up at the outer end. The end of the siphon within the aquarium should be covered with wire gauze to prevent the escape of the insects or other aquatic animals.

The quiet water aquaria may be permanent or temporary. The temporary ones may be simply nothing more than a glass

*LIFE IN AN AQUARIUM, by Mary Farrand Rogers, being No. 11 (April, 1898) of Teachers' Leaflets on Nature Study, prepared by the College of Agriculture, Cornell University, Ithaca, N. Y.

tumbler or fruit jar, into which a few water insects, snails or minnows have been put, for present observation. For the permanent aquaria something more is necessary. If a large rectangular aquarium case, of glass and wood, or glass and metal, cannot be bought or made, then get two or three large "battery-jars," cylindrical jars of large diameter and no neck, or specimen jars. Each of these jars may be transformed into an aquarium. (See fig. 25).



Fig. 25. Battery Jar Aquarium

Put first a layer of sand two inches deep into the aquarium (the large rectangular one or the smaller cylindrical one) at the bottom; put over this a thinner layer of small pebbles with one or two larger ones; then plant in the sand a few water plants (necessary to keep up a supply of oxygen in the water). Now put in the water and finally the water animals especially desired to study, with a few others for the sake of variety or to serve as food.

Elsewhere in this series of nature study lessons I shall give an account of some water insects which may be kept in the school-room aquaria, so that here only the special care of the aquarium as a whole will be discussed. The following points should be attended to:

There must always be growing plants in the permanent stagnant water aquarium.

The aquarium must not be tightly covered over; fresh air must have access to it.

Do not keep the aquarium in the direct sunlight; it should for the most part of the time be in a shady spot.

The temperature should be kept, if possible, between 40 and 60 degrees Fahrenheit. Occasional variations, if not too extreme, will not be dangerous.

Do not put in too many live things; if the aquarium is overstocked the death rate will be high.

Keep specially voracious carnivorous insects in an aquarium by themselves with, of course, a supply of food. Do not keep them in the general aquarium.

Occasionally add a little rain water or clear brook water to the aquarium to make up for the loss by evaporation.

If you are keeping the immature stages of insects which, when adult, do not live in the water, as dragon-flies, May-flies, etc., cover the aquarium with netting to prevent the escape of the adults and put in a stick or two projecting above the water so that the insects may have something on which to rest.

With attention to these general directions for looking after the aquarium, and by reference to the special directions for collecting, caring for, and observing the various water insects discussed in the chapters on the "Mosquito," "How Insects Breathe," "Some Water Insects," etc., the nature study class may, it is hoped, find the caring for an aquarium a matter not too difficult, and in the observation of the life of the aquarium a source of much interest.

The Bee and the Lupine.

The myriads of flowers that brighten the fields and hills with their masses of color, or give a charm to every nook and



Fig. 26. THE CALIFORNIA POPPY (*Eschscholtzia*). (a) A sprig of the plant bearing on the right an unopened bud with the calyx cap still on it; on the left the corolla opening; the calyx has dropped away, (b) the calyx cap dropping from the bud, (c) a section through the center of the flower showing the pistil in the center, surrounded by stamens, these by the petals of corolla: (1) ovary, (2) style, (3) a stigma, (4) an anther of stamen; this bears pollen.

corner of the forest demand a place in the school-room. Their beauty and grace often are recognized, but in addition to their simple charms of form and color their deeper meaning as the active factors essential in an important part of the life of the plant make them most profitable material for lessons in careful observation and clear thinking. They show more clearly and in a more interesting way than do most other parts of the plant how it adapts itself to the conditions in which it exists. It is in the flower that the ingenuity of the plant rises to the highest pitch. Its contrivances in the forms of baits and traps are so plain and need so little of difficult learning to understand them that they appeal immediately to the youngest and oldest member of the school. As in the lesson with seeds, their distribution and germination, so here seeing the plant do something to its own advantage adds greatly to the clearer insight of the greatest fact in the knowledge of living organisms, that of adaptation, that is the fitting of the organism to the world of nature around it to its best advantage.

A knowledge of certain facts must precede these lessons, but as this knowledge is of immediate use, it is easily imparted and received.

First, it is to be known that the work of the flower is to produce the seeds. Next it is convenient to know the parts of the flower. Any common flower will answer to teach this lesson, but in the first lesson a good-sized one such as the poppy has advantages over small ones. In the lessons on seeds it was seen where the ripened seeds were found. It is a good point to begin with in learning the parts of the flower to determine where in the flower the minute beginnings of the seeds are placed.

These are easily seen in the poppy. This part of the flower is the *pistil*. The part of the pistil containing young seeds or those things that are to be seeds is the *ovary*. This ends above in a short stem supporting four threads, each bearing a surface called a

stigma. Many flowers have but one stigma of the form of a knob. The short stem between the ovary and the stigmas is the *style*. Standing around this pistil are a number of little bodies bearing orange-colored dust. The dust is the *pollen* and the bodies with their stems are the *stamens*.



Fig. 27. A single flower of the common blue-and-white lupine, (*Lupinus bicolor*). The upper part is the signal, the lower part is the boat-shaped platform which encloses the part shown in fig. 28.

Now the great fact about the flower is that the seeds will never form into good seeds unless pollen gets on the stigmas and its grains grow down thru the style and find and touch a part of the minute beginnings of seeds in the ovary. This is called fertilization. *Pollen must get to the stigma.*

Thus it is seen that the stamens and pistils are all important parts of the flower. The other parts of the flower are the corolla and calyx. The corolla in the poppy is the orange-colored showy part which surrounds the stamens and pistil. Its separate pieces are called petals. The calyx is the green cap which comes off as the flower bud opens. The uses of these parts are to be learned later. All these parts are of different forms in the different kinds of flowers. In many, the reason of the particular form can be discovered and thus be a constant source of nature study lessons, as will be shown as we proceed.

Another fact of great importance is that in most flowers the pollen can not get to the stigma of the flower in which it grows. Either it does not ripen at the same time with the stigma, or there is some contrivance to keep the pollen away from the stigma of its own flower. Pollen from one flower reaches the stigma of

another. This is cross fertilization. How is it accomplished? That is, how is the pollen carried from one flower to another?

In this the lupine may teach a lesson. There are a great number of species of lupines in California. Any one of the common forms will answer. Where possible take the class into a field where many lupines are in bloom. Let each one watch a group of lupines for visits of bees to the plants he has under observa-



tion, and let him try to find out exactly what both bee and flower do during the visit. The bees are in a hurry and what they do is done so quickly, and what motions the plants make are over in such a flash, that it is hard to make out at first what has happened. But careful work will solve it.

This is what can be seen: The bee hovers over the flower for an instant, then alights on the little platform she finds there. Next she thrusts her head down into a part of the plant after nectar. She does not get any, as lupines do not furnish it. In this she is deceived by its being like so many honey plants. While she thrusts her head down into the flower, the part of the flower she is clinging to is pressed down, and out of a point in the very front of it a little stream of pollen oozes out on her body. As she gets no honey she will usually take to gathering pollen.

As the bee has probably visited many other flowers, her body has already on it pollen from them. As she presses down the part of the flower, not only the stream of pollen comes out of the small hole, but the stigma of the pistil is also pushed up from this hole against her body, and thus may get covered with the pollen from flowers of other lupines.

Fig. 28. The flower shown in Fig. 27 with both the parts shown in it removed. The part shown here incloses the stamens and pistil. When the bee alights on the platform of 27 the point a is pushed through it against the bee's body and a stream of pollen is pushed out of the point a.

To understand this better and appreciate the contrivances used, have the class now examine the flowers closely. If it is the common blue-and-white lupine that is in hand, the parts of the corolla which show without opening the flower are as follows: The upper blue and white part, which is the signal flag to show the bee where the flower is. Below this is a boat-shaped part which is blue. If we gently press this down without touching what is within we find a whitish part tipped with a dark purple point. Now if this be pressed down an orange mass of pollen comes out of the tip, then the stigma protrudes. If we take this covering entirely off we find that in it are included the ten stamens and the



Fig. 29. One side of the covering as shown in Fig. 28, removed, showing the arrangement of pistil and stamens. Five stamens have ripened and discharged their pollen, five other stamens behind these are growing and crowding the pollen in the apex of the conical covering.

one stigma. A closer study of this covering shows it to be in two parts lightly adhering at a part of their edges in such a way as to make a cone with a minute hole in the apex covering over stigma and anthers of the stamens.

An examination of the growth of the flower in the bud shows that when the conical covering, which, by the way, is formed of two petals, forms, five of the stamens mature in the bud and the pollen comes off, making a mass of it. Then the other five stamens grow and crowd the mass of pollen forward into the cone.

In the meantime the stamens and pistil grow into the curve they present. Two other petals grow around these in the boat-shaped form and conceal them and make the platform for the bee to light upon, and the other petal grows up to be the flag signal to attract the attention of the bee. Now the trap is complete. In many other flowers of much the same form the trap is baited with

nectar. But for some reason the lupine neglects this, but the bees visit it, try for nectar and take the pollen.

If the lupine is not at hand or convenient, there are many other forms of flowers much like it which are similar traps, altho they may differ in some points, such as having nectar, or in protruding the stamens with the pollen instead of pushing the pollen out of a cone and in other ways. Such flowers are those of the locust tree, peas, beans, clovers of the various kinds, plants belonging to the family known as the *Leguminosæ*, a very numerous family. One rather common member is excellent for observation. This is the "broom" and is cultivated for its showy orange yellow bloom.

The detail given above in the study of a lupine seems, on reading it, to be too difficult for younger classes. But it will not be found so in the actual work. Of course it will take some care and time, but it will be done with enthusiasm, and when it is thus well done it gives the class a clearer insight into this bit of nature and a drill in finding out her ways that are vastly more valuable

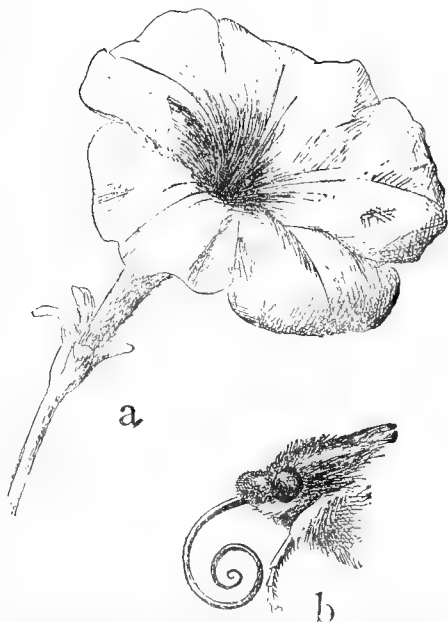


Fig. 30. (a) A flower of the Petunia, showing its funnel-shaped corolla ending in a long tube, at the bottom of which is the nectar, (b) head of a sphinx moth, which sometimes visits the Petunia. Its tongue is partly uncoiled. This it straightens out and inserts into the long tube of the flower.

than simply seeing bees visit flowers and go away with pollen. The pupil has seen the real secret of the showy flowers. They furnish food for insects, nectar and pollen, to entice them to visit them; they furnish colored signals in the corolla to enable the insect to find them by sight, and perfumes to help them by smell, and then arrange some kind of a trap, sometimes elaborate, sometimes very simple, which requires the insect to pass over the pollen and stigma, so that the pollen of one plant is brought to the stigma of the other by the insect's body.

With this lesson well seen there are numberless others possible that can follow in the same lines. Every form of flower may be subjected to inquiry as to how it makes use of insects, and what insects it makes use of. For example, flowers like the petunia, with the corolla formed into a funnel with a long narrow tube with the nectar at the bottom, can not depend on bees, as they can not reach the nectar. Let the class find by their own work what insects it does depend upon. The sphinx moth often visits it. This moth has a long tongue, which it usually keeps coiled up under its head. This it uncoils and thrusts down into the tubes of the corolla.

This will lead to the study of the structure and ways of many insects, for they are adapted to the flower as is the flower to them. For example, not only the lupine and its contrivances may be made the subject of study, but the bee and its contrivances. When she gathers pollen from the plant, let the pupil determine how she disposes of it. The bee can be seen to scrape the pollen off and pack it into a lump on the part of her hindermost leg called the "basket." If one of the hind legs of a bee is examined it will be found that the division of the leg on which she carries the pollen is covered with a number of hairs, which holds the pollen she packs there. The next division of the leg below the pollen basket is covered with rows of stiff hairs and is used as a brush to sweep off the pollen. Other kinds of bees have hair brushes on the abdomen which they use for carrying pollen.

While colored and perfumed flowers look to insects and some birds for fertilization, that is, to animals which see and smell, there are many plants which depend upon another agent altogether, the wind. Such are the grasses, wheat, corn, rye, oats and the many forms of wild grasses. The inconspicuous odorless flowers of these may be examined, and it may be seen how their pollen is adapted to be borne on the wind, and how, to provide against the small chance of a single grain of pollen meeting the stigma, immense quantities of pollen are sometimes formed.

Besides these plants there are the pines, spruces, cypress and the like, the Conifers, usually not regarded as having flowers, which produce immense quantities of pollen in the small pollen bearing flowers, as they should be called. Some of the pollen finds its way to the young cones and fertilizes the parts which are to become the seeds. They use the wind to carry the pollen.

The fertilization of plants by insects has an interest from its relation to the farmer. All the fruit trees depend largely on the insects, principally bees, for the fertilization of the flowers. While the peach, prune, apple, apricot and cherry may have some of their flowers manage to become fertilized without the aid of insects, still, careful experimenting has shown that only a small per cent. of the fruit will "set" unless insects have free access to them. Many who have not understood the habits of bees have accused them of doing harm to both the blossom and the fruit. There is no flower that the honey bee harms. On the contrary, as has been seen, she is essential to many of them. Extensive experimenting has shown that the honey bee never bites into fruit

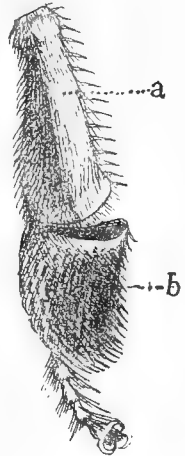


Fig. 31. The pollen-collecting apparatus of the honey bee, joints of the hind leg, (a) smooth surface of tibia bounded by margins of stiff hairs constituting the "pollen basket," (b) upper part of tarsus covered with rows of stiff hairs. This is the pollen-brush.

of any kind. When a wasp or other insect has broken the skin of a fruit the bee may suck the juices from the wound. Worse than this she never does. When fruit is cut and put upon the trays the bees annoy by visiting it and sucking up the juices while it is still moist. But they do not bite into it and they cease their visits when it is too dry to furnish juices. The bee being such an important instrument in forming the fruit ought to have some consideration in its final disposal. Many orchardists recognize the importance of bees in their success and provide bees to fertilize the flowers of their trees so that an abundance of fruit may set. All of the melon family—watermelons, muskmelons, squashes, cucumbers and pumpkins—depend wholly on insects for fertilization, since the stamens and pistils are borne in separate flowers. Those who, in the eastern States, raise cucumbers for the market very early in the Spring in greenhouses, have had to put bees into the greenhouses, or make the rounds of the flowers themselves and dust the stigmas with pollen. Where melons have been raised on a large scale in a country where bees are not common, the melon producers keep large numbers of colonies of bees. Buckwheat depends upon bees. All have heard that, when red clover was introduced into Australia, it was found necessary to introduce bumble-bees also, to raise seed from the clover. Honey bees' tongues are too short to reach the nectar in the red clover, but in most other clovers they find it well enough, the white clover and alfalfa being noted honey plants in the regions in which they flourish.

SOME WATER INSECTS.

We may roughly divide water insects, from our point of view, into two groups, (a) insects which live in running water, in brooks, and (b) insects which live in quiet or stagnant water, in ponds. We may observe water insects in their homes, i. e., in the brook and in the pond, and we may bring them alive into the school-room and watch them there. To do this we need aquaria. To keep the brook insects alive long enough to observe their habits and transformations we shall require a running water aquarium, which only a few school-rooms are in position to have. But the quiet or stagnant water aquarium can be easily made and maintained in any school-room. (For directions for making and caring for aquaria, see the earlier lesson on "Rearing Insects.") Our observation of water insects may be divided into field work and school-room work; that is, observation of insects in the brooks and ponds, and observation of them in the school-room aquaria. Most of the observing of brook insects must be field work; while most of the observing of pond insects can be done in the school-room.

Brook Insects.

YOUNG STONE-FLIES AND MAY-FLIES. Find a place where the brook is shallow and running quickly, and has a stony bottom. Examine the under side of a number of the stones of the bottom and you will almost certainly find on them certain flattened insects from half an inch to an inch in length, which run quickly and attempt to hide in the inequalities of the stone. Note that altho these insects live in the water they do not, like many water animals, have fins, but they have three pairs of legs with which they can either run about on the stones or swim in the

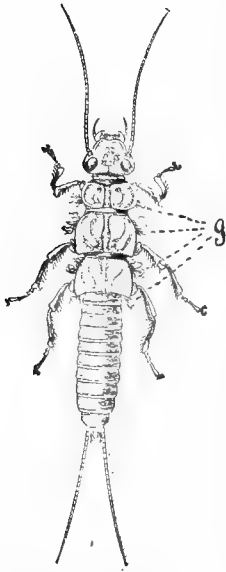


Fig. 32. Young Stone-fly; *g*, gills.

water. These insects are either young stone-flies (fig. 32) or young May-flies (fig. 33). The young stone-flies have two tiny claws on their feet (examine with a magnifier) and are usually more flattened and broader-bodied than the young May-flies, whose feet end in a single small claw. Take some of these insects alive to the school-room, where they can be kept in

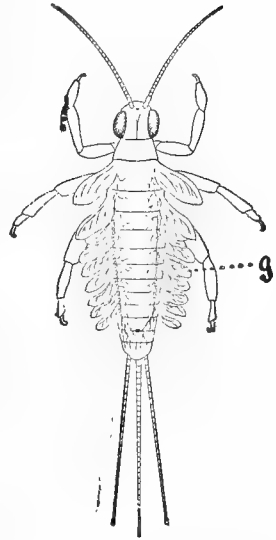


Fig. 33. Young May fly; *g*, gills

a glass jar of water for a day or two. Put one of them into a watch glass of water, and examine it with a magnifier. Is it a young stone-fly (two claws on feet) or a young May-fly (one claw on feet?) Examine the delicate gills projecting from the sides of the body: the young stone-flies usually have three pairs of gills on the thorax (part of the insect from which the legs arise), which are tufts of short gill-hairs; the young May-flies usually have gills all along the abdomen, which may be transparent thin plates, or composed of gill hairs. (For an account of the way in which water insects breathe, and of the tracheal gills, see the lesson, "How Insects Breathe.") Note that the legs of the young stone-fly are flattened and thickly fringed with stout hairs. What for? So that the legs may serve for swimming as well as

for running. Note the long filaments projecting backward from the posterior tip of the body. Those of the young May-flies are usually three in number and fringed with hairs. They aid in the locomotion of the insect. Those of the stone-fly are usually two in number, and their use is not known. Some kinds of young May-flies live in ponds.

I have been careful to speak of these insects always as young stone-flies and young May-flies. For they are stone-flies and May-flies in their immature, or so-called nymphal condition. The

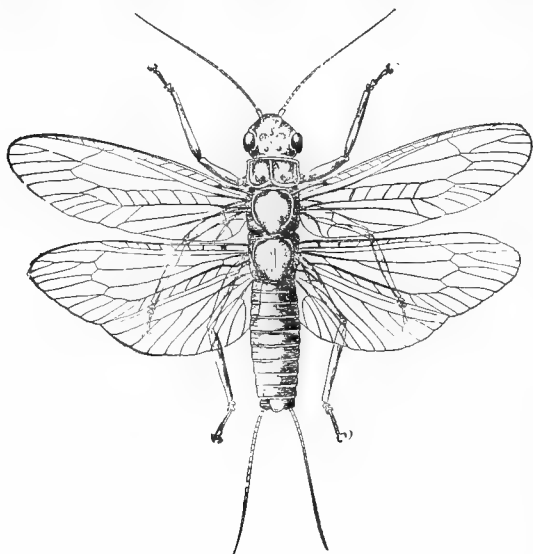


Fig. 34. A Stone fly.

adult stone-flies (fig. 34) and May-flies (fig. 35) are winged insects which live in the air, and have a very different appearance and very different habits from the young. It is possible that you may be fortunate enough to obtain some of the winged adults from the young which you carry

into the school room aquaria. If you can find some young May-flies in a pond, so that you can keep them alive in the permanent quiet water aquarium, your chances for seeing the issuance are very much better. There is a certain kind of May-fly whose young I have found abundant in watering troughs in September

and October (near Stanford University) and winged adults of which were issuing constantly thru those months. The young May-flies live for many months, some species for one or two or even three years, in the water. The life of the adult is, on the contrary, at longest, not more than a few days, and some kinds live in the winged condition for but a few hours. The stone-flies do not spend so much time in the water, nor die so soon after acquiring wings.

CADDICE-WORMS—Firmly attached to stones, especially large ones, in swift parts of the stream, may be found small cases (fig. 36 *b*) or houses composed of many small pebbles fastened together with silk. In more quiet places in the stream may be found either attached to stones or resting on the bottom, or sometimes floating in the water,

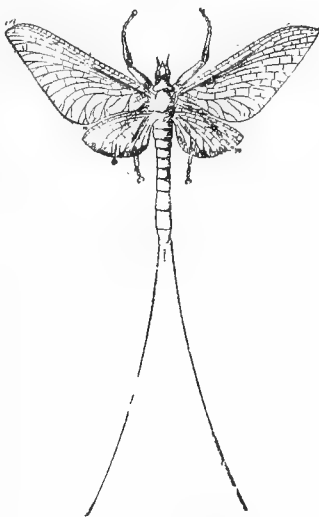


Fig. 35. A May-fly.

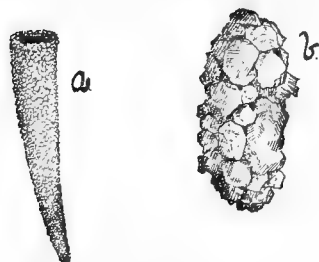


Fig. 36. Caddice-fly cases made of sand (*a*), and pebbles (*b*).

elongate cases (Fig. 37), an inch to two inches long, made of bits of wood fastened together with silk or bits of pine needles or even grass stems tied cleverly together by silken threads. Or tiny cornucopias (fig. 36 *a*) composed of sand grains, may be found. All these are the cases of the caddice-worms or case-worms, and the caddice worm itself may be found snugly concealed in its case.

Find and collect as many different kinds of caddice-worms cases as you

can; find cases with the head and fore part of the body of the worm projecting; find cases moving, i. e., dragged by the slowly walking caddis-worm. Examine a caddis-worm carefully; note its long, soft, grub-like body; note that the head and the front part of the body from which arise the legs, namely, that part of the body which projects from the case, has a strong, hard outer wall.



What is the case for? To protect the soft, defenseless caddis-worm

Fig. 37. Young Caddis-fly in its case made of pebbles and bits of wood.

from the many predaceous animals which live in the brook. Why is the head and front part of the body so much **harder** than the rest of the body? Can you easily pull the caddis-worm out of its case? How does it hold itself so firmly in its case? By the pair of strong hooks (legs) which are located on the posterior tip of the body. Note that the front pair of legs (how many pairs are there?) are longer than one would expect to find on such a worm-like insect; what is the reason for this condition of the legs? How does the caddis-worm breathe?

Not all of the caddis-worms live in cases, and some which make cases do not remain in them all of the time, so that you may sometimes find caddis-worms crawling about on the stones. Some of these home-leaving caddis-worms make tiny nets of silk stretched between two near-by stones. These nets are "usually funnel-shaped, opening up-stream and in the center of them there is a portion composed of threads of silk extending in two directions at right angles to each other, so as to form meshes of surprising regularity. It is as if a spider had stretched a small web in the water where the current is swiftest." The caddis-worms which build these nets live in rude cases on the under side of stones. The cases are composed of an inner silken tube partly covered with little pebbles.

All these caddis-worms are the young, or larvæ, of caddis-

flies (fig. 38), moth-like flying insects, with four wings covered with hairs, among which are distributed many flattened scale-like hairs. The antennæ are very long and thread-like and the insects may be found fluttering among the foliage or alight upon it, at the brook's margin.



Fig. 38. A Caddice-fly.

Collect and put into the school-room aquarium a number of those caddis worms (in their cases) which you find in the quiet places of the brook. These may live in the aquarium and an opportunity thus had to observe their habits more closely and also, perhaps, to observe the manner of their transformation into winged adults. The caddis worm or young caddis-fly does not transform directly into the winged form as does the young stone-fly or May-fly. When ready to transform it closes the opening of the case by spinning a silken sheet across it or filling it with a stone. The opening is not absolutely closed, but space is left for the ingress of water which carries oxygen to the insect within. Thus enclosed, the caddis worm changes to a pupa, that is, to a stage in which the insect lies quiescent, taking no food, while it is undergoing the great structural changes necessary for the development of the caddis-fly from the caddis worm. The occurrence of this change to a pupa (pupation, the changing is called) can be recognized by noticing the closed-up condition of the case. Such closed cases may be found in the brook, and perhaps in the aquarium. Open one of these closed cases and examine the pupal caddis-fly within. Note how the legs and the developing wings of the caddis-fly are folded against the body. Can you find any tracheal gills on the pupa? Can the pupa move? It can only wriggle a little. This wriggling or bending of the body is necessary to keep going some sort of a current of

water, so that oxygen may be brought in and the exhaled carbonic acid gas carried away.

OTHER BROOK INSECTS.—The young stone-flies, May-flies and caddice-flies are the insects of the brook most certainly and easily found. On the surface of quiet pools may be seen water-striders and whirligig beetles, but these may more certainly be found on ponds, and are described among the "pond insects."

You may find, perhaps, clinging to the rock-bed of the stream where the water is shallow but flowing swiftly, many small black worm-like animals (fig. 39, *a*) holding firmly to the rock

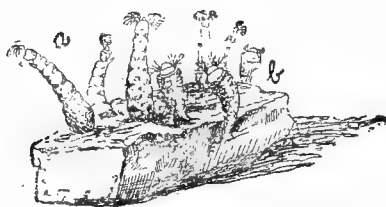


Fig. 39. Larvæ (*a*) and pupæ (*b*) of the Black-fly.

by one end while the rest of the body stands nearly upright in the water waving about as the swiftly running water strikes it. These are the young or larvæ, of the black fly, a small jet black, hump-backed, two-winged fly (fig. 40).

The black-fly is a biting fly of more vicious disposition and more effective biting ability than the mosquito. Take some of these squirming black larvæ to the school-room and examine them in a watch-glass of water with a magnifier. (They cannot be kept alive long in quiet water). Note the odd shape of the body. Note the sucker at the posterior end of the body, by which the larvæ holds fast to the rock despite the swift current. Note the two fan-shaped organs attached to the head, which are composed each of fifty hairs rising from a short, stout process; these organs are waved about in the water, sweeping microscopic water organisms into the mouth. You may find among these black-fly larvæ a number of odd little cornucopias (fig. 39, *b*), fastened to the rock by their lower end. From the upper end of each cornucopia a pair of tiny tufts of short filaments (tracheal

gills) project, and wave gently in the water. These cornucopias are the pupæ of the black-flies; that is, the black larvæ transform into these cornucopias, and from the cornucopias finally come the winged black-flies. If there are no pupæ among the black-fly larvæ when you first find the colony, return occasionally to the spot and you will certainly find pupæ in time.



Fig. 40. A Black-fly

Pond Insects.

Certain pond insects are found swimming or running on the surface of the water, others swimming in the water, and still others live habitually crawling or slowly swimming over and thru the soft mud and organic detritus at the bottom of the pool or pond.

WATER-STRIDERS AND WHIRLIGIG BEETLES.—Running quickly about on the surface of almost any pond or quiet brook pool, may be seen numerous rather large, blackish, narrow-bodied long-legged insects (fig. 41), the water-striders, or pond skaters, as they are sometimes called.

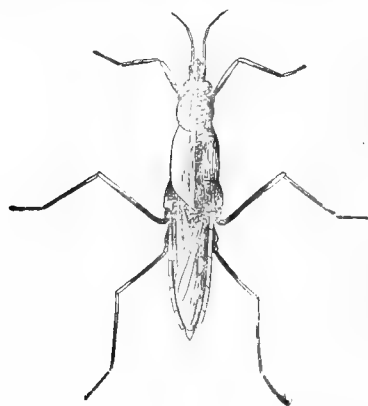


Fig. 41. A Water-strider (*Hygrotrechus*.)

The water-striders run or leap quickly over the water's surface when disturbed; when at rest they have the two hinder pairs of long, thread-like legs outstretched, while the front pair of shorter, stouter legs is held projecting forwards close to the head, ready for grasping and holding smaller insects which are the prey of the water-striders.

For these insects are predaceous, living on the blood of other insects which come up from below to breathe, or the flying insects which may happen to fall into the pool.

The water-striders may be observed on the surface of their own pool, or they may be brought to the school-room and readily kept and watched in the quiet water aquarium. (A glass jar half filled with water.) A few house flies or other non-swimming insects should be thrown on the water to serve as food for the water-striders. The surface of the water should not be too near the

top of the aquarium, for the water-striders can leap several inches, and might thus escape.

Observe the character and disposition of the different pairs of legs of the water-striders. Note their use in running and grasping their prey. Are the legs of the water-strider thrust into the water? No, they rest on top of the water, the whole weight of the insect being supported by the tense surface film (see the lesson on the mosquito). Note the "dimples" or depressions in this film where the feet press it down. Are the water-striders winged or wingless? They may be, strangely enough, either winged or wingless; that is, there are two kinds of individuals of water-striders. In addition to the elongate narrow-bodied forms you may see some individuals with shorter, broader bodies, either entirely without wings or with short wing-pads or growing wings. These are simply the young or immature water-striders. Examine one of the insects closely, using, if necessary, the magnifier. Note the slender, sharp-pointed, little beak which projects from the head. Note the black bead-like eyes. The under side of the body is covered with a fine pile or pubescence. If you hold the water-strider in the water (underneath the surface) the underside of the body will be silvery white, showing that a film of air is held entangled in the pubescence, and preventing the wetting of the body. When you let loose of the insect it will rise immediately to the surface, and run about as usual, having not been wetted by its submersion in the water.



Fig. 42. Whirligig-beetle (*Gyrinus*).

The whirligig beetles (fig. 42) are, like the water-striders, surface insects; they are to be found in the same places with the water-striders. These whirligig beetles are small (usually about one-third of an inch long), oval or elliptical, flattened, shining black insects, which dart swiftly about in curving paths on the water. They may readily be kept in the school-room aquarium. Do they

run and leap as the water-striders do, or swim? Unlike the water-striders also, they occasionally dive and swim beneath the surface. How do they breathe? Note the little silvery bubble almost always visible at the posterior tip of the body when the beetle is swimming underneath the surface. Examine one of the insects closely, using a magnifier. Note that it has four eyes, one pair on the lower surface of the head, just underneath the pair on the upper surface. Note also the peculiar shape of the legs, the front pair being rather slender and oar-like, while the hinder two pairs are short, broad and paddle-like; all are, however, adapted for swimming.

In addition to the water-striders and whirligig beetles, numerous other smaller insects may be found on the surface of pools and ponds. Many small two-winged flies run about on the surface in search of food, and certain small sucking bugs may often be found running about on the wet shores of the pond or upon the water near the edge.

WATER-BUGS AND WATER-BEETLES.—In the pools on the surface of which the water-striders and whirligig beetles are found, may be found certain insects which swim vigorously about in the water, coming occasionally to the surface and resting there a short time. These are the water-bugs

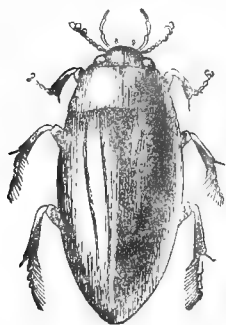


Fig. 43. Water-scavenger beetle (*Hydrophilus*).

and water-beetles. The water-beetles (fig. 43) are large, shining black, elliptical insects from half an inch to an inch and a half long; the water-bugs (figs. 44 and 45) are smaller, being less than half an inch long, and they are gray in general color instead of black. Each of these water-bugs and water-beetles has three pairs of legs, of which one pair is usually especially long and flattened, so as to be oar-like. They have wings, which are kept closely

folded on the back while the insect is in the water. With a water net collect a number of both the larger black insects (the water-beetles) and the smaller gray insects (the water-bugs) and put them into glass jars of water in the school-room.

Watch the big black beetles first. There are two kinds, both looking much alike, but differing in their food habits. One kind, the "predaceous diving-beetles," kill and eat other water insects; while the other kind, the "water-scavenger beetles" (fig. 43), feed on decaying vegetation (tho they occasionally attack other insects). Try to observe the feeding of the beetles in the aquarium. Observe the position of the body, when one of the beetles is at rest, just underneath the surface. If the beetle hangs head downward with the tip of the abdomen at the surface, it is one of the predaceous diving-beetles; but if the head end of the body is kept at the surface, it is one of the water-scavenger beetles.

When the beetles are resting at the surface they are breathing, or rather they are collecting air which they breathe after they sink beneath the surface. The water-beetles do not remain at the surface most of the time as the mosquito wrigglers do, nor do they remain underneath the surface all the time as the young May-flies do. They do not have to come to the surface every time they wish to breathe but they have no gills to enable them to take up the air which is mixed with water. The way in which they solve the problem of breathing under water is this: they come to the surface occasionally and collect a supply of air which they take down with them. The two kinds of beetles do this in different ways. The predaceous diving-beetles force the posterior tip of the body above the surface and slightly lift the tips of the horny black wing-covers which lie on the back. Air rushes in under these wing-covers and is held there by the closing of the tips. This process can be readily observed. The breathing pores or spiracles of the beetle are situated along each side of its back underneath the wing-covers so that the air held under the wing-

covers readily finds its way into the beetle's body. The water-scavenger beetle carries most of its air supply on its under or ventral surface, where it is held in a lot of fine short hairs. The air gives the under side of the beetle a shining silvery appearance. The air is held by the fine hairs by virtue of the surface film. If you dip a bit of cloth having a pile, as velvet, into water, you will see that it retains underneath the water a nearly complete coating of air. The under side of the water-scavenger beetle is covered in places with a fine pubescence which acts as the pile of the velvet does.

Kill one of the beetles and examine it. How many wings has it? Note that the hind wings, which are larger than the front wings and are thin and membraneous, are folded both longitudinally and transversely underneath the stiff, horny fore wings. The hind wings are the true flying wings, the fore wings being chiefly used as a firm protecting covering for the hind wings when the beetle is in the water. Altho the water-beetles live naturally in water, they are provided with wings with which they are enabled to escape from a drying pond or from a pond which becomes over stocked with their kind.

There are two kinds of water-bugs as well as two kinds of water-beetles. Some of the bugs swim with back downward, i. e., upside down, and are called back-swimmers; the others swim in normal position with back uppermost and are called water-boatmen. The two kinds differ, also, in their markings, the water-boatmen (fig. 45), having the back greenish gray with a fine black mottling,

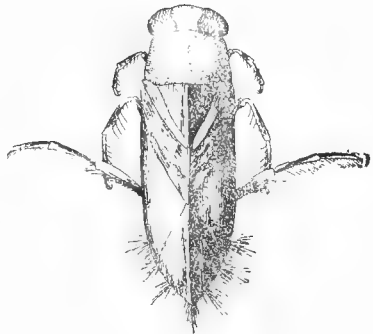


Fig. 44. A Back-swimmer (*Notonecta*).

while the back-swimmers (fig. 44) have the back bluish black with large creamy white patches. Both kinds come to the surface to get air, the water-boatmen very much more rarely than the back-swimmers. The water-bugs, like the water-beetles, carry down with them into the water a supply of air held on the outside of the body. The air clings to a large part of the body lying both under the folded wings and on the exposed surface of the body. Note the difference in the disposition of the air in the two kinds of bugs. Is there a difference in their weight as compared with the weight of water? What part of the body projects above the surface when the bug comes up for air? Note the customary position of the body and legs as one of the back-swimmers lies at rest just underneath the surface with the tip of the abdomen projecting very slightly above it. Which pair of legs is the rowing pair? Throw some non-swimming insects, as house-flies, into the water and observe the actions of the back-swimmers with regard to them. Kill a few back-swimmers in the cyanide bottle and examine them. Note, that altho they are aquatic insects, they

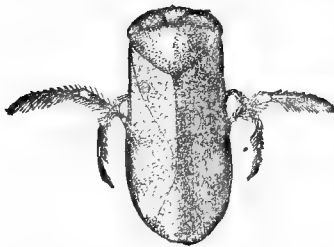


Fig. 45. A Water-boatman (*Corisa*).

have wings; they are thus able to fly from pond to pond. Note the oar-like character of the swimming legs; note their broad fringes of hair. Note the sharp-pointed strong beak which the back-swimmer thrusts into the bodies of its prey, and thru which the blood of the captured insect is sucked. Care must be exer-

cised in handling live back-swimmers, as they can inflict a painful sting with the sharp beak.

Note that the water-boatmen keep usually to the bottom of the aquarium, coming only rarely to the surface for air. Note their favorite resting position. In what way does this differ from

that of the back-swimmers? Note that the long oar-like legs are the hind-most pair, not the middle pair, as in the case of the back-swimmer. The water-boatmen, like the back-swimmers, suck the blood of other insects by means of a beak, and have wings.

A third kind of water bug may often be found resting or crawling at the bottom of ponds. These are the giant water-bugs, some kinds of which are really giants among insects. The larger ones, the true giant water-bugs, are readily recognizable by their size, their bodies being an inch wide and two and a half inches long. They are not black like the great water-beetles but a dingy brownish gray. Their fore legs are fitted for grasping and they have a short, sharp beak projecting from the under side of the head. Some of the members

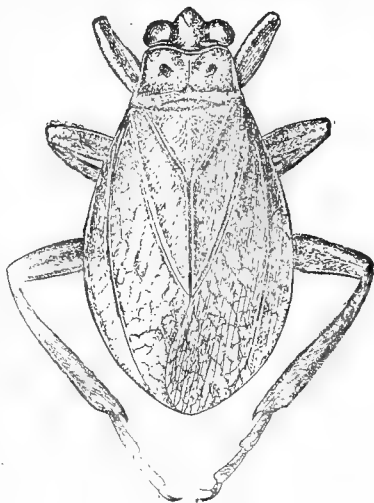


Fig. 46. A Giant Water-bug (*Serpheus*).

of the giant water-bug family are smaller, a kind common in California, being about an inch and a half long and about half as wide (fig. 46). If you can find one of these giant water-bugs put it into the aquarium and observe its manner of hiding. It keeps itself concealed as well as possible under the stones at the bottom. It is a blood-thirsty creature feeding, like the other water-bugs, on the blood of other insects. The giant water-bugs are so strong that they often seize and kill young fish.

YOUNG DRAGON FLIES.—Drag out with a rake some of the decaying vegetation and muddy detritus from the bottom of a stagnant pond, and you will almost certainly find in the slimy

mass a number of curious creatures of the appearance shown in figure 47 or figure 48. These are young dragon-flies and can be unmistakably known by the peculiar, folded, broad flat under-lip which covers mask-like the whole of the under side of the head,

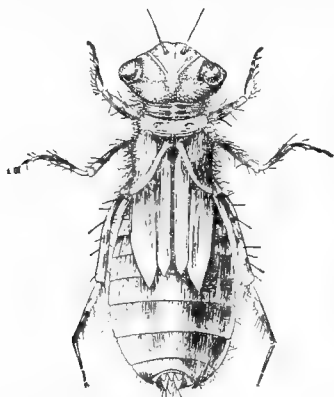


Fig. 47. Young Dragon-fly; short, thick-bodied kind.

(fig. 49). This lower lip can be unfolded and projected some distance in front of the head (fig. 50). Some of these young dragon-flies live on the very bottom of the pond crawling about in the mud and decaying vegetable matter while others cling to the stems of the water plants, some distance above the bottom. The young dragon-flies vary considerably in appearance, but there are two principal groups into which they may be divided. First, stout-bodied, usually rather short ones (fig. 47); and second, long slender-bodied ones with three usually long, blade-like flaps projecting backward from the posterior tip of the body (fig. 48.). Collect some of both kinds and carry them, in a jar of water, to the school-room. Here they may be kept alive in the still water aquarium, and their feeding habits, and perhaps their transformation into adult, winged dragon-flies, observed. Kill one or two of each kind in the cyanide bottle, and examine the bodies. On the back may readily be seen the growing wings. With a pair of forceps or a pin, unfold the hinged lower-lip and note that its broad tip is composed of two jaw-like flaps, each fringed on its inner margin with fine teeth. Examine the hinge, and note how far this grasping lower-lip is folded.

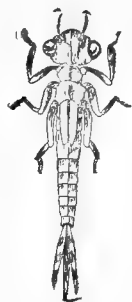


Fig. 48. Young Dragon-fly; slender-bodied kind.

Examine, also, the thin flat blade or oar-like processes at the posterior extremity of the slender-bodied young dragon-flies. These are tracheal gills for breathing, and with a magnifier the fine dark branching air-tubes (tracheæ) can be seen in them.



Fig. 49. Young Dragon-fly; front view showing face covered by the folded under-lip.

Observe now the young dragon-flies in the aquarium. If there are some soft-bodied insects in the water, you will not have to watch long before you can see the grasping lower-lip at work. As an unsuspecting insect swims by the masked face of the young dragon-fly, like a flash the lower lip darts forward and those two fine-toothed grasping flaps at the tip seize the insect, and carry it, as the lip folds up again, to the strong jaws of the captor. The young dragon-flies are very voracious, and they will soon capture and eat most of the other soft bodied insects in the aquarium.

The eggs of the dragon-flies are either dropped into the water by the females which fly about over the pond, or are placed in slits cut into the stems of water plants. The young dragon-flies live for from a few months to nearly a year, gradually growing larger, and the wings slowly developing. When ready to transform, the young dragon-fly crawls up on the stem of some water plant or projecting stick or stone, out of the water; the skin breaks along the back, and slowly the winged dragon-fly issues. This transformation takes place usually in the early morning hours, and this cannot be conveniently observed by the class. If you bring into the aquarium, however, a number of young dragon-flies at the time of year (the late spring and early summer) when they are transforming, the process may be observed in the school-room.



Fig. 50. Head of young dragon-fly; the seizing lower lip stretched out.

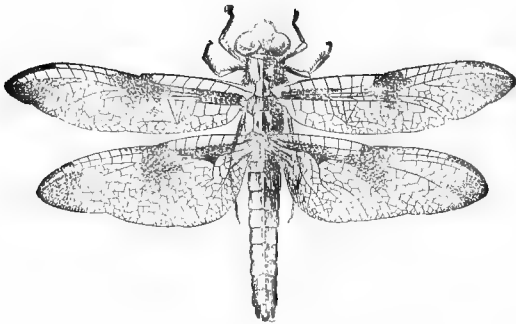


Fig. 51. Dragon-fly; broad-winged kind.

It will be interesting to have the class observe the behavior of the adult dragon-flies. They may be found flying swiftly about over the surface or along the banks of ponds, and along the shores of quiet streams. The dra-

gon-flies are among insects like the hawks among birds. They capture in the air other smaller insects and eat them.

“While one is standing by the pond, let him follow awhile the actions of a dragon-fly that is making short dashes in different directions close to the bank. Let him fix his eye on a little fly hovering in the air, and note that after the dragon-fly has made a dart toward it, it is gone. Let him repeat the observation as the dragon-fly goes darting hither and thither. It will be hard to see the flies captured, so quickly it is done, but one can see that the place that once knew them

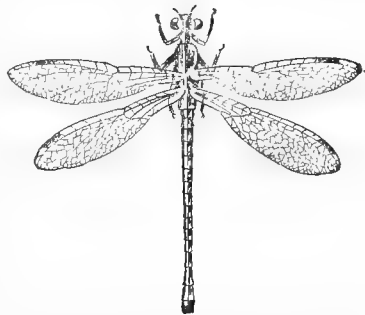


Fig. 52. Dragon-fly; narrow-winged kind, sometimes called damsel-fly.

knows them no more.” The flying dragon-flies are of different kinds, but like the young dragon-flies can all be roughly classed in two groups; the large dragon-flies (fig. 51) with heavy bodies, and with rather broad wings, the hind wings being broader than the fore wings, and smaller dragon-flies (fig. 52) (or

damsel-flies, as this kind is sometimes called) with slender bodies, and narrow wings, the fore and hind wings being equal. The first kind are the adults of the short, stout-bodied young, and the second kind, or damsel-flies, are the adults of the elongate, slender-bodied young.

HEAT.

With this subject will be introduced a series of lessons on some of the most common phenomena of air, water and soils. It seems more generally thought that plants and animals furnish the best material for nature study lessons. On this account it is not out of place to point out here that certain excellent advantages possessed by non-living phenomena have been overlooked, and consequently some of the best material for this work has been widely neglected.

In the first place it is usually supposed that children have a more vivid interest in plants and animals than in things without life. This is apparently true, but their interest has arisen from the conspicuousness of the plants and animals, especially the latter. They are constantly disporting themselves before them. Then their kinship in the possessing of life, and their sympathy in the organisms exhibiting that life is keen and peculiar, and cannot be replaced by any other forms of interest. Still this interest may be strong, and may even be strengthened with but little advance in the study of nature. The animal and plant constitute little as educational material if they simply appeal to the emotions. We must make use of those phenomena for this work which allow the seeing of facts and the drawing of conclusions from them; for example, the adaptations of the plant or animal to its surroundings, or the contrivances it has for doing those things which make up its daily life. In other words, we are to seek explanations of the organism. Since the life of the animal or plant is very complex, it naturally follows that the number of phenomena in the life of any plant or animal which can be fairly isolated, and whose explanation is fairly within the powers of the child are comparatively few. We are then led into temptation in two directions: either we pass over into the region which requires more power of analysis and of generalization than the child possesses,

as in the more difficult matters of structure and of function, or we take up that which has no significance at this stage, such as the number and names of the parts of an insect's leg, or the technical names of the shapes of leaves. In either case the work in nature study will be a failure, and is to be classed with other meaningless work that children are called on to memorize.

Now, among the phenomena of the world of non-living things, there are a number which are simple enough to be readily grasped by school children. They are of intense interest to them when once seen. Their lack of initiative interest in them is easily accounted for by their ignorance of their existence. The peculiar nature of many of these phenomena allow them to be fairly well isolated, so that they can be studied without involving, at the time, confusing relations. The experiments can be repeated as often as necessary to allow better seeing to correct errors in observation and conclusion. The materials are always available and the success of the experiment does not depend on time and place, but may be completely under the control of the one making it. Thus they give the means of that most excellent drill involved in planning and executing an experiment which is a real inquiry of nature.

The value of the information received from lessons on the common physical phenomena is certainly second to none other of the school course, since it deals with such important matters as air, water and soil.

Many of these lessons, beside forming a part of the nature study course, may well take their place in the work of geography. There are many subjects touched upon in the usual courses in geography, which would have more meaning if the phenomena on which their explanation depends were experimentally studied by the classes. Among such subjects are rain, frost, ice, winds, storms, electricity, magnetism, and means for measuring time. There are many experiments which would throw much light on

these larger phenomena, which can be performed in the school room with small trouble, very simple apparatus, and without the requisite of a technical training in physics and chemistry.

The lessons that follow must necessarily be limited in number, and are chosen to illustrate the kind of material that is open to us. As in other portions of this series of papers, the subjects treated are to be regarded as representative of a rich field, from which the nature study teacher is privileged to draw. Those here selected are arranged so that they lead to a general progress into larger phenomena and wider generalizations, still within the limit of children of school age. This is not to be regarded as an attempt at teaching the science of physics in the lower grades.

The following subjects experimentally treated, beside being most excellent material for drill in what nature study is to give, will also furnish a good basis for understanding much about heat, air and water, and the large part played by these agencies in the form and structure of the earth's surface. We will begin this series with some simple lessons on heat.

Heat Expands Water.

Fill a flask or a bottle with water. Such a flask as given in the figure is of a kind of glass that can be heated without danger of breaking. Close it with a cork thru which a glass tube passes. A short tube will answer, but if two or three feet long it will be better.

To start with, have sufficient water in the flask to extend up into the tube two or three inches. Be sure to have no air bubbles in with the water. Allow members of the class to fill and arrange the apparatus. Let all see clearly just how everything is arranged.

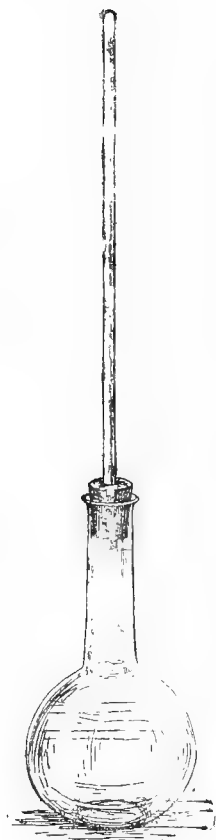


Fig. 53 Expansion of water by heat.

Place the flask on the stove, or over an alcohol lamp, and have the class observe the result, and, if they can do so, explain why the water rises. If the simple explanation that the heat makes the water larger (expands it), is not given, do not give it but allow them more time to think on the matter. If wrong explanations are offered do not immediately reject them, but ask for proofs or devise experiments which disprove the offered explanation. For example, if a child insists that the water rises in the tube "because heated water is lighter and goes up," place the apparatus so that it extends in a horizontal position, and repeat the experiment. The above may occupy the time of more than one lesson. It ought not to be hurriedly passed over. In subsequent lessons it may be proposed to experiment with other liquids. Allow the children to select the liquids, arrange the apparatus, and try the experiments as far as possible. The effect of cold may be studied also.

When a few liquids are thus experimented with and comparisons made between them, the thermometer may be introduced. It is to be seen as a small flask filled with mercury, or with colored alcohol.

A number of simple experiments can be devised with the thermometer which will make clear its use in determining the temperature of things.

In all experiments give as much chance as possible for each

one to express his individual opinion, and to ask his own questions. Do not by your conduct with the class put a premium so much on any kind of answers, even bright ones, as on *earnest* questions and answers. Give all such, even if apparently ignorant and far from right, every consideration. Children, like other people, are sensitive in regard to the respect given to their opinions. Nothing with them is so inimical to the independent formation of opinion as to have their opinions treated with disrespect. If one is wrong, prove that he is wrong, but neither ridicule him nor ride over him. Avoid allowing a few to lead the class and set opinions for the rest.

HEAT EXPANDS AIR—

Use the flask and tube of the experiment of heat expanding water. Have the flask clean and dry. Place the end of the tube under water. Warm

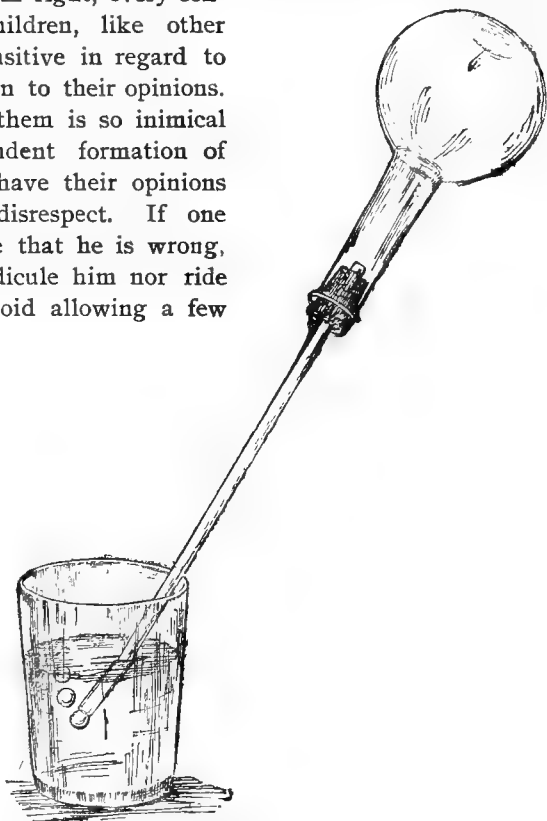


Fig. 54. Expansion of air by heat.

the flask with the flame of the lamp. As the bubbles of air escape have the children observe what happens and explain. Cool the flask. Repeat the experiment several times; or better, allow the children to repeat it.

See how sensitive the air is to even a small amount of heat. Arrange flask and tube so that the mouth of the tube is covered with water, having driven out enough air so that the water will rise well up in the tube. Place the hand or just one or two fingers on the flask and observe the change of volume.

Arrange the flask and tube in a horizontal position. Get a little water in about the middle of the tube. It is better to have it colored with ink or some other coloring matter; this will enable its motions to be more plainly seen. Repeat the experiments with this apparatus. It will be very sensitive to small amounts of heat.

In addition to these experiments, which are to be examined very closely and seen clearly till they are well understood, many other illustrations of the fact that heat expands air may be devised by both the pupils and teacher. For example, a football or a bladder partly blown up, then heated, fills out by expansion of the contained air.

The flask and tube with a paper scale may be used as an air thermometer. For this purpose support the flask so that it stands perpendicularly with the mouth of the tube immersed in water, with the water rising a little way up in the tube. Or support the whole in a horizontal position, putting a drop of liquid in the tube. In the latter case a drop of water can not be used, as it will evaporate. Use a small tube and a drop of strong sulphuric acid or a drop of mercury.

What makes the best thermometer of the substances thus far used? Why? Give time for discussion and comparative experiments.

Heat Expands Solids.

The question may now be asked of the pupils: Does heat expand solids? They will be ready to say that they think that it does, and now comes the opportunity of having them devise a means of proving it. If, unaided, anyone of the class can invent such apparatus the results will be excellent. The following are some simple forms of apparatus used to illustrate expansion of solids. A metal ball just passing through a metal ring at the ordinary temperature of the room will not pass when heated, and will pass more readily when the ring is heated. An iron or other metal bolt nicely fitting into a hole in another piece of metal may be used in the same way. A simple apparatus can be made which will show expansion in rods of various metals, or of various forms such as poker, stove lid, gas pipe, etc. Two heavy blocks of wood are used to support the object. Into the top of one block a nail is driven projecting above the top of the block. One end of the object (iron poker for example) is supported by this block, the end of the poker being pushed firmly against the projecting nail, the other end of the poker is supported by the other block, the end projecting beyond the block. When the poker is heated the strip prevents the expanding poker from pushing in that direction, thus the whole of the movement is shown at the

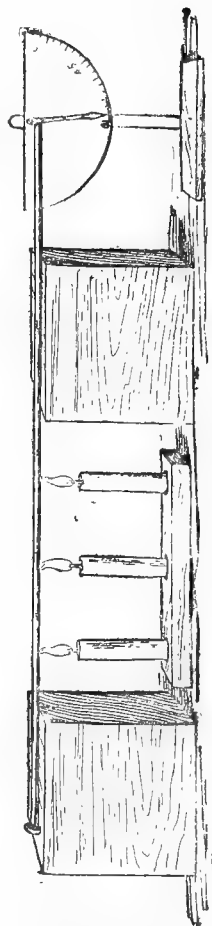


Fig. 55 Apparatus for showing expansion of a metal rod by heat.

free end. As the expansion is very small, it may be made conspicuous by use of an indicator, made as follows: On a small upright support high enough to stand just behind the free end of the poker, place a card with degrees of a circle marked on it. At the center of the circle fasten a pin or small nail on which turns as a pivot a slender strip of wood as a lever. If the short end of the lever is placed against the end of the poker when it expands the long end as a pointer passes over the graduated circle, giving a magnified view of the expansion. If one end of the lever is very short, and the other long, a small amount of expansion may be detected. On this simple apparatus many objects may be tested. The heating may be accomplished by alcohol lamps, or a row of candles.

If two strips of different metals are riveted together, and heated, the unequal expansion of the metals will cause the double strip to bend. Iron and copper are good selections.

Illustrations of effects of expansion of solids may be found if pupils are set to looking out for them.

Currents in Air and Water.

Immediate application of the facts learned in the last lessons on heat in its expansion of both liquids and gases may be made in the study of currents formed in air and in water by heating them. It will be clear to pupils that if a portion of air is heated and by this means is expanded it will be lighter than the surrounding cooler air in which it rests. The same, of course, is true for water. Such a heated mass of air will begin to rise being pushed up by the heavier air as would a cork in water by the heavier water.

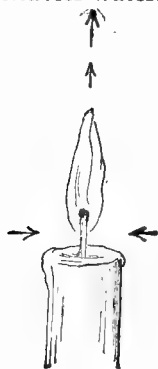


Fig. 56. Currents of air about a candle flame.

There would be, then, two movements in the air, the upward movement of the heated air, and the movement of the surrounding cooler air toward the space below the upward moving portion. These would be the beginning movements but it is plain the disturbances of air thus started would be extended very much. The movements of air are termed currents of air.

Since the transparency of air prevents our detecting currents in it, some means must be sought to make its movements visible. This can be done by blackening it by smoke. For such purpose a substance that will burn continuously with smoke but without flame is desirable. The small sticks sold by the Chinese called by the children "punk" will answer well for this. Excellent "smoke paper" can be made by soaking strips of blotting paper or carpet paper in a solution of saltpetre and then drying them.

With strips of lighted smoke paper have the pupils explore the condition of the air about a candle-flame or about a lighted lamp. Currents of air will be seen rising above the flame and others approaching it from the sides. Care must be taken to have the air as still as possible and it is to be remembered that the heat

from the lighted strip produces currents in the air. This makes it necessary to manage the smoke paper so that the smoke at some distance from the burning part is allowed to fall in the way of the currents to be tested. The condition of the air about a stove, a radiator, or a register is next to be explored. The same tests may be applied to the air about a person sitting quietly in a room. These experiments will reveal the fact that in a closed room where all else is quiet, the air in all parts is in constant motion, the motion being caused by some of it being heated more than the rest.

Next allow the pupils to open the windows at the top and at the bottom and find out at which points the air is entering and at which it is escaping from the room. Various combinations of opening and closing of the different windows may be studied as well as the condition with doors partially or wholly open, also with other openings which may be in the room. These experiences making familiar the movements of air and their cause form a good basis for study of both ventilation of rooms and of means of the greater movements of air outside in the phenomena of winds.

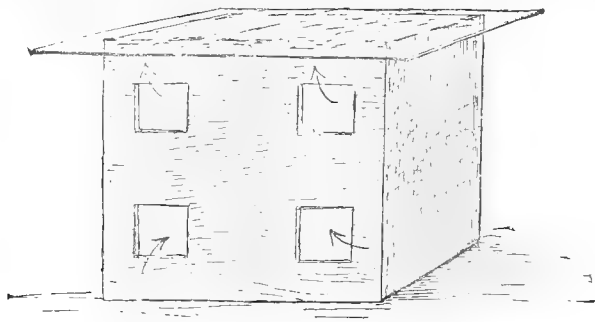


Fig. 57. Ventilation in a miniature room.

Beside the study of a real room in reference to its ventilation, which of course is the best subject, the matter can be further

vividly illustrated by a miniature room formed of a soap box into the sides of which small windows are cut. Short pieces of candles placed on the bottom may be used as the sources of heat. The top of the box is covered with a board, or better, if one wishes to watch the condition of the candles, with a sheet of glass. The windows are closed by pasting paper over them and opened by tearing it away. By opening and closing the windows in different combinations it can be seen under what arrangement the candles burn best. Good ventilation keeps them bright; poor, dims them or puts them out. The smoke paper shows into which windows the air enters and from which it escapes. Some of the pupils may make a more elaborate miniature house into which ventilating flues may be introduced according to some system used which they may have seen placed in some building during its construction.

To show how a heated mass of air may reach a considerable height, a balloon made of tissue paper filled with hot air serves excellently. In the hot air balloon we have, of course, a definitely outlined mass of heated air whose movement and course we may actually watch. Such a balloon can often be purchased at the toy counter, but one made by the school children has more of interest in it. One not less than four feet in diameter will give the greatest satisfaction. The mouth must be pretty wide or it will catch fire in its swaying about. In the school room the balloon may be filled with heated air by holding it over a large lamp. When thus filled it will rise slowly to the ceiling and when cooled will gradually sink to the floor.

Out of doors the heat for filling the balloon is best made by building a fire at the bottom of a joint of stovepipe fixed in an upright position. This will be tall enough to prevent the flames catching the balloon. By this means sufficient heat is furnished to carry the balloon up but a moderate distance. To send it up a good distance a piece of cotton soaked with paraffin suspended

by a fine wire at the mouth of the balloon is lighted. In a town, or in the country during the dry season, this should not be attempted from the danger of fire.

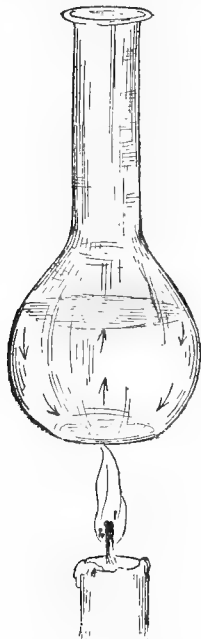


Fig. 58. Currents in water.

The hot air balloon showing a heated mass of air rising to a great height illustrates vividly how larger masses of air lying next the ground, which is heated by the rays of the sun, will become heated and rise.

The cooler air comes rushing in as it pushes the hot air up. The balloon may be made to illustrate this last point also. In the school room when the balloon is well filled with hot air, quickly turn it upside down and observe the sudden rush of hot air up out of its mouth and the equally sudden crushing together of the sides of the balloon made by the cooler air rushing toward it.

Currents in Water.

Fill a glass flask about two-thirds full of water into which there has been sprinkled some fine chalk dust that will show any movements in the water. Place the flame of a candle or alcohol lamp under the flask. Immediately currents of water will start from the bottom to the top, and down the sides to the bottom. As these are caused in the same way in which the currents in the air take place, their explanation can easily be arrived at. If a glass jar of water, the larger the better, has sprinkled over its surface some fine dust of an aniline dye, the particles of the dye as they sink and dissolve make delicate colored threads in the water. By heating either the sides or bottom of the jar ever so slightly currents are formed as shown in the swaying of the colored threads.

Evaporation.

A lesson on evaporation could begin as follows: On a sheet of clean glass place a drop each of: water, gasoline, alcohol and glycerine or molasses, and have the children watch the result. The gasoline soon disappears, later the alcohol, the water much more slowly, while the glycerine persists indefinitely. Questioning and study of this will bring out clearly the fact of evaporation before the class and something of its nature and how different liquids behave in this respect. Place a few drops of gasoline at the bottom of a glass tumbler closed with a covering. The gasoline disappears from the bottom. It can not escape and thus it is seen that the vapor must be transparent like the air with which it is mingled. A lighted match placed at the mouth of the tumbler proves the presence of the vapor of gasoline by the slight explosion and burning.

Bisulphide of carbon, used so much in the destruction of squirrels, evaporates readily, gives a vapor so heavy that it can be poured from one glass to another. It also explodes when lighted in a glass.

The rate of evaporation of water in the conditions of the school room may be observed by the use of a jar of water, the height of the water being noted at definite intervals.

With a few crystals of iodine placed in the bottom of a test tube and gently heated over the flame of a lamp a beautiful purple vapor can be produced. Crystals of iodine may be obtained at any drugstore and this experiment is excellent as giving a vapor that can be seen, one that is very heavy and can be poured out. It thus by its different appearance makes clearer the conception of a vapor. It is also an example of a solid changing to a vapor.

That the process of evaporation is a cooling one, that it uses up heat, can be shown by placing a bit of cloth moistened with water on the bulb of a thermometer and seeing the fall of the mercury as the water evaporates. With the use of a rapidly

evaporating substance like gasoline or bisulphide of carbon a very low temperature can be obtained. Drops of these on the hand produce a marked cooling effect as they evaporate.

Applications of the facts learned about evaporation will readily suggest themselves in regard to the drying up of the ground after a rain, the filling of the air with moisture from the sea, lake and rivers.

Boiling.

The study of boiling may well follow that of evaporation. For this purpose the glass flask which has already been used is excellent as it allows the phenomenon to be seen. Fill the flask two-thirds with water and use an alcohol lamp, as considerable heat is needed. Have the whole process watched very carefully. The following points are to be successfully made out: first, the currents of the water from the heating, then the formation of bubbles on the sides of the flask. These are bubbles of air which have been dissolved in the water which the heat expands. They will rise to the top and disappear. They have nothing to do with boiling. Later some bubbles will form just over the flame. These will rise and disappear within the liquid, or only reach the top as very much smaller than when starting. These are bubbles of real steam, but as the water is not yet well heated throughout, they wholly or partially condense in the cooler water as they rise. Their collapse makes a tinkling noise in a glass flask. Many of them sounding together make the singing noise preceding the actual boiling. In a short time the water is so well heated that the bubbles of steam reach the top in full size and push out the air. The steam now pours out at the top where reaching the cool air it condenses into a white cloud. This usually is called the steam, but it consists of minute particles of water condensed from the steam. The steam is the transparent vapor over the water in the flask.

Clouds, fogs and the white masses which arise from steam

engines are composed in like manner of fine particles of condensed vapor of water.

There are many points of difficulty in this with the children, from former notions picked up here and there. It is hard to understand that steam is invisible, as are many of the vapors in the preceding lessons (of gasoline, ether, etc.). But these very difficulties give opportunities for questions, which they discuss with each other, for the settling of which they may devise experiments. Do not be in too great a hurry to have it all taught. We may remember that what we wish of our material is, that it may give just those questions which it is possible for the children to work on. We should give them a chance to work at these questions when we find them. For those pupils who are ready for it, the thermometer may be used, and the gradual rise of temperature observed until the water boils, when it will be seen that it stands at 212 degrees Fahrenheit, whether in the boiling water, or in the steam just above it (not in the fog formed outside). Alcohol may be used to show that other liquids have a lower boiling point.

Condensation.

The phenomenon of condensation will constantly come up in the foregoing experiments and is, of course, to be noted. The iodine vapor condenses in crystals on the cool sides of the test tube, or if poured on a cool piece of glass. A lump of camphor heated in a test tube in the same way will evaporate and condense on the sides of the tube. Many experiments may be devised to further illustrate the results of evaporation and condensation of water. It must be seen that such high degrees of heat as for boiling is not needed for evaporation.

A glass vessel, partly filled with water, and the mouth closed, will show water constantly on its inner surface, coming from condensing the vapor arising from the water.

The condensation of water on the cold surface of a plate of

glass exposed to the breath, or to the surface of the skin, or the under surface of a leaf, or over the flame of a lamp or candle, will show that there is vapor of water coming from all these sources.

Water may be distilled from a flask, by connecting it by a tube to another vessel. The water boiled in the flask will pass as steam into the tube, which is kept cool by moistening it. From the tube the water drops into a receiving vessel.

It may be said, in passing, that it is now taught that in the formation of fog and clouds, each particle of water of the fog or cloud has condensed upon a particle of dust in the air, and if there were no particles of dust there could be no fog, clouds or rain. By "dust" is meant any small object floating in the air, such as go to make up what we commonly speak of as dust and smoke.

The application and illustration of the above lessons will occur to each one.

Solution and Crystallization.

The solvent action of water is such an important agent in the world of nature, both the living and non-living, that it becomes a good subject for nature study work.

The substances which plants take from the soil must be in a state of solution. The various forms of the foods that animals use must be reduced to a liquid form to be absorbed and they are in the blood in solution. The solution of one or more of the ingredients of a rock which act as a cement to hold the rest together, allows the rock to fall to pieces and to become soil. The solution of certain substances from the soil permits them to be carried great distances to be deposited as minerals in veins or in masses of crystals, or, as in salt, in great salt lakes or in beds of salt. In some situations immense quantities of rock are entirely dissolved out and carried away, as in the caves in limestone strata, of which the Mammoth and Wyandotte Caves are notable examples. The beautiful cave formations are the result of regaining dissolved substances from their solutions. Most of the wonderful things to be seen in the Yellowstone Park are the result of solution and the regaining of substances from solution. Thus by solution and a regaining of substances from solution the character of the crust of the earth may be constantly undergoing changes.

To illustrate the facts of solution have the pupils make solutions of some common substances such as table salt, sal ammoniac, alum, sugar, copper sulphate and bichromate of potash. This selection contains substances of different colors and all readily obtainable. They all make clear solutions. Have comparisons made with attempts to dissolve powdered sulphur or powdered chalk, which will not dissolve in water.

Have the pupils by experimenting learn that some substances like sal ammoniac, dissolve readily in water, the water taking in a large amount, while others, like bichromate of potash, dissolve

much less readily, the water taking up but a small amount of the substance. There are other liquids such as the acids and alkalis which will dissolve substances which water will not dissolve, but the solvent power of water is sufficient for illustration of the facts of solution, and it is water with which we have the most to do. Test-tubes are the most satisfactory vessels in which to make the solutions, but bottles or drinking glasses will answer very well.

After making solutions we may follow with lessons on the regaining of the dissolved substances from the solutions. That is done, of course, by evaporating the water which leaves the substance in solution behind. This is most rapidly done by heating the water to boiling, when it quickly passes away. All the substances above suggested should be regained from their solutions. Sugar dissolved in water exists in beets, in sugar-cane or in the sap of maple trees. The juices are extracted and "boiled

down," that is, the water is evaporated away and molasses or sugar is left.

When a substance is regained from solution by the rapid process of boiling it is left behind generally in the form of a fine powder of very minute crystals. If, however, we allow the evaporation to go on slowly, as in an open vessel in the temperature of the school-room, then the dissolved substance will form into large, beautiful crystals. If strings or slender sticks are suspended in the liquid the

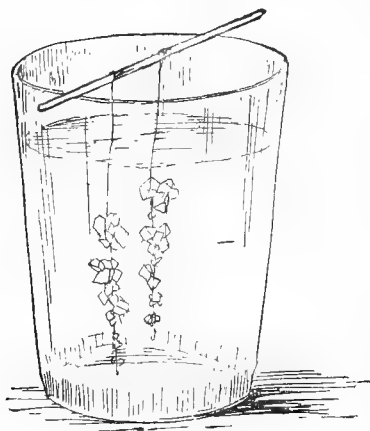


Fig. 59. Apparatus for obtaining crystals on strings.

crystal forming on these may be easily lifted out without breaking. A very instructive and interesting method of forming crystals is that of smearing a solution of a substance over the surface of a clean sheet of glass. As the water evaporates the crystals may



FIG. 60. Sal ammoniac crystallizing on a sheet of glass.

be seen to form over the surface of the glass. If the formation of the crystals be observed by means of a hand lens or under a low

power of the microscope, the crystals will be seen to shoot rapidly across the field. Sal ammoniac is excellent for this experiment.

Indications have already been made of the possible application of these facts. In nature the water dissolves certain substances from the soil or rocks which are carried to greater or less distances and in the new situations by evaporation the substances take the form of crystals, of quartz, limestone crystals, and the various other beautiful crystals and gems found in the earth's crust. In making solutions of all those substances which produce the crystals in the rocks, water is aided by other substances mixed with it, such as carbonic acid and other acids and alkalis.

To show that water always dissolves something from the soil, soak a jar of earth a day or so in distilled or rain water. Filter off the water and evaporate it in a clean vessel and when all the water has disappeared the vessel will be coated with a thin crust of the substances which were dissolved in the water. For comparison boil down in the same way an equal amount of distilled or rain water and no crust will be found to remain. The inside of a tea-kettle long in use becomes coated with a thick crust of the substances dissolved in the water used, which are left behind by the evaporation of a large amount of water from the kettle.

In the lessons on the foods of plants it was shown that carbonic acid and water are the main foods, but in addition the plants obtain other substances from the soil. These come into the plant dissolved in water. In burning a plant in open air those parts made out of the carbonic acid and water disappear in gases, the product of the burning. There is left behind some ashes. These ashes represent mainly what the plant had received from the soil dissolved in water. While this is proportionally small in amount it contains important and essential elements of the plant's food. Thus it is seen that water is not only itself food for plants, but it

also acts as the medium by which other important foods are brought into the plant's body.

The Soil.

The facts brought out in the lessons immediately preceding may be made to introduce a more careful study of soils. The general structure of the soil, and the different kinds of soils may be studied; also the relation of these to growing roots and percolating water.

In general, soil may be said to be made up of clay, sand, gravel and vegetable or animal remains. All of these may be present, and in different soils in varying proportions, or only one or two of these may be in soil from a particular locality.

Clay consists of very fine particles only; and when alone, it makes a compact, stiff, heavy soil that is hard to work with farming tools.

Sand is composed of larger particles, and when alone, makes a loose, light soil, easily worked.

Gravel is made up of coarse particles and stones of various sizes.

Secure a portion of soil from any source, and have the pupils separate the sand from the clay as follows: In a suitable vessel, stir the soil up thoroly with water, and pour off the muddy water into another vessel. By repeated washings all the muddy parts (which are the clay) are separated from the sand and gravel. These, if both are present, may be separated by a fine screen (wire netting). The vessel containing the muddy water is allowed to stand, until the soil settles; then the water is removed. The sediment is the clay. All may be dried and the proportional amounts determined.

Next study the properties of clay and sand. Placed on a filter (a funnel with a cloth or filter paper), clay retains the water, while sand allows it to pass rapidly thru. Note the effect of pack-

ing each firmly before water is poured on. Now you may come to questions in regard to the percolation or retention of water falling on the surface, the formation of underground reservoirs, of springs, of wells, etc.

Before studying how water rises in the soil from moist regions below, some experiments in capillary attraction would better be taken up.

Capillary Attraction.

With a series of small glass tubes standing in a shallow dish of water, observe the height the water will rise in each. Two sheets of glass brought close together will show that the nearer they approach, the higher the water will rise. A sponge, a cloth, a lump of sugar, a piece of bread, or new brick may be used to further illustrate capillary attraction.

Arrange lamp-chimneys (or other large glass tubes) one filled with gravel, one with sand, one with clay, and others with mixed parts, or with any soil desired. Place them in a shallow vessel of water, and observe the rising of the water in each.

In California the rains in the winter sink down into the lower depths of the soil, and in the summer with no rain, the plants must depend upon this water which rises by capillary attraction to the roots of the plants.

The reason given for cultivating the orchards in the summer is to break up into a loose mass the upper surface, and thus in this layer destroy the conditions good for capillary attraction, which, if good, would allow the water to rise to the upper surface and be evaporated by the sun and thus lost. The cultivated layer of soil acts as a covering retarding evaporation. To be a good covering it should be stirred often with the cultivator, and not allowed to pack down close and thus establish good capillary connection with the surface.

For study of how roots act in different kinds of soils use the glass frames used for seed-planting. Pack the clay well.

What gives the dark shades of color to the soil? Where a ditch or other cut in the surface of the soil shows a section, note that the upper part is of a darker shade than the lower; sometimes it is quite black. Take a portion of such soil, and in a crucible (a big spoon will answer) in an open fire burn the soil thoroly. The dark color will disappear. It was due to partially decomposed vegetable (rarely animal) remains, that is, of roots, stems, leaves, etc., and the fire has burned this organic matter away. This dark layer is sometimes called loam, while the brighter colored soil beneath is called the subsoil.

Experiments With Ice.

FROST.

The method of making ice-cream has already taught most children that salt and ice make a freezing mixture. To show by its means the formation of frost, fill a tin cup, or other similar metal vessel, with a mixture of salt and pulverized ice. Stir the mixture. Soon the sides of the vessel will be covered over with moisture condensed from the air. As the vessel further cools, this moisture is frozen, and the vessel becomes covered with a coating of frost. Press the tips of the fingers firmly against the frosted area until the small space thus covered is melted. Remove the fingers and watch the formation of the frost crystals as the film of water freezes.

The temperature of melting or forming ice is 32° F. This can be determined by the thermometer in a vessel of melting ice or in a vessel in which water is made to freeze. The latter can be accomplished by surrounding a small vessel of water with the ice and salt mixture. As long as any of the water remains unfrozen, it does not sink below 32° .

Why does ice float? Of course former work has shown it is because that, bulk for bulk, it is lighter than water, that is, when water freezes, it expands. Fill a small bottle with water and place it in a freezing mixture, keeping it there until its contents are frozen hard. The bottle will be broken by the expanding ice. This also illustrates the action of freezing water in breaking up rocks, a very active disintegrating agent in cold countries, also in high mountains, as in the Sierra of California, etc.

An experiment showing that a solution of salt and water requires a lower freezing temperature can be performed. Have the pupils show that when the solution of salt freezes, the ice separates the salt out from itself, the ice being fresh.

These experiments may be much varied; their application to geographical phenomena are obvious. For other freezing mixtures see some work on Physics. How is artificial ice manufactured?

About Spiders.

Spiders offer certain disadvantages and many advantages in their use as objects of nature study. The fear which they inspire in both children and teachers is a disadvantage; their actual capacity for making slight wounds by biting is a disadvantage of more importance, in that it cannot be quite so readily overcome. The abundance, variety, wide distribution, and interesting habits of spiders and the ease with which they may be kept alive and observed in captivity are preponderating advantages. A word as to the biting and poisoning capacity of spiders. The bite of no one of the common small spiders of house and field and garden should cause any anxiety; if there is no anxiety there will be no trouble. The bite of the tarantula and large running spiders may cause some pain. But there is absolutely no necessity of being bitten at all in studying spiders. I have never been bitten by a spider and I have studied them, as much, at least, as the nature study teacher is asked to in this lesson.

Spiders should be studied both in the schoolroom and out of doors. The suggested work is divided into schoolroom work and field work. The getting acquainted with the spider's body and some of its feeding habits and even some of the spinning can be done in the schoolroom. The rearing of spiders from the eggs, and the observation of the habits and growth of the spiderlings should also be done in the schoolroom. But the study of the homes of spiders, the different kinds of webs, and the general habits of the different common kinds of spiders, as well as the manner of web-building, must, most of it, be done in the field or garden or along the roadside; in a word, out of doors.

Identifying and Collecting.

Spiders are too familiar to require any special diagnosis for identification. There are, however, many kinds of spiders, and

direction is given later in these notes for the identification (mostly by habits) of some of these kinds. Collecting spiders is not difficult nor does it carry the collector far afield. The collector should provide himself with a number of empty pill boxes, cap boxes, or other similarly small, paper, wooden or tin boxes with well fitting cover. Each of these boxes will serve as collecting tool for one spider, and as cage to keep it in until the schoolroom is reached again. Search for spiders in or near their webs, in the corollas of flowers, on the bark of trees, under stones and sticks on the ground, and (for tarantulas and other spiders with tubular nests in the ground) in their nests in the ground. Spiders

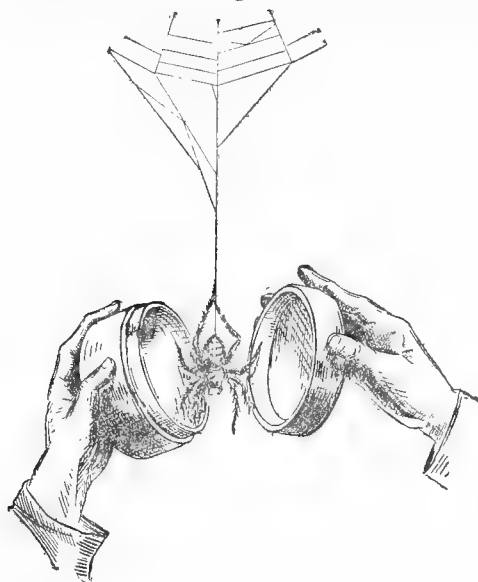


Fig. 61. Catching a spider.

living off the ground, i. e. on webs, flowers, trees, etc., are very prone to drop quickly to the ground when disturbed. Take advantage of this and be ready to catch the falling spider in a pill box, quickly clapping the lid on. Use the pill box and lid as catching equipment. You will soon get expert in the work. Small spiders, especially those in webs or flower cups can be caught with perfect impunity in the

hands. But there is always danger of crushing the soft body of the creature, or pulling off a leg or two in handling. Trust

chiefly to manipulation of the box and lid. There need be no holes in the pill box for the admission of air for the captive inside. The boxes are by no means air tight. The silken egg-sacs or cocoons of spiders, if you know them, (and some of them are described and figured later in these notes), may also be collected, and the young spiders reared in the schoolroom. The spiderlings will be of special interest to the children, and some thoroly interesting experiments may be made with them.

For the first lesson of spiders to be given in the schoolroom collect a number of common house spiders and ground spiders. The house spiders may be found especially readily in wood sheds, stables, or other out buildings, and in attics. The ground spiders may be found under stones. Keep some of both kinds of spiders alive in covered glass jars in the schoolroom and kill some by means of chloroform. In the jars with the live ones put a number of small live insects to serve as food for the spiders.

Observing and Questioning.

SCHOOLROOM WORK. Have the children watch the live spiders. Notice their behavior with regard to the insects put in for food. Do the spiders catch the insects? Is there any difference in the behavior of the two kinds of spiders, the smaller house spider and the larger ground spiders? What do the spiders do with their captured prey? Do they spin silk about their bodies? Do both kinds of spiders do this? How do spiders eat their prey? Do they eat the whole body of the captured insect? They simply suck out the body juices, casting aside the flaccid skin. If the spiders spin silk around their prey from what part of the spider's body does the silk come? The silk issues from small papillæ or finger-like processes situated at the posterior tip of the body. Do the spiders spin silk except around the bodies of their prey? Whenever the house spiders run they leave behind

a silken thread which is attached to the bottom or sides of the glass jar. Take out from the jar one of the house spiders on the end of a pencil. The spider will drop from the pencil not free, but attached to a delicate almost invisible silken thread which issues from the posterior tip of the body (fig. 62). By quickly lifting the pencil before the spider reaches the table or floor the presence of the hold-

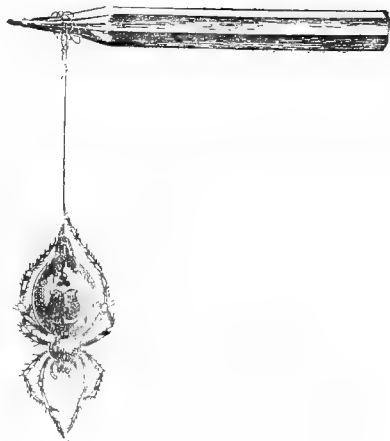


Fig. 62. A spider falling.

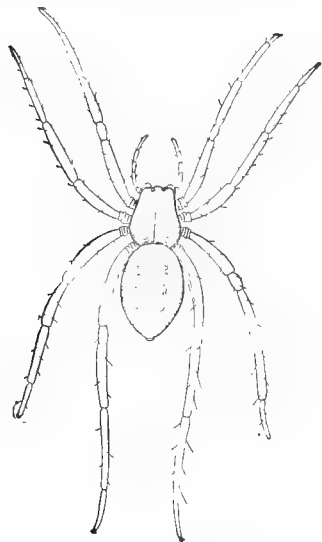


Fig. 63. A ground spider.

ing thread may be demonstrated.

After the children have observed the live spiders, give them dead spiders to examine. These dead spiders should be of the larger sort, the ground spiders (fig. 63), in order that the parts of the body referred to in the following notes can be readily made out. How many legs has a spider? There are four pairs of true legs; a pair of shorter processes which look, at first glance, like legs, and which are situated in front of the first pair of true legs, are feelers or papi. They

are always directed forward, it may readily be seen that they are not used in walking. Into how many parts is the body divided? To which part are all the legs attached? Have the children look for the eyes of the spider. Where are they and how many are there? The eyes of spiders are shining little black spots situated on the upper frontal part of the anterior half of the body, (that part which bears the legs, and is the head and thorax of the spider joined together). The eyes vary in number and arrangement in different kinds of spiders, and vary in size on the individual. The common ground or running spiders have eight eyes (which is the more usual number among spiders) and they are arranged as shown in figure 64. Have the children discover which of the eyes are larger than the others. Have the children look for the jaws (mandibles) of the spider. With a pin press the jaws apart laterally and examine one of them carefully. Each jaw (fig. 64) is composed of a firm, smooth, sharp, pointed tip and a thicker hairy basal part. The tip is the fang, which is thrust into the prey and the basal part contains the poison sac. From the poison sac the poison runs thru the fang and out of it thru a tiny hole near the point. Examine now the spinning organs. At the posterior tip of the body may be seen a few small finger-like



Fig. 64. Front of head of spider showing eyes and mandibles



Fig. 65. Spinnerets.

projections, the spinnerets (fig. 65); (some of these are so small and so much concealed by the others that it will be difficult for the children to determine exactly how many there are). From these comes the silk when the spider is "spinning." Each of these little finger-like spinnerets bears on its surface many very small papillæ, the spinning tubes. These cannot be seen with the unaided eye, but

if the teacher has a microscope, and will cut off a spinneret and mount it in glycerine on a glass slip, the numerous tiny spinning tubes may be readily seen (fig. 66). When the spider is spinning i. e. when it is producing a silken line, a slender thread issues from each of the spinning tubes on each spinneret. All of these fine threads from the many spinning tubes unite to form the one strong line which we see.

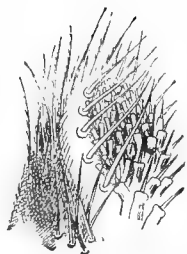


Fig. 66. Tip of a spinneret showing spinning tubes.

FIELD WORK. To find and get acquainted with the appearance and habits of some of the commoner different kinds of spiders, the teacher should take the class afield. It will not be necessary to wander far; the immediate vicinity of the school house, especially if there be flowers and shrubbery in the yard, will contain nearly all the kinds of spiders written of in these notes. For the sake of teaching the teacher we shall find these spiders in a very regular sort of way; a way which will not be readily repeated in the field. But because the teacher can get his knowledge of the few kinds of spiders we wish to study much more readily and certainly if some orderly sequence in the observation of them is followed, a sequence in finding the spiders is adopted.

It is a familiar fact, I hope, that some spiders spin webs for catching their prey, while some do not, but trust to pursuit by running or leaping. At any rate such is the fact and it may be our basis of primary classification of spiders by habits. The house spiders with their cob-webs, the field spiders with their silken sheets among the grasses, and the garden spiders with their geometrically regular orbs hung in the shrubbery, are spiders which belong to the web-weaving group. The black, swiftly running spiders that lurk under stones, the fierce-eyed little black and red fellows hiding on the bark of trees, and the daintily colored crab-like one lying quietly in flower cups, are spiders

which belong to the non-web-weaving group. We shall attend, in our consideration of the different kinds, first to the spiders which do not spin webs for catching prey.

Under stones or lurking in half concealment elsewhere on the ground may readily be found certain blackish rather hairy spiders mostly of rather large size. These are the Running Spiders, and they catch their prey by swift running. Their legs are long, the

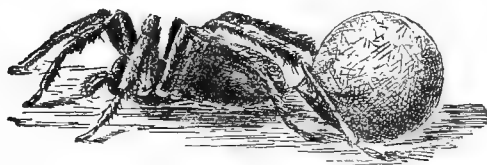


Fig. 67. Ground spider carrying egg-sac.

hindmost pair being the longest. Some of these spiders have the body, exclusive of legs, an inch or even more in length. One of these large spiders may be found, perhaps, dragging after it a dirty white silken ball (fig. 67). This ball is the silken egg-sac which is strongly attached to the spinnerets of the female. The egg-sac is carried about by the spider until the spiderlings hatch. They issue from the egg-sac and climb onto the back of the mother spider, and are thus further carried and protected by the mother until they are able to care for themselves.

Upon fences, the sides of out buildings, on the bark of trees, or fallen logs, may be found certain small robust, short-legged spiders which move chiefly by sudden leaps. These are the Jumping Spiders (fig. 68). They are usually black, with red or other strikingly colored markings, and two of the eight shining black eyes are much larger and more conspicuous than the others; much larger, indeed, than the eyes of any other spiders of equal size, and they give the Jumping Spiders a peculiarly threatening appearance. These spiders can walk side-

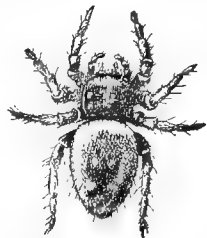


Fig. 68. A jumping spider (*Salticidae*).

wise or backwards with facility, but are readily distinguished by their leaping and their big eyes from the true sidewise moving or crab spiders described in the next paragraph.

In cracks and crevices of fences and bark and on plants, may be found certain short, broad, flattish, usually greyish spiders, which can run sidewise or backward more readily than forward.

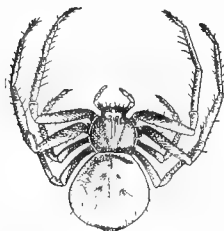


Fig. 69. A Crab Spider.
(*Misumena*.)

These are known as Crab Spiders (fig. 69). Some of them lie in wait for their prey in flower cups, and these are usually white and parti-colored so as to harmonize with the bright colors of the corolla. They are rendered inconspicuous by this sort of color mimicry, and small insects alight unsuspectingly within reach of the waiting spider.

The front two pairs of legs of these spiders are longer than the other two pairs, and "so bent that the spider can use them when in a narrow crack."

The running spiders, jumping spiders and crab spiders are the most easily found and easily recognized of the spiders which do not spin webs to catch prey. But there are other groups of spiders characterized by this habit; among them those giant spiders, the California Tarantulas or Mygales, and the trapdoor spiders. The tarantulas and trapdoor spiders live in cylindrical burrows in the ground, and they do their hunting chiefly at night. They are not, thus, very commonly found, altho they are abundant, in California. Perhaps the most certain way to obtain a live specimen of the tarantula is to dig it out of its burrow. The burrow can be recognized, with some certainty, by the fact that they are usually thinly lined internally with silk. They are open at the surface of the ground, and are about an inch or an inch and a half in diameter. The live tarantula can be kept in a glass jar or wooden box in the bottom of which several inches of soil have been placed. It may be that the tarantula will build a



Fig. 70. Nest of trap-door spider.

correspond exactly with the character of the ground, covering immediately surrounding the mouth of the burrow. As the door fits exactly, lying, when closed, perfectly even with the surface of the ground, and showing hardly a visible crack or line at its point of meeting with the surface of the ground, it is extremely difficult to find the trap-door spider's nests. But by being constantly on the watch for them, a happy chance may discover one. The trap-door nests may be specially looked for in the woods, and in uncultivated ground.

Two nests in the entomological collection of Stanford University were found in a bare and well-trod path, which was in daily use. If a nest is found it should be carefully dug up, and removed to the school-room. Here the interesting details of its construct-

nest (burrow) while in captivity, tho it probably will not. It should be provided with insects or with raw meat for food. Notice its hairy body, its great fangs, its long strong legs. The trap-door spiders are of great interest because of the curious nests they make. The burrow or vertical tunnel in the ground (fig. 70) is closed at the surface by a hinged lid, a veritable trap-door, composed of soil and silk. The inner surface of the door is quite covered with silk, while the outer (upper) surface is skilfully covered with soil or soil and bits of leaves, sticks, or moss, so as to

ion can be examined at leisure. The silken walls and the silk used in making the trap-door show that these spiders possess the power of spinning silk, even tho they do not spin webs for catching their prey.

The webs or snares of spiders present a great variety in form and type of construction. The different webs made by the individuals of any one species of spiders are always alike however; indeed, each family of web-weaving spiders has its own peculiar type-plan of web construction and as we could distinguish various families of non-web weaving spiders by their habits of locomotion so, we can distinguish the various families of web weaving spiders by the character of the webs.

Most familiar to us probably, are the "cobwebs" of the neglected corners and byways of the house and outbuildings. The family of cobweb weavers is a large one, and its species are not restricted to an indoor habitat, but many spin their loose, irregular webs in bushes. The web is a tangled maze of silken threads mostly in the form of a flat or curved sheet of silk, on the under side of which the spider stands or runs back downward. Sometimes the owner of the web has a silken nest in a crack near the web, and there is sometimes a short silken tube leading from the web to the nest. The spiders themselves are usually small and very slim-legged.

Have the children examine a cobweb carefully. Note the irregular unsymmetrical character of the web. Can the general sheet-like form of the web be made out? Are there vertical threads running to the web from above? Is the web sticky, i. e. are the threads of the web sticky? Are all the threads of the web sticky? (see description of orb-webs). Are there any remains of insects in it? Throw a house fly into the web, and if the spider comes to it, watch carefully all the movements of the spider. Does it run out on the upper or under surface of the web?

Does it swath the fly's body with silk? Does it carry the fly to its nest, or to another part of the web to eat it?

A grade higher in point of symmetry of construction are the snares of the funnel-web weavers. These webs (fig. 71) are

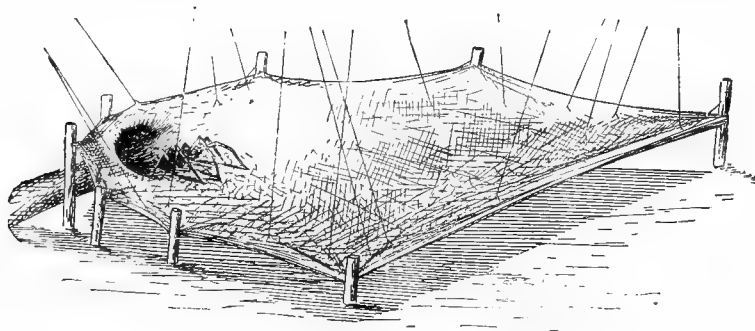


Fig. 71. A funnel-web (after Emerton).

spun in the grass of meadows, pastures, gardens and roadsides, and because of their lowly and obscure situation they do not usually appear to be very abundant; they are, in fact, the most abundant of all webs. We are often surprised to find, some dewy morning, the grass nearly covered with glistening spider webs. This abundance of webs is revealed to us by the tiny drops of water, which cling to the silken threads, reflect the sun's rays and make the otherwise almost invisible webs, very conspicuous. It is desirable to choose a dewy morning or the first hour after the lifting of a heavy fog for spider web hunting. The webs are not only easily found then but they are then specially beautiful. The funnel-webs are horizontal concave silken sheets supported in the grass by strong silken lines or cables attaching to the grass stems and blades. They have at one side a funnel shaped tube running downwards and opening near the ground. The spider lies in hiding in this tube, and from it runs out upon

the upper surface of the web to seize its prey, or runs away when necessary by issuing from the lower end of the tube, and escap-

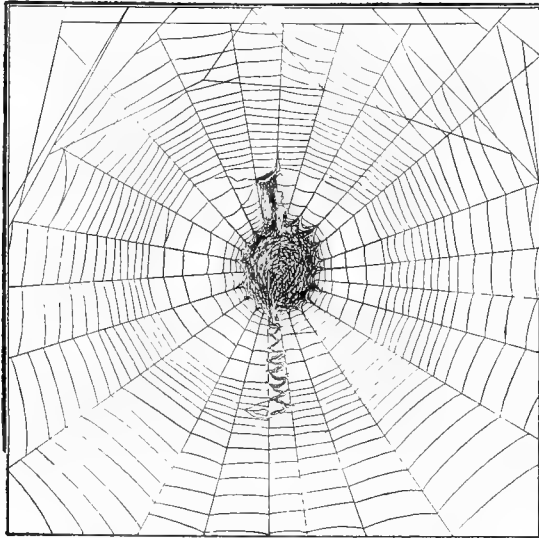


Fig. 72. The orb-web of *Argiope* (after McCook).

ing unseen on the ground among the grass roots. The funnel web weaving spiders are long legged, usually brownish spiders very often of considerable size and with one of the pairs of spinnerets unusually long. Have the children see how the web is sus-

suspended by stout supporting lines.

Note the funnel-shaped tube with its upper and lower openings. Find a tube with the spider in it. Touch the web slightly with a pencil point, trying to induce the spider to come out upon the web. Observe its manner of escape.

A great advance in degree of symmetry and elaboration of design is shown by the round webs or orb-webs (fig. 72). These are the most interesting as well as the most beautiful of spider's snares, and they furnish the nature study teacher with a fascinating subject of observation. The orb-webs may be found suspended between the branches of shrubby plants or between the bushes themselves, in fences, in open door ways or wherever in the garden a convenient frame work presents itself. They are

characterized by their circular outline within which are disposed numerous radii and a series of concentric circular or spiral threads. The circular snare is usually placed within an irregular triangle, or quadrangle, or polygon, which is held in shape and position by stout stay lines extending and fastening to the adjacent branches or fence rails or door frames or whatever serves as frame work for the snare. The webs vary greatly in size, the largest being sometimes a foot and a half to two feet in diameter. The spiders

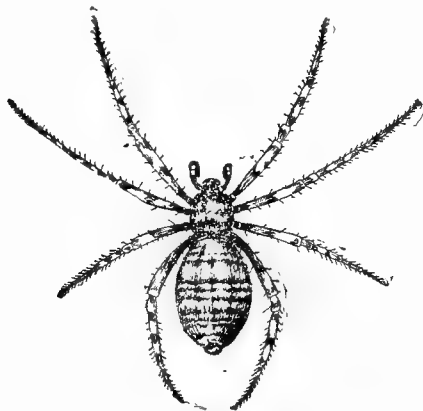


Fig. 73. *Argiope*, an orb-weaver.

which spin these webs are called garden spiders or orb-web weavers, and most of them are highly colored and have a nearly spherical abdomen (fig. 73). They may be found "hanging head downwards usually near the center of the net; others have a retreat near one edge of the net in which they hang back downwards. While resting in these retreats they keep hold of some of the lines leading from the net so that they can instantly detect any jar caused by an entrapped insect."

Find one of these orb-webs in good condition, i. e. not torn and ragged but new and complete. Examine it and note the regularity of its construction. Trace the stay-lines to their attachments; note the shape of the outer polygon; note the "spiral zone," i. e. that part of the snare filled with lines laid down in apparently concentric circles; note that these apparently concentric circles are not separate circles but are spiral and that the line composing it is continuous; between the outer polygon and the spiral zone there is a region crossed by the radii but without other

lines, this is called the "outer free zone;" between the spiral zone and the center of the snare there is another zone free from spiral or circular lines, or with these lines very far apart, this is called the "inner free zone"; the central part or central zone of the snare has a close spiral in it, and in this central zone the spider if it has no side retreat usually rests. Touch one of the radii or one of the foundation lines with a pencil point; touch the spiral with a pencil; a difference in the character of the two kinds of lines is at once manifest. The spiral thread is "sticky," the radii and foundation lines are not sticky. The web is made of two kinds of silk. If a bit of the spiral line be examined under a magnifier it will be seen that ranged along the silken thread, like beads on a string, are many tiny globules or drops. These drops are a sticky, viscous sort of silk, which does not dry and harden as the usual spider silk does. These sticky drops make the spiral line much more effective as a snare. Throw an insect into the web and observe the behavior of web and spider.

If possible, observe the spinning of an orb-web. Tear partly away an already made web, and if the spider is not too badly frightened, she will probably rebuild the web. Parts of this work of rebuilding, at least, can probably be observed. The spider works in a regular way, putting in first the foundation and radial lines, and then the spiral lines. Two sets of spiral lines are put in; a first set, which is put in from the center outwards, is not viscid, and serves as a scaffolding upon which the spider works when putting in the second set. The second set is viscid and is put in from the outer part of the web toward the center. The temporary spiral or scaffolding is torn out as the work of putting in the viscid permanent spiral progresses. The work of building the web includes a great deal of interesting behavior on the part of the spider, the delicate manipulation of the viscid lines, and the almost geometrically accurate disposition of the lines composing the snare, combining to render the whole performance little sort of marvelous.

There are other kinds of webs which other kinds of spiders spin. Indeed, among the orb-weavers alone, there is great variety in the character of the webs; some orb-webs for example, lack a sector of the circle, the web being otherwise constructed on the regular orb-web plan; others are composed of perhaps less than one-half a circle, although still with radii, and with concentric arcs of circles in place of complete circles in the spiral zone. Certain kinds of spiders spin a peculiar broad line or rather band of curling silk, which leads from the snare to the

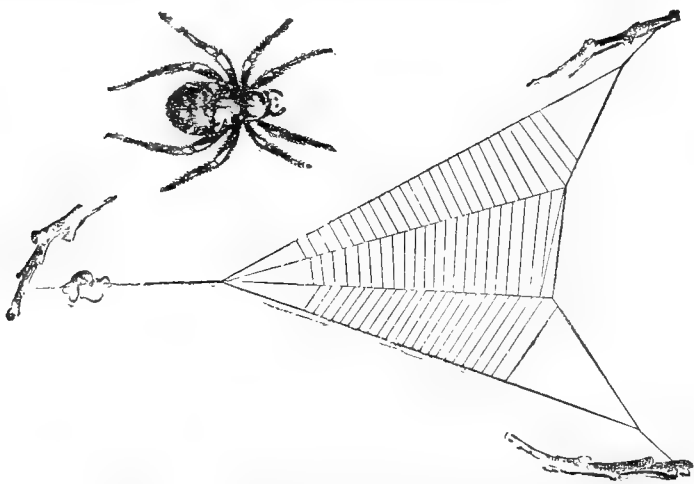


Fig. 74. The triangle spider (*Hyptiotes*) and its snare.

side retreat of the spider. Or they make out of this band of curled silk a central zone not composed of a spiral line but of a closed oval or circular shield. A certain very small spider spins a triangular web (fig. 74), from which a main stay line runs upon which the spider—triangle spider it is called—rests with a loop of the stay line held between the fore and hind legs. When an insect alights upon the snare the spider loses the hold of the

hind legs on the stayline and the web springs suddenly, further entangling the prey. For these and other kinds of webs the teacher and class may search. There is an unlimited and always interesting field of observation in the study of spiders' webs, and it is a field always open to the nature study class.

Finally, there is one other peculiar phenomenon which may be observed in connection with spiders and spiders' silk. On some bright warm days, there may be noticed many "spider webs" or long threads of spiders' silk, floating in the air. Some of these threads are floating at considerable heights. Careful observation will show that not only are "spider webs" floating, but attached to many of them are small spiders which are thus sailing or "ballooning" thru the air. These are called ballooning or aeronautic spiders. Examine carefully the top of fence posts or other exposed raised points and you may be fortunate enough to discover one of these spiders about to make an ascension. The small spider will be standing with its legs close together and straight, the body being thus lifted as high as may be, and the tip of the abdomen pointing upward. From the spinnerets (at the tip of the abdomen) are issuing lines floating freely. These line are gradually spun out (being really drawn out by the pull of the wind) until they become so long that the wind bears them off with the spider attached to them. Spiders may make long journeys in this manner, and get themselves widely dispersed from an original habitat. These ballooning spiders are mostly young, and hence small individuals of various species; but some adult spiders of small size are also aeronauts.

From this brief account of some of the habits and manners of spiders it is hoped that the nature study teacher may obtain suggestions for numerous lessons. The observations can be made as opportunity offers; field work should be attempted only on bright sunny days when insects are all astir, and the spiders are busy. Schoolroom work can be more definitely controlled; the

live spiders can be watched; the egg-sacs examined to see if the young are hatching, and the spiderlings experimented with in all the ways that the teacher's ingenuity can suggest.

Plants Without Flowers.

Ferns.

Altho ferns are very common and very attractive plants, both as wild and as conservatory and house plants, yet their life history is not generally known. The whole of even the brief account which immediately follows could hardly be worked out in the nature study class, but it is given for the teacher who may not have been a student in botany. Having traced it once, the judgment of the teacher may be relied upon to select the main features which can be used in this class.

There are two stages in the life of the plant, during one of which it lives as a very small inconspicuous plant whose very existence is not known to great numbers of admirers of ferns. The fern plant as we see it growing bears spores. A spore when deposited in the proper conditions sprouts and grows into a minute plant which looks as little like a fern as possible. This little plant lives an independent existence and is known as a prothallium. In the course of its life, it produces on its under surface organs which correspond to stamens and pistils of flowering plants (male and female organs). As in the higher plants pollen grains fertilize the ovules, so here cells from the male organs called antheridia fertilize a cell in the organ corresponding to the pistil called an archegonium. Then as a seed is formed in an ovary of a pistil, so here the fertilized cell forms by growth a germ of a minute fern which soon grows up from the prothallium. This tiny fern continues its growth, the prothallium in the meantime dying, until it attains the characteristic size and form of the species to which it belongs. Thus a spore from a fern plant produces a prothallium, and then the prothallium produces a fern like the one from which the spore comes. These two forms or stages, or generations, as they are called, alternating thus, are spoken of in biology as an alternation of generations.



Fig. 75. A leaf of a fern showing the underside with numerous dots which are made up of the spore-bearing organs.

The class may take up the following concerning the fern. Any common fern will answer for study. See the whole plant, with leaves (fronds), underground stem or root stalk, and roots coming off from this. Examine the leaves and find on the backs of some the spore-bearing organs. These are arranged differently in different ferns. In many, as shown in figure 75, they are in round dots. Examine with a hand lens these dots, and each dot will be found to consist of a bunch of little roundish knobs, each knob born on a small curved stalk. Figure 76 shows one of these stalks with the surmounting knob highly magnified. The little knobs are capsules which contain spores (fig. 76). The stalk with the capsule is called a sporangium. When the spores are ripe the stalk straightens out, the capsule breaks open and the spores fall out.

By sowing the spores under proper conditions and caring for

them, prothallia can be raised in the school-room and ferns grown from the prothallia. This will prove very interesting and instructive.

The spores may be collected by placing the spore-bearing leaves on sheets of paper, and letting the leaves dry, when the spores will be discharged, covering the paper as a fine, brown powder. If the spores are sown on fine, rather

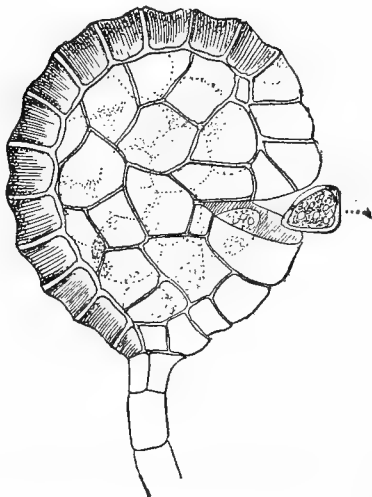


Fig. 76. A single spore-bearing organ of a fern highly magnified. Taken from one of the dots shown in fig. 75. At S is a spore escaping.

closely-packed earth, and kept moist, and covered with glass so as to prevent evaporation, a fine green, moss-like growth will make its appearance in a week or two, and by the end of five or six weeks, the little flat, heart-shaped plants spoken of before as the first stage will appear. They are of a dark green color, and are the prothallia. These prothallia are attached to the ground by fine root-hairs. Very soon we may find growing from the under side of some of the larger of these little plants the fern as we know it. It is attached to the ground as well as to the prothallium (fig. 78). As the plant grows, the prothallium dies, leaving the fern as an independent plant, which afterwards bears the spores.

The reproductive organs are on the under-side of the prothallium as shown in figure 77. These can be readily made out with a hand lens if the pupils are old enough to appreciate this work.

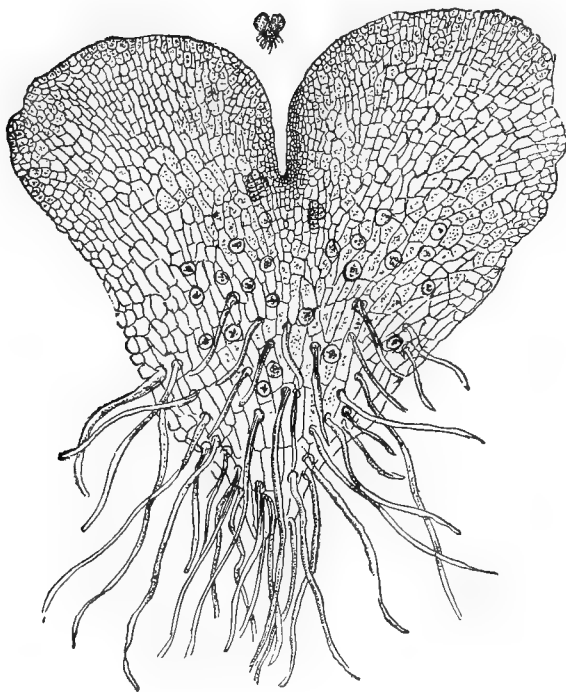


Fig. 77. A prothallium of a fern magnified. The small figure at the top shows the natural size. Both figures show the underside of the plant. The archegonia are shown near the notch, below are the antheridia, the round dots, and numerous hairs acting as roots.

Lichens.

The lessons on the mushrooms will prepare the class for another group of fungi, the lichens. They are very common

everywhere and altho they are at first puzzling, the children become very much interested in them.

They are the plants which often form drab or gray-colored patches on the bark of trees or on the surface of stones. There are many forms—some make fringes and fuzzy coverings on fence boards or on trunks and limbs of trees. One strange form is the so-called "hanging moss," which grows so abundantly in California, hanging in long festoons from the oaks. (Not the "hanging moss" of Florida). They reproduce by means of spores, borne oftentimes in colored cup-shaped surfaces. The spore surfaces are sometimes carried up on stalks, thus being elevated above the plant body. In some forms small portions of the plant-body become detached. These will grow into a new plant.

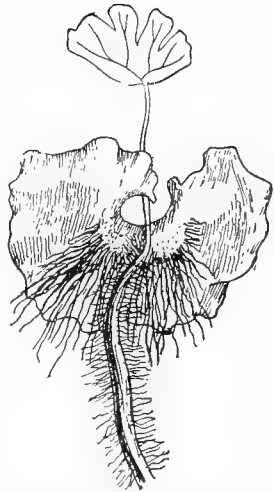


Fig 78. A prothallus of a fern from which a young fern is growing. (From Sachs).

Their method of attachment to bark or stone, method of growth, and method of bearing the spores may be seen. For older classes, by the use of the microscope, the wonderful bit of natural history shown in the relation between the lichens and the bit of green algae on which they are parasites, may be made out.

Mosses.

Mosses are more common than ferns and little understood, except by botanists. They may be the subjects of many interesting lessons. Many of the facts about them which are of great interest from a scientific point of view, are difficult to make out and would better not be attempted in this course. Teachers who wish to learn of them are referred to works on botany, especi-

ally with regard to the reproductive parts. The following account is only meant to refer to parts which can easily be observed.

There is a great number of forms which would be puzzling to those who are not botanists. Common forms may be found growing in moist places on the ground or on the trunks or limbs of trees. These plants consist of small stems clothed with minute green leaves. The stems are fastened to the ground by means of thick felt or hair-like threads. The whole plant is a beautiful and interesting object seen under the simple microscope. A simple leaf under higher powers shows a thin plate consisting of a single layer of plant cells. The green grains in the cells are chlorophyll bodies. These are the same in all green leaves.

Those pupils who are ready for it, may be taught that it is by means of these bodies that the plant is able to make such substances as starch out of carbonic acid and water, the two great food substances of the plant. It would do no violence to any correct pedagogical principle to tell any one who can see the green grains that by means of them the plant in sunlight, makes starch out of carbonic acid and water. As it is in mosses, so it is all plants. When the subject of the use of chlorophyll is taken up, the moss leaf is one of the most convenient objects in which to see the chlorophyll well. (See topic, "The Plant's Food.")

The moss reproduces by means of spores. These in many common forms are contained in a little vessel on the top of a slender stalk which raises it above the general bed of moss.

The spores sown in moist places first grow into minute green threads (protonema). These, in time, bear minute buds which develop into the moss plants as we generally see them.

The children may find different forms of mosses; find their spore-bearing parts; the protonemal stage passing into the adult plant. Flower pots in which other plants are growing, if kept moist, often have all of these stages.

Note to the teacher:—For yourself, you will find it a matter

of great interest to learn how the spores are formed, altho the subject is a rather difficult one to make clear to young children. Reference is made to the formation of the male and female plants, the fertilization of the oospore by the antherozoids, and the development of the sporogonium.

The Green Scum of Ponds.

In the many excursions made by the pupils the ever present green scum of ponds and ditches must have attracted their attention and have been the source of many questions.

If a lesson with it goes no further than to show that this slimy mass really is made up of a number of very definite and beautiful forms of plants among which live a large number of interesting animals, it will have accomplished much in extending the view of nature. With a microscope it can supply a never ending train of beauties and wonders. What is given here is but the merest beginning with these objects, one that all can make.

Have some one bring in a portion of such scum. Place it in a vessel of water, giving it plenty of room to spread out well. Take up a very small portion (too great a portion will give confusion only) and mount it in water on a glass slip with a cover glass. Allow the children to see it well and make out some of the forms. There will be great interest on the part of the children, but at first very wrong conceptions of what is seen.

One form of plant is very likely to occur. It consists of a single, long, unbranched thread. Within it are green spiral bands with chlorophyll. The partitions across the plant are the ends of plant cells. The plant consists of a single row of cells. Those who are students of botany will recognize the plant as *Spirogyra*, of which there are at least forty species in the United States. Of course the children will demand names for the numerous things which they may chance to see, but few botanists or zoologists could give them all. A frequent examination of pond

scum from different sources will allow the children to become familiar with some of the most common forms which will repeatedly occur. The names of many of these may be ascertained and supplied in time.

DIATOMS.

Diatoms are almost always present in the above described preparations. They are small objects, generally brownish in color, often tapering at each end like a canoe. They move across the field like small boats. There are many other shapes than these among the diatoms. Diatoms are plants having delicate shells of silica. When the plant dies, the shell drops to the bottom of the pond. In certain places, ponds or lakes which have been the homes of diatoms for ages have a deposit of fine mud at the bottom made up largely of diatom shells. In ancient geological times there were thus formed in some places in California and in other countries, deposits making thick strata of rock composed almost wholly of diatom shells.

If in the first lesson neither *Spirogyra* nor diatoms are in the material observed, equally interesting forms will be seen.

Flowering Plants.

In former lessons the dispersal of seeds of flowering plants and also their germination and growth were taken up. When the seeds that were planted have become of considerable size many matters of interest demand attention. Among the questions which may-be studied are: What are the foods of the plants and how do they obtain them? What are the uses of the various parts of the plant? What is the meaning of the different forms of stems? What of the arrangement of the leaves? How are the seeds formed?

The study of these questions with the plants themselves will suggest many other questions pertaining to the contrivances by which each kind of plant, thru leaf, stem, branch and root, and the various parts of each, is adapted to its particular kind of life. Studying a plant from these points of view will not require learning the names of the parts of the plant except where there is occasion to use the name, nor the learning of the technical names of the forms of leaf, stem and root, which are used very rarely except in technical descriptions in systematic botany. Altho these have in the past formed a prominent part in the conventional courses in botany, they should have little or no part in Nature Study by children.

The Plant's Food.

The food of plants consists mainly of (1) *carbonic acid*, obtained from the air, and (2) *water*, obtained from the ground; also (3) a small amount of various substances dissolved from the soil by the water.

To show that plants take up water by means of roots and root-hairs, dig up a plant and carefully wash the dirt from the roots, harming the root and root-hairs as little as possible. Place the root in a bottle or flask, allowing the stem to pass thru a cork. The cork is slit and placed around the stem. Thru the cork also extends one end of a glass tube bent in such a way as to form a

guage. The tube is filled with water. Very soon the water descends in the tube and continues to do so rapidly, showing that the plant is using up the water. The cork ought to be covered with paraffine so that evaporation from that source can not take place.

This apparatus may be balanced on a pair of scales, or a pot with a growing plant in it may be thus balanced, and it will soon show loss of weight. (A simple and effective pair of scales may be made by the children of a rod of wood eighteen inches long, strings and two pieces of board six inches square.) To show that the water escapes from the plant by the leaves, allow the leaves to rest on the polished surface of a cold piece of glass or polished steel.

If this plant, or a plant in a pot is inclosed by a bell-jar or glass shade, the water coming from the plant will be condensed on the sides of the glass.

To trace the course of the water absorbed by the roots, place a solution of some aniline dye in the water (eosin is good.) The coloring can be traced in the stem, if translucent, and thru the veins of the leaves after some hours or a day.

These experiments may well be followed by an examination of the epidermis of a leaf with the microscope to see the stomata, the openings thru which the water passes. By tearing the leaf crosswise portions of the thin transparent skin which covers the leaf can be obtained, mounted in water, and the outline of the epidermal cells may be seen. Notice also the curved cells bordering and making the stomata.

Thru these not only does the water go out, but the oxygen sometimes passes out and the carbonic acid passes in (sometimes oxygen comes in). Thus it is seen that thru the root-hairs the water and certain substances dissolved in water, and thru the stomata in the leaves the carbonic acid enter as food. The water passes up thru fibers in the root, from these thru fibers in

the newest portion of wood and bark of the stem, and from these again thru the fibers of the veins of the leaf. Now the water and carbonic acid are together in the green part of the leaf. In the presence of the green substance of the leaf called chlorophyll, by means of sunlight, the leaf changes the water and carbonic acid into starch, which is a plant substance from which other plant substances are made by the plant. The starch may be changed to sugar, this in solution may pass over the fibrous pathway in the veins of the leaf and in the stem to serve as nutrition for growing parts or be deposited as sugar or changed to starch again and stored up for future use.

The importance of the leaves and the meaning of their arrangement on the stem are brought out by these facts. The leaf presents great surface to the air and to the light. They are arranged on the stem in such a way that they are well presented to the light and at the same time shade their fellow leaves very little or none at all. Gather branches of various plants and examine the disposition of the leaves with reference to this fact. Whole plants, such as the geranium, begonia, filarilla, turnip, and in fact any plant will illustrate well how the leaves are arranged on the plant to occupy spaces unoccupied by other leaves, and presenting their upper surfaces to the light without shading those below. This method of arrangement of leaves sometimes throws them into a rosette, compact or loose, sometimes into a mosaic. The live-forever and young filarilla are examples of the former, while certain forms of ivy and of maiden hair ferns of the latter.

Fruits.

Lessons with the various common fruits may with profit be given thru August and September. These may be adapted to all grades. The lessons on distribution of seeds have explained the use of the edible parts of many fruits. It may be shown how cultivation and selection have changed fruits to the form most

desired by man, sometimes to the detriment of the seeds themselves. The lessons may include the structure of some of the following kinds of fruits. Let each pupil have at least one specimen of the fruit studied. Have him cut into it and examine carefully all its parts and just how they are arranged in reference to each other.

The peach, plum, cherry, apricot and raspberry. (These are called by the botanists drupes).

Gooseberry, orange, grape. (These are known as berries).

The apple-like fruits.

The melons, cucumber and squash.

The tomato.

The fig, the pod fruits, the winged fruits (maple), the strawberry. Any kind which any pupil may find, either wild or cultivated, should receive attention.

Ripening of Fruits.

In some of the upper grades the question of what takes place in a ripening fruit may well be investigated. It has just been seen how the leaves in the presence of sunlight make starch out of carbonic acid and water. Further it was shown that starch in the leaves is changed to sugar or into some other soluble substance, and may then be distributed to different parts of the plant and changed to starch again.

The fruits serve to illustrate some of these changes. A few simple experiments can be performed which will make clearer these facts. A good test for the presence of starch is needed. A solution of iodine is used for a test for starch. A solution of iodine gives starch a blue color and thus proves its presence even where mixed with other substances. A solution of iodine is made by dissolving a few crystals of iodine in a solution of iodide of potassium.

To show how the iodine acts on starch, a drop may be placed

on a little powdered starch, or in water in which starch paste has been mixed. It shows a blue color. If a drop of iodine is placed on a fresh-cut slice of a potato or with the scrapings from the slice, it gives the same color.

If a potato has been allowed to sprout and the sprouts grow until the potato becomes watery and shrunken, it will not give the blue color. The starch has disappeared.

With a microscope one can show the starch grains in the cells of the potato by examining a thin slice. This, stained with iodine, will show the starch grains blue. In the sprouted potato, the cells will be seen empty of starch grains.

The change from starch to sugar may be shown well with barley grains. Crush grains of barley and with the iodine show that they contain starch. Sprout other barley grains by keeping moist and warm. When just beginning to sprout, stop the process and dry thoroly with gentle heat (do not scorch); these grains will be quite sweet to the taste showing presence of sugar.

In many fruits, starch is first formed in the green fruit which is changed to sugar on ripening. A green apple will show by iodine the presence of starch in abundance, while the ripe apple will show the absence of starch and the sweet taste shows that sugar is present.

It may be taught in this connection that the digestion of starch in the human body by the saliva and by the pancreatic juice is a process exactly similar to that in the potato, grains and fruit. In the plant, the starch is changed to sugar by a substance in the plant's juices, and in the body, by a substance in saliva or pancreatic juice.

In the plant, the sugar is food for growing cells in the sprouting tuber or grains; in the body, sugar is food for the action or growth of the cells of the body.

The Pine Tree.

In very early spring the pine trees in the neighborhood may be observed with interest. The growing branches, the main axis of each, the terminal bud and the small side branches containing the young needle leaves may be made objects of observation. The branches which become flowers may be noted. The one kind furnishes an immense amount of pollen, the other constitutes the young cones. In the one see just how the pollen grain is borne; in the other, just where the ovules are located, that is just at the base of the scales making up the cone. In the older cones, find the seeds. These have developed from the fertilized ovules. The ovules must receive the pollen grains before they can develop into seeds. How does the pollen reach them? The settling of this question will bring out the advantage in producing such immense quantities of pollen. It insures that the chance currents of wind will carry the pollen to the young cones.

The microscope will show the interesting form of the pollen grains, and how, by sort of minute wings, they are better carried by the wind. The yellow dust on the sidewalks or on little pools after a wind-storm at this time of the year is pine pollen. The microscope will prove this.

Having seen how the pollen-producing flowers (staminate) and the cones (pistillate) of the pines are arranged, the same organs in the redwoods, cypress, firs, cedars, and whatever cone-bearing plants which may be in the region of the school, may be observed. The parts of these organs are essentially the same, altho the size and shape of the cones differ greatly. This, of course, gives an excellent opportunity for an exercise in making comparisons and drawing conclusions.

The parts bearing the pollen and the cones with the ovules were referred to as flowers. While they are essentially flowers they are not called "true flowers." This term is applied to those flowers which have their ovules in a closed case as in the lupine

and poppy, as seen in other lessons. The pine and all cone-bearing plants have their ovules lying exposed on the scales of the cone. However, after fertilization of the ovules the scales grow so that they are crowded tightly together and thus remain until the seeds are ripe and ready for distribution. In this way they are well protected. The seeds are in some pines two years in ripening. The pupils may determine this point for the conifers to which they have access.

Parasitic Plants.

In the lesson on the plant's food only those plants were referred to which made food for themselves out of carbonic acid and water, and matters dissolved in water. Two very common plants may serve as examples of those which rob other plants of nutrition gathered by them, the Dodder and Mistletoe.

Dodder.

While hunting for examples illustrating seed-distribution, in July to September, the pupils will likely come across a curious parasitic plant known as Dodder. As it illustrates the life of a plant without roots or leaves using those of other plants, it makes an instructive lesson.

The dodder occurs as slender leafless vines twining about the stems of other plants, sending into their leaves and stems little processes by which they suck the juices of the host, which supplies them with their whole nourishment. This parasite relying on the leaves and roots of its host has none of its own; the leaves may occur as the merest rudiments. It bears flowers and these form seeds. The seeds germinate in the ground. Thus, at first, the plant has a root which serves its purpose until it can grow up and attach itself to its host, when it discards its roots. There are different species of dodder. One very common one in the coast marshes forms conspicuous orange patches of fine tangled vines. Another is of pale yellow color and is found on many kinds of plants more commonly growing in low, moist situations, altho found sometimes in the fields and hills. These plants belong to the same family to which the morning-glory belongs.

Mistletoe.

The study of the robber plant, dodder, will almost surely suggest to many pupils the question of the life of the Mistletoe.

This is very common and specimens are readily obtained, and the facts of its life ascertained. Here we have a plant that is not completely parasitic as is the dodder. Its roots penetrate the limbs of the tree host and draw nourishment from it. But it bears leaves which take food from the air as do the leaves of other plants. The seeds are covered with a sticky substance by which they adhere to the bills or feet of birds and are thus carried to the limbs of trees. The most conspicuous species in California is the one growing on oaks. There is another less conspicuous one with smaller leaves growing on the pines. Have the pupils see by a cut section how the attachment of the plant is made to the host.

Eggs of Frogs, Toads and Salamanders.

Toads, frogs and salamanders (water dogs, mud-puppies) lay their eggs in water. Here the eggs hatch out into tadpoles. In the tadpole stage they breathe by means of gills, at least in the earlier part of this stage. Later they gradually develop lungs and finally become air breathers. The toad and frog tadpoles gradually lose their tails by absorbing them, while a

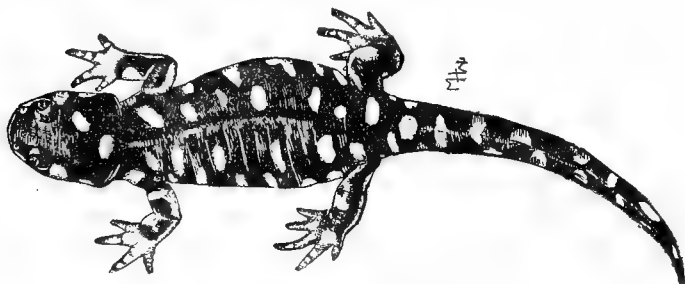


Fig. 79. The tiger salamander.

salamander tadpole's tail develops to a considerable size and is retained thru life as a swimming organ to be used when the animal goes to water. One of the most common salamanders in California is the red-bellied salamander which is found in great numbers in the ponds and streams in winter during the egg laying season. The spotted tiger salamander, fig. 79, is also to be found. Any of the salamanders may be kept in a box, the bottom of which is covered with moist earth in which ferns or moss is growing. In winter the red-bellied salamander does well in the aquarium, or any vessel of water. It should be well fed with earth worms.

The eggs of toads, frogs and salamanders should be gathered and placed in the aquaria and their development watched. The

eggs of frogs and salamanders are in masses of a transparent jelly-like substance which is attached to sticks on plants in the water. The eggs themselves are little round bodies embedded in the jelly. The eggs of toads are in strings of a jelly-like substance.

These may be obtained during the winter time. Secure some and place them in a jar of water. Put a few eggs in a single jar. Do not have the water very deep. Keep a very small amount of green algæ in the jar. The development of the eggs into tadpoles, and of the tadpoles into adult animals may be watched day by day with great interest if they are kept successfully. If the eggs are obtained while in the earliest stages of development, the fact can be clearly seen with a hand lens that the little globule which constitutes the egg is at first a smooth sphere, and then soon it has a crease formed on its surface dividing it into halves, that these again divide and so on till the divisions become so small that they can no longer be seen. Of course the full significance of this fact one would not attempt to teach here, but it is well worth seeing as a fact. Then every step of formation of body, head, limbs, tail, etc., may be noted as the process progresses.

Snails and Slugs.

These animals are so familiar that they will be recognized without description. The slugs are in form and anatomy and habits of life about the same as the snails, except that they have no shell. The shell of the snail of course offers it protection against outside attacks, and gives it a place in which to withdraw when the air is dry. But snails and slugs require a certain amount of moisture in their surroundings that they may move about, and feed and lay their eggs. The pond snails of course live in the water. The large orange or yellow colored slug to be found in some parts of California is a giant among slugs.

Land snails and slugs may be easily kept among the plants in a moist space, or under a glass vessel, or in a fernery. They live on vegetable food. The pond snails live well in the aquaria. The parts that may be studied are: Their method of locomotion, their feeding, their breathing, their eye and touch tentacles, their general habits of life. The eggs are very interesting objects. Even under a low power what can be seen of the gradual change from a small round single cell, to the form of an adult snail or slug is very interesting. Pond snails will often lay a bunch of eggs against the side of the aquarium in a good place for observing the development with a lens. In the spring and summer large numbers of these eggs may be found on the weeds in ditches and ponds.

Land snails and slugs lay their eggs in moist places such as under stones, pieces of wood, leaves or in moss. They may be obtained if the animals are kept in confinement under the proper conditions at the right season.

Earthworms.

These animals are so abundant, easily kept, and have such a wealth of literature in regard to them both in respect to their natural history and concerning their structure, development and physiology, that they become valuable as school material.

For lessons, without going into the technical matters of their structure and development, there is good material in the habits of life of these animals. Among these are: Their method of locomotion, just how it is accomplished. This will require observation of method of elongation, of shortening of the body, of the use of the mucos, of the position and method of using the minute projections, found in rows along the sides of the body (called *setæ*); their method of making and using their burrows; their method of feeding; their egg-laying and the hatching of the eggs; their work in relation to the soil as shown in the work by Darwin on "The Formation of Vegetable Mould by the Action of the Worms." This book is very interesting and is instructive beyond most books of its kind, giving, besides a wonderful chapter on natural history, illustrations of how great things in nature are accomplished by insignificant and quiet agents, and how the patient, scientific method of observation and study may reveal the most wonderful operations going on under our very feet.

Earthworms may be kept indefinitely in a box half filled with moist earth with a tightly fitting cover of either glass or wood. The earth should contain decaying vegetable matter and should be kept moist.

Covering of Animals.

The coverings of animals are adaptations to the conditions of their life, and are all interesting objects of study. Hair, scales, thick epidermis, bony plates, spines, and feathers of various forms are in endless varieties.

Feathers.

Feathers are characteristic of birds and are very interesting when their true meaning is seen. For a lesson on feathers, provide a bird freshly killed, a duck or a fowl from the market, and a quantity of feathers sufficient to allow each pupil to have examples of each kind in hand during the lessons. If the question is asked: "What is the use of feathers?" the answer that will usually come is: "To keep the animal warm." This is one

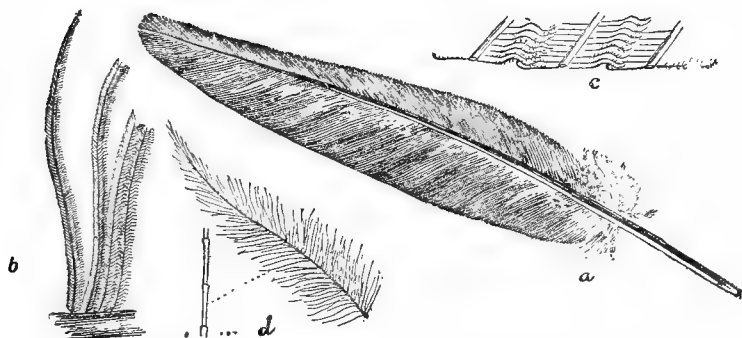


Fig. 80. A feather, also separate parts magnified; a, quill feather of a pigeon; b, four barbs (magnified) from the vane, showing the barbules, some separated, some still clinging together; c, a cross section of three barbs showing how they cling together; d, a barb and barbules of the down; at one side a barbule more highly magnified. These always remain loose.

use of feathers, but the lesson is to show that this is by no means the only one, perhaps not the most important one. (The uses are

not to be told, but if possible to be brought out by the observation of the pupils.)

First of all, feathers are different in kind and have different uses. The most characteristic, or special use is for flight. For the water birds the feathers are arranged as a boat in which the body can float. The bird would sink without its feathers. For all birds, feathers keep warm in cool weather, protect from the rays of the sun in hot weather, protect from rain, from scratches and other mechanical injury in flying, or in running thru brush, etc. They serve as ornamentation to distinguish each other and to attract mates.

Examination of feathers. To have a basis for comparison examine the parts of a single feather, *e. g.*, a wing feather (fig. 80). It possesses an axis, running its length, called the *stem*. The hollow part is the *quill*. The whole of the broad portion is the *vane*. The axis of the vane is the *rachis*. The branches of the rachis are the *barbs*, and the minute branches of the barbs are the *barbules*.

The *wing* feathers and often the tail feathers are large and strong. The barbs and barbules of each feather adhere quite firmly, and the feathers overlap so that when the wing is extended it presents a broad, firm surface with which to strike the air. Have the pupils separate the barbs and barbules, smooth them till they again adhere, and examine them with a microscope or hand lens to determine how they adhere.

The *contour* feathers are those all over the body whose ends come out on the surface and overlap one another like shingles on a house. The barbules on the outer ends adhere as in the *wing* feathers. These thus fitting over each other make the outline of the body, and when well oiled, as they are in many birds, they make a good waterproof coat. The inner ends have barbs and barbules, very fine and not united, being downy.

The *down* feathers have all their barbs very fine and diffuse.

These feathers have minute quills, and being next the body are for warmth. They make a soft backing for the contour feathers, and thus also give protection against injury, and help make the "float" for the swimming bird's body to rest in.

Many birds have oil glands at the root of the tail from which they get oil to rub on the feathers.

Ornamental feathers of many forms are interesting—such as those in the tails of roosters, peacocks, etc.

The color markings on the feathers of birds may form a series of good lessons. How they are arranged; how they sometimes extend from feather to feather to make definite figures, etc.; how in some the markings are stripes so arranged that the birds can hardly be seen in the dry grass; in others, brilliant to attract the attention of mates, etc. Always, if possible, procure the bird for the lesson.

The *moulting*, or shedding of feathers is an interesting subject. Why do birds moult? How often? In what manner? These are some of the questions to be put. Most birds moult annually, some twice a year. (Ptarmigans in fall get a white plumage so they may not be easily seen on the snow; in spring, a brown to enable them to hide in weeds, rocks, etc.)

There are muscles under the skin by which birds can raise their feathers. Some of these are strong as in the crests of some birds, and in the tails of turkeys and peafowls which have the habit of strutting.

If the feathers be removed from the bird, and the naked skin observed it will be found that the feathers have very different kinds of arrangement. The arrangement differs in different kinds of birds. There are naked patches, and patches covered with feathers, and in the latter the feathers are arranged in rows. In some forms this definite arrangement is not so distinct as in ducks, chickens, and our common birds. The children may from time to time compare forms.

NOTE.—These lessons on feathers may serve as suggestions for lessons on the coverings of other animals.

Marine Life.

The waters of any portion of the coast furnish material for the study of marine forms. In the markets there are exposed for sale many forms brought in by fishermen from the grounds along the Coast. It would take a long time to exhaust this large field at the very doors of the schools. Many forms may be collected by the pupils for the school work, others may be obtained in the markets or thru fishermen at a trifling expense.

Shrimps.

Shrimps may be obtained in the market. It would be well to begin with live shrimps kept in a jar of sea water. They will live quite a while in fresh water. Their motions are to be observed, by what parts they are accomplished, and how. The dead shrimp is then studied, its appendages (antennæ, jaws, legs, and swimmerets) are examined and the attachments to the body, the joints and forms and uses of each; the body, its divisions and the joints which make it up. The two parts which in the insect are known as the head and thorax are, in the shrimp, fused into one case known as the cephalo-thorax. The part posterior is the abdomen, corresponding to the abdomen of insects. The shrimps in the aquarium will feed on shreds of meat.

Lobsters.

Lobsters may be obtained in the market (not alive). Those which are red have been boiled. The form is to be studied in the same way as that of the shrimp, and then the two compared, and the pupils will readily perceive that they are very much alike thruout, altho at first they appear so different. Fresh water crayfish can sometimes be obtained in the market. It is well to compare this form with the lobster.

Crabs.

Crabs may also be obtained at the market. There is an abundance of small crabs to be found along the marshes and creeks coming into the ocean. If some of these are placed in a jar half filled with sand moistened with sea water, they will remain alive some time, will burrow in the sand and their motions and habits may be studied.

The study of the parts of the crab will show it to be of the same plan and structure as that of the shrimp and lobster. The cephalo-thorax is, however, very broad, and the abdomen very small and narrow and folded up under the cephalo-thorax.

Have the pupil compare the three limb by limb. Preparations of each of these make interesting additions to the museum. These forms are of the group Crustacea.

After the above forms are studied, a good lesson may be made by comparing the structure of a shrimp and an insect (grasshopper or beetle).

Clams.

Clams may be obtained in the market, or, as some of the pupils well know, by digging in the mud at low tide in certain situations. The clams buried in the mud have what are called "long necks." This is a projection reaching from the body of the clam, as it is buried some inches below the surface of the mud. It contains two tubes, one of which brings water to the body of the animal, while the other carries a stream of water away from the body. The animal may thus hide away in the mud and yet have a current of sea water loaded with oxygen and the fine particles of food on which it lives flow thru it, passing its mouth and over its gills. In the study of the body, the shell, its hinge, its muscles, the body, the gills and the "foot," are to be looked for. In some of the higher grades these points in structure may be made out, and then the pupils led to find the same, if they can be detected, in mussels and oysters, forms without the "neck."

Ants' Nests.

An exceedingly interesting and instructive object for pupils of all grades is a colony of ants so kept that they can be observed in their daily work in and about their nests.

Students of ants have devised various means for thus arranging their nests. One method is to place the colony in a glass jar partially filled with earth. The mouth of the jar is covered with gauze or netting to prevent their escape. The jar should have its sides covered with a thick dark cloth, which can be removed to make observations. In capturing the colony, the queen should be obtained if possible. Soon after the ants are placed in the jar with the dirt, they will begin to make excavations, and some of their tunnels may be against the sides of the glass. If this is fortunately the case their life in the nest may be observed.

A much better nest was devised by Sir John Lubbock. It consists of two sheets of glass of about 8x10 inches. These are held apart at the edges by narrow, thin strips of wood, about the thickness of a lead pencil, the thickness being but slightly higher than the ants to be confined. These strips are placed between the sheets at their outer edges. At one corner a space of about a quarter of an inch is left, which is to be the door for the entrance and exit of the ants. The remaining space between the glass sheets is filled with pulverized earth, very slightly moist.

This is to be the nest. This is placed in a shallow box a few inches wider each way than the nest. Around the edges of the box is tacked a strip of fur, which acts as a fence to retain the ants within bounds.

The margin between the nest and sides of the box give a space for the ants to wander about in, and in which to place food and water. A piece of cloth should cover the nest. A large sheet of glass may cover the shallow box to prevent too rapid evaporation.

The next step is to capture the ants and induce them to enter the nest. A colony of ants with the queen is captured as before. The queen may be distinguished from the workers by her larger size. They may be brought home in a glass jar mingled with the earth of their former nest. The whole mass of ants and dirt is placed on top of the nest prepared as above. The ants, as this dirt dries out, bury themselves deep in it. Scrape away and remove all the dirt that you can from the mass from time to time. This reduction of the dirt in which they are hiding leads them to look for other quarters. They will be likely to discover the door left for them, at which point they will begin to excavate a tunnel into the prepared nest. This tunnel finally becomes a system of tunnels and passages, forming their new home. In this can be studied the wonderful life of the colony, by removing the black cloth. The ants must be well fed and watered. Sugar, bits of meat, crumbs of bread, and seeds of plants are foods of different ants. This nest may be kept for a long time. For fuller accounts consult Lubbock's "Ants, Bees and Wasps," International Scientific Series. There is an excellent description of an ant's nest in Comstock's *Insect Life* (Appleton) page 276.

Gases.

Oxygen.

The air contains constantly oxygen, nitrogen, argon, carbonic acid, and vapor of water. The first two make up the main bulk of the air, the last three are very small in amount. We wish to study each of these gases, except argon, a recently discovered one, which in this work we cannot make or isolate. Oxygen can be made and studied with very simple apparatus.

The materials used are *potassium chlorate* and *black oxide of manganese*. The potassium chlorate gives up the oxygen it contains very readily on heating. In fact it is liable to give off such a large quantity of gas at once, as to produce an explosion. Consequently we mix with it the black oxide of manganese, which seems to retard the giving off of the oxygen.

Mix well equal amounts of the two substances (fig. 81.) A test tube one-third full will make sufficient gas for the work. Fit the test-tube with an air tight cork and a glass tube to carry off the gas. To catch the gas, have ready at least five wide-mouthed bottles (8 to 15 oz. in size). These are filled with water and inverted in a pan of water. The delivery-tube carrying the gas from the test-tube is bent so that it can be made to conveniently reach under the mouth of an inverted bottle. When all is ready, with the alcohol lamp heat the potassium chlorate and black oxide of manganese mixture and the gas will rapidly come away and bubble up into the inverted bottle, displacing the water and filling the bottle. Then another bottle is brought over and so on, till all are filled, or the oxygen gives out.

In beginning to apply the heat, do so at first gently and to the upper part of the test-tube. This will heat the tube and prevent moisture forming on it later and breaking the tube. Next heat the upper part of the potassium chlorate mixture, first ex-

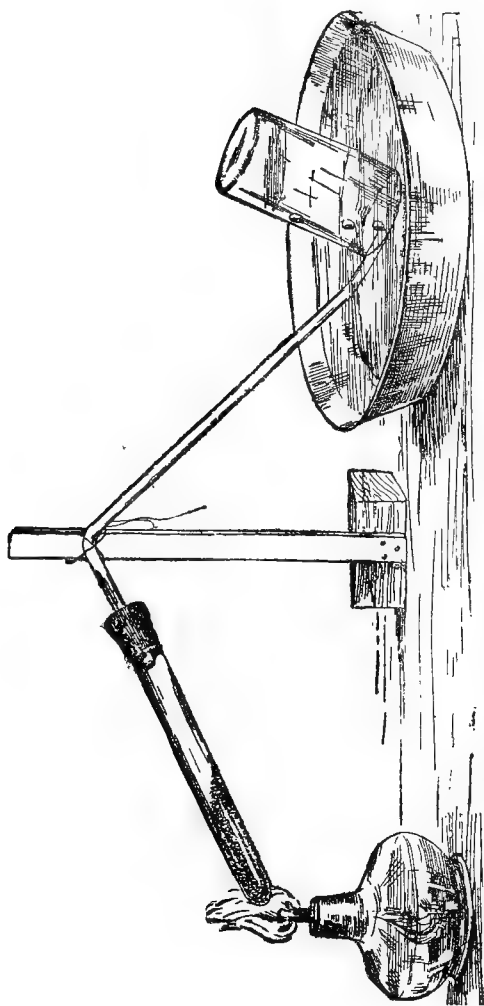


Fig. 81. Arrangement of apparatus for making oxygen and catching the gas. The material is in a test-tube; the delivery tube is glass. The gas displaces water in a wide-mouthed bottle.

hausting its oxygen, then work downwards. If you begin at the bottom of the mixture, as the gas comes off, it is liable to puff the black dust up and choke the delivery tube. After once beginning to make the oxygen, the lamp flame must not be taken away from the test-tube while the delivery tube is under water. The cooling of the tube will contract the gas, and water will rush back and break the hot tube.

All the apparatus may be held with the hands. One pupil may attend to the bottles; one hold the test-tube, using a thick handle of paper as a holder; another may manage the lamp. A stand and other conveniences may be used. For descriptions and figures see any elementary text-book in chemistry.

NOTE—Every single operation of the above should be questioned about, and explained by the pupil, as every step is a good lesson.

Now that we have five or more bottles of oxygen, they may be tested as follows:

Into one bottle, have one of the children insert a lighted splinter. Let the fire be extinguished except a small glow at the end. Also have a small piece of lighted candle attached to a wire thrust down into the jar.

A piece of sulphur may be burned in the next jar. A little cup made from a piece of crayon fastened to a wire can be used to hold the lighted piece of sulphur while inserting it into the jar.

A fine iron or steel wire may be burned. The wire may be bent into a spiral form by wrapping it about a round lead pencil. To one end of the wire attach a very small splinter, or bit of sulphur to serve as a lighter. The wood or sulphur is lighted, and the wire thrust into the jar of oxygen.

To burn charcoal, a charred splinter, or a glowing coal fastened to a wire may be used.

A brilliant effect is produced by heating a teaspoonful of

finely powdered charcoal to a glow, and then letting it fall into a jar of oxygen.

The burning of phosphorous gives the brightest light. Phosphorus must be handled with care. It is best to use a pair of forceps, and cut the piece to be used under water. Dry the water off with blotting paper. It lights easily by friction, and a small piece of burning phosphorus on the hand makes a painful and bad wound. It is poisonous. Handled carefully there is no danger. All small pieces must be picked up and put back into a bottle of water where it is best kept. The phosphorus is burned in the crayon cup as was the sulphur.

Now questions will arise as to what are the results of the burning in each case. The white smoke in the last is a combination of oxygen and phosphorus, and in each of the other cases an oxide is formed *e. g.*, of carbon, of iron, and of sulphur. Each of the above experiments should be repeated until it is clearly seen just what has taken place.

These experiments are so interesting to children, that they will not mind having them repeated many times. This is good for giving them clearer notions, better command of handling apparatus, and a familiarity with the facts.

Carbonic Acid.

Most of the children have learned that there is carbonic acid in the air; that it comes from the lungs in air breathed out, and that it is made by burning lamps and candles.

As a good test for the gas will be of great service, it would be better at the very start to explain how lime water is so used. Lime water is readily made by putting some lime into water and allowing it to stand until the excess settles, leaving the solution above clear. Pour off the clear liquid for use. It can be purchased ready made at the drug store.

A small amount of carbonic acid shaken up with the lime

water makes a white substance in the water, thus giving a milky appearance. The substance formed is carbonate of lime.

One of the children can breathe air thru a small amount of lime water in a test-tube or other glass vessel. The lime water turns white, thus proving the presence of carbonic acid.

A bit of a candle is placed in the bottom of a glass tumbler, which is covered with a book. The candle soon goes out. Test the gas left with lime water.

An inverted glass is held over the chimney of a burning lamp. Slip a card over the mouth, and test the carbonic acid. The gas coming from various burning substances may be tested.

To make carbonic acid in a quantity unmixed with air, etc., pound up into small pieces limestone or marble; place in a wide-mouthed bottle or flask, into which is fitted a cork and delivery tube. Cover the marble with water, then pour in some muriatic or sulphuric acid. Bubbles of carbonic acid come off rapidly. As it is heavier than air of the same temperature, it can be caught in empty jars or bottles standing upright, lightly covered with cards. When a few jars have been obtained, try them with lime water, lighted candles, lighted splinters, etc. Show that the gas is heavier than air by pouring carbonic acid into a jar which contains only air, then testing this jar's contents; or pour some into a jar at the bottom of which is a lighted candle.

Many other experiments can be made with the carbonic acid, making the pupils familiar with its properties.

Diffusion of Gases.

That gases diffuse themselves out into the air from the vessels which contain them, may be shown by leaving a jar of carbonic acid uncovered for a short time. Altho heavier than air, it leaves the jar. An inverted jar of oxygen will show the same. Altho lighter than air it will not stay in the jar. The same is true with illuminating gas, vapor of gasoline, of ether, etc. These experi-

ments make it clear why the different gases in the air are thoroly mingled, instead of the heavier settling to the bottom and the lighter going to the top.

Making Gas.

The process of making illuminating gas may thus be illustrated:

Into a test-tube place bits of wood, shavings, or sawdust. Arrange apparatus as in figure 81. A delivery-tube is fitted to this, as in making oxygen. Jars for catching the gas are arranged also as in the oxygen experiment. The test-tube full of wood is now heated, and the gas coming away is caught. The first gas coming off is heated air from the tube. Later, gas from the decomposing wood will fill a small jar. This gas may be lighted, and it will be seen to burn with a blue flame. It is a mixture of gases.

In the test-tube is found carbon, the charred remains of the wood. The delivery-tube will be coated inside with tar. If a larger apparatus be used, say an iron retort (this may be made of iron gas pipe), a greater heat may be used, and coal may take the place of wood, and by this means a considerable amount of gas can be obtained.

It may now be shown how, in making illuminating gas, a very large retort is used; arrangements are made to separate the tar and other substances from the gases; also those gases in the mixture which interfere with the illuminating power; show that the large iron gas tank corresponds to the jar catching gas in the experiment.

A visit to the gas works will now be of great interest, and the main processes there carried out can be clearly understood.

The Candle Flame.

The special study of the candle flame will be best taken up some time after the making of gas out of wood. The pupils are

to find out that it is a gas flame, the brilliant light being produced by minute particles of carbon becoming incandescent as they pass from the central portion, where no combustion is going on, thru the part lying just outside of this where the gases are in active combustion. The gases which burn and the carbon which thus makes the light and is finally consumed, are all from the oil of the candle being decomposed into these products by the heat, just as the same products are made out of coal by heat in the process of the manufacture of illuminating gas, and in the making of gas out of wood in the experiments already given. None of these facts is to be told at first.

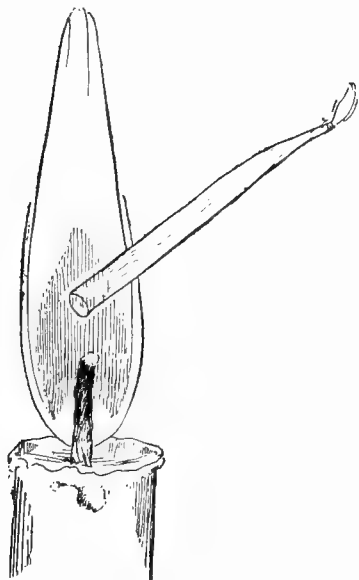


Fig. 82. Candle flame showing the four parts described in the text, also showing the method of introducing a small tube into the dark position in the center to conduct out the gas.

By cutting a few candles into short pieces each pupil can have his own flame to study.

Let each try to make out the parts of the flame (fig. 82). It will be found that there are four: the blue cup at the bottom; a thin, almost transparent outer sheet of flame; a brilliant light-giving part just underneath this; and a dark central portion. In the dark central portion is a mass of gases charged with black floating particles of carbon (smoke). If a sheet of paper held horizontally is suddenly thrust down on the flame to about its middle and held for a short time, but removed just before it breaks into a flame, a round ring is scorched on the paper corresponding to the two outer coats

of flame. The center is unscorched and may be blackened. This is where the dark central portion of the flame was in contact with the paper. If a splinter of wood is held across the flame a short time, it will be scorched where the outer coats touch it, but unscorched where the central portion meets it.

A very small glass tube three or four inches long may be thrust into the central portion and the outer end inclined upward. In this position it will tap the central portion, when smoke will issue from the tube. This may be lighted, and thus give us a new small flame, showing that the central portion is composed of combustible gases,

The blue cup at the bottom is just in the position where the ascending currents of air strike it to the best advantage, and insures good combustion without smoke and floating particles of carbon. This gives great heat, but little light.

The air reaches the two outer coats of the flame, and combustion takes place in them. In the one next the dark center the carbon particles, as has been said, are passing thru and glow with a bright light. They are completely burned in the outer coat.

That particles of carbon may make a colorless flame bright may be shown by sprinkling lamp black or powdered charcoal into an alcohol flame. On the other hand, if with a glass tube drawn out to a fine point, or with a blow pipe, air is blown well into a candle flame, the whole of the flame will become blue, no longer giving out much light.

A better supply of air makes a more prompt combustion of all gases and carbon, but with the result of less illumination.

If the supply of air to the candle flame is interfered with, the flame smokes, much of the carbon and gases escaping unconsumed.

The smoking lamp or the smoking fire means poor combustion. In each case the smoke can be reduced by a better supply of air. Questions may be proposed which will explain the

advantage of lamp chimneys, smoke-stacks, tall chimneys, and other devices for causing better combustion.

Cooling the candle flame by thrusting into it a cold substance, such as a bar of metal, causes it to smoke. Carbon burns only at a high temperature, and in this case much heat is lost to the cold substance.

Those substances which contain much carbon, such as turpentine, camphor, and sealing wax, may be made to give out a very black smoke. The carbon may be caught as soot or lamp black, which subsequently can be burned.

In general, we depend upon the carbon for the light in the illuminating flame, but in the calcium light a very hot flame is used to heat a piece of lime (calcium oxide) to a white heat, which gives out the bright light. In the stereopticon, oxygen and illuminating gas are used to heat the lime. In the class room a blow-pipe and an alcohol flame can be made to give a bright glow to a piece of lime sufficient to illustrate this point. In burning a bit of magnesium ribbon, it is the white dust, the magnesium oxide resulting from the combustion, that gives the light.

The foregoing should be broken up into many lessons. These will suggest many others. The applications of what has been given are very numerous, and if well followed out will make clear many things in every day's experience with lights and fires.

Magnetism.

Magnets.

For lessons on magnets an ordinary horse-shoe magnet, such as any boy may carry in his pocket, will answer. It is well also to have a bar magnet.

Provide some small articles of soft iron and of steel. Ordinary knitting needles or sewing needles will do for steel. Try the soft iron first. It will readily be drawn to the magnet. While it is still attached, put the free end of the soft iron into iron-filings. Then withdraw the magnet. What happens? Try the same with a piece of steel. If you have pure soft iron, it will be found that it remains a magnet only when in contact with a magnet, but that steel retains its magnetism for some time. Let the children find what things are attracted by the magnet, what not.

Sewing needles may be magnetized by drawing one pole of the magnet several times across them, drawing the magnet only one way. A needle is conveniently suspended by being thrust thru a cardboard triangle, and the triangle suspended from one of its points. Note in what position the needles come to rest. Suspend two needles near together and bring two south poles together. What happens? Bring two north poles together. What happens? A north and a south? The facts of attraction and repulsion may be shown as well by using one needle and a magnet, but care must be taken that the magnet does not come into contact with the needle, or the poles of the needle may be reversed. For reason see some text-book on Physics. The compass may now be brought in and the class will be able to see that it acts in the same way as their suspended needles. It may be interesting to children to know that the earth acts as a huge magnet, but that its magnetic poles do not correspond with its geographical poles. The magnetic needle does not point to the true geographical north, but to the east or west of it. At

Stanford University the compass points 19 degrees east of the true north. (1899.)

A pretty experiment to show lines of magnetic force can be performed by shaking a few fine iron-filings over a piece of paper or glass under which the magnet is placed. If the lines do not form at once, shake the paper or glass gently.

The children may be interested in finding out about natural magnets, how magnets are made, and their uses.

Variation of the Magnetic Needle.

To determine the true direction of the magnetic needle (that is, the "variation of the needle"): After dark on a clear night suspend two plumb lines (threads with weights attached about one foot apart) from suitable supports. The back of a chair may be used for this. Then bring the two stretched threads in an exact line with the North Star. On a support (a box on end will do) between the lines lay a sheet of paper horizontally placed. With a ruler and pencil draw a line on the paper just in line with the two threads. This line, if all is done carefully, is approximately the true north and south direction. By placing the compass on this line, the "variation" of the needle will be found to be about 19 degrees east of north—that is, the true north is 19 degrees west of the magnetic north. This varies in the different parts of the world very much, and is changing, slightly, every year here (Stanford University).

It must also be remembered that the North Star has an apparent daily revolution of a very small diameter about the true north, consequently it is exactly north but twice in twenty-four hours, but it requires more accurate instruments than ours to detect these differences. (See text-books on Physical Geography and Astronomy.)

Many questions will rise in connection with this rather simple experiment, which with some of the grades may be

pursued with profit, such as, Why is a certain star the North Star? the difference between the North Magnetic Pole and the North Pole.

The Pendulum.

The pendulum as our time marker, and its importance in relation to timepieces, is sufficient excuse for making some simple lessons with it as the subject.

Suspend a small weight from a convenient place by a strong thread, thirty-nine inches long, the length counted from the point where the thread is attached to the center of the weight. Have the pupils determine how many times in a minute this pendulum vibrates. If it does not vibrate sixty times in a minute, correct the length till this is its rate. Keep this pendulum as the time keeper for the succeeding experiments.

Have them make other pendulums of the same length, some with much heavier weights and some with lighter weights, and determine if there are differences in the rate.

Have the pupils construct a pendulum long enough to vibrate once in two seconds, and one short enough to vibrate twice in a second. Let them measure and compare these with the seconds pendulum. Do the same for pendulums vibrating once in three seconds and three times in a second. A high ceiling, a window or a tree will give an opportunity for hanging a long pendulum.

The use of the pendulum as a time instrument can now be explained. The importance of accurate and uniform time in business and in railroad and other travel, etc., may be seen. On Mt. Hamilton every day at noon a pendulum in a fine clock stationed there is connected by electric wires with most Western Union Telegraph Offices on the Pacific Coast. In any one of these offices at noon any one can hear the telegraph instrument beating in unison with the pendulum on Mt. Hamilton. Thus all timepieces might be kept in accurate accord with this one.

In other parts of the United States there are centers from which

the time is sent out in the same way over regions assigned to each center.

The story of the discovery of the properties of the pendulum and the effect of its application to time keeping, could be made interesting and profitable. (See Encyclopedia, etc.)

The relation of the pendulum to falling bodies; the effect on the pendulum if the earth were heavier or lighter or if the pendulum were near or farther away from the center of the earth, are subjects which might be taken up in some of the grades under certain conditions, but would perhaps better be deferred at present.

Soap Bubbles.

Blowing soap bubbles is a fascinating exercise for almost any grade, and may be repeated without fear of tiring. They are so familiar to every one that how to make them and what to do with them need hardly be told. It might be worth while to say that for making very tenacious bubbles that will become very large and stand rough handling, use very good soap and rain-water or distilled water. Slice the soap into shavings and make a very strong solution, and mix with this a good quality of glycerine or molasses; the latter is better. It is wonderful what may be done with these bubbles.

Bubbles show the tenacity of liquids (try pure water, alcohol, glycerine, or molasses alone). As the bubbles grow older they become very thin in their upper parts, showing brilliant colors, due to interference of light (see text-books on Physics). They may be made to contain different gases, e. g., air, carbonic acid, illuminating gas, hydrogen, and thus used to show which is lighter than air. To blow bubbles with these gases is somewhat troublesome, as gas bags or reservoirs filled with the gas under pressure are necessary. The clay pipe is connected with a tube from the reservoir, and the gas turned on as required to fill out sufficiently the bubble. One may be fortunate enough to have the gas come off from the

generator with the pressure and regularity necessary to blow the bubbles. In a room, fans are convenient to keep the bubbles up in the air. Placed over a stove or radiator or furnace opening, they will rise with the current of air.

Lead Pencils.

This lesson will make plain the structure and materials of the most common instrument of the schoolroom, the lead pencil.

If possible, obtain some pieces of graphite, also a cake of stove polish, and a tube of bicycle-chain lubricant. For comparison, have a bar of lead. Soak some lead pencils in water until the two parts of wood will separate. Have at hand a series of pencils ranging from very soft to very hard.

Begin the lesson with an examination of the pieces of graphite. The children will note the properties; heavy, black, will rub off easily, and consequently will mark a paper, will soil the hands, etc., (marking by a substance will be seen to be a rubbing off of a part of that substance). It is also very smooth, being soapy to the feel of the fingers. This is *graphite*, the substance which forms the center part of our lead pencils. It is not lead at all. Now compare with real lead. It is soft, will mark a paper also, but is quite different from graphite. Graphite used to be called black lead, and this gave the name to the pencils.

The children may now listen with interest to an account of how lead pencils are made. The graphite is reduced to a very fine powder and mixed with water into a sort of black mud. A similar mixture of fine clay and water is made. Then a mixture of these two is placed in a press, which has for a bottom a sieve-like plate, the holes being the size of the leads for the pencils. Great power is brought upon the press, forcing the thick paste thru the holes. This makes long, slender "leads." These are placed on boards, dried, and then baked in a hot oven.

Two pieces of wood are prepared, as the soaked pencil will show, which are to be glued together. In one is sawed a groove into which the lead fits exactly. After the two pieces are glued together, the whole is turned round or cut into octagonal or other shapes, polished, varnished, and the name pressed on.

A soft pencil has more graphite and less clay than a hard pencil. The hard pencil was also baked with greater heat. Show the use of the hard and soft pencil, and what is a good and a bad pencil. Sometimes fine graphite is sawed into leads without going thru the process of mixing with clay.

Graphite is carbon, the same substance as charcoal, coal, and diamond. It is mined in the United States and England.

Other uses of graphite are as a lubricant, as stove polish, as crucibles. Illustrate and bring out the properties which make it useful in each of these cases.

The wood of the best pencils is cedar, which is almost wholly derived from the swamps of Florida.

Metals and Minerals.

The metals may be made the subjects of a large number of lessons. The lessons may be upon the properties and the *uses* of the metals, such as are found in the house, in the car, in the shop, and wherever the pupil may discover them. Following these, there may be in some of the grades a limited number of lessons on the ores of some of the metals, the location of mines, methods of mining and extracting the metals.

Provide for work with the metals: a file, a hammer, a thick piece of iron to use as a small anvil (a flat iron, sometimes with the smooth side up and sometimes with the pointed side up, will serve well), a knife with a strong blade, a large iron spoon, and a large alcohol lamp, or other method of getting a strong heat.

Begin the lessons with lead, copper, zinc and iron in the form of strips, or of thick wire. These may be examined carefully in respect to the appearance of each, then each tested with the above instruments by the pupils; their properties, the relative hardness, flexibility, action under hammer, file, and knife, and ease of melting. Very small wires of each would allow the comparison of strength of each. If rods of equal sizes are equally heated at one end, the pupils may easily detect, by holding the other ends of the rods, the relative quickness with which they are heated. Allow them to find, also, which tarnishes or rusts most readily. When the properties of each are well seen, have the pupils seek in the next few days' experience the places where these metals are used, and why they are so used in the positions in which they are found.

Of course in some cases properties which the pupil has not discovered, such as its relation to electricity, or such considerations as economy, may have led to the use of the metal in some particular position.

After these lessons, aluminum, nickel, platinum, silver and gold may be taken up and examined in the same way,

Some of the more rarely seen and interesting metals can easily be obtained, such as antimony, and bismuth, beautifully crystalizing, easily melting; mercury, a liquid even at low temperatures; sodium and potassium, which are lighter than water, and burn when they touch ice or water; magnesium, a thin strip of which will burn in air with a most brilliant light when lighted with a match.

Space will not allow the detailed directions for the numerous lessons that may be made with all of these metals. The obtaining the metals (easily accomplished), consultation of encyclopedias and works on chemistry for further facts in regard to them, and experimentation with them, and some ingenuity on the part of the teacher, will supply the details which will make this series sufficient in amount and interest, to extend, with the intervals of other subjects, thru some years.

In this connection are to be examined some of the more common alloys, such as *brass, type metal, solder, gun metal, bell metal.*

The sources mentioned above will also give information in regard to the composition and uses of these alloys.

Minerals make a most interesting and profitable field for nature study. A knowledge of the common rocks of the neighborhood and their constituent minerals would give the teacher a very rich source of material.

The Moon.

A study of the motions of the moon makes a good beginning toward a clear understanding of the apparent and real motions of the sun, moon, and stars.

On the first evening that the moon can be seen after "new moon," have the pupils note how near it is to some star. Venus may be in a good position near the moon. On the following evening they are again to note its relation to this star. They may make their notes by making a sketch of moon and star each night. The changing shape of the illuminated part of the moon is also to be noted each night. Soon the moon will be so far from the star that it cannot well be used to mark the progress. Then another star nearer to it, in its new position, may be used as the mark.

At first only these notes are to be taken. After the moon has made considerable progress among the stars, inquiries may be started as to what is taking place. Most, if not all of the pupils will know that the moon, in common with the sun and with the myraids of stars among which the sun and moon move, rises in the east and sets in the west daily, and they will know that the cause of this apparent motion is the earth's revolution. But most of them will be surprised to find that the moon moves east among the stars. These observations may be carried on and discussed by the pupils until they make out for themselves that this is the motion of the moon around the earth.

The time of revolution may be determined by noting the date when the moon passes some "fixed star" until it passes it again.

If the pupils understand circles and degrees, a simple apparatus can be arranged by which they can determine approximately the number of degrees it moves in every twenty-four hours.

Provide a rod about four feet long, sharpened at one end, so that it may be thrust into the ground (a tripod is more convenient, but more difficult to make).

To the upper end attach a platform of board about four inches square, on which to place a level, by means of which the platform is to be made horizontal. A small iron spirit level can be obtained for fifteen cents.

On the edge of the platform is tacked a thick cardboard with a semicircle drawn on its outer side. The diameter of the circle lies on a level with the surface of the platform. The semicircle is marked off in degrees as carefully as possible, and marked from 0 degrees to 180 degrees, the 90th degree being on the end of the radius exactly perpendicular to the surface of the platform. With this apparatus, using pins as sights, the position in degrees of the moon above the horizon may be read for a few successive evenings at the same hour. See if the rate of movement, thus determined, corresponds to the rate calculated by the observation of how many days the moon takes to make a revolution (360 degrees).

Another line of questioning to be pursued is that in relation to the cause of the changing of the illuminated part. Pupils may, in their own way, prepare models to illustrate this.

Why is one side of the moon always turned toward the earth? How long is the moon's day?

Children from ten to twelve years of age have worked out all the above with no trouble except the setting of the work. This work, of course, must be given out for the pupils to do at home of evenings but if the teacher can meet them, some evenings, much more interest might be aroused. A small telescope, or even a good spy glass, will add greatly to the interest.

After the above work, the pupil can more successfully understand the motions of the earth.

[NOTE.—If the pupils do not know that the “fixed stars” maintain their same relative position, they may be set to watch any group of them for successive periods. The motions of some of the planets among the other stars may, later, be made subjects of observation.]

Pressure of Air and Liquids.

The previous lessons on air and water will have brought out questions requiring some knowledge of the pressure they exert, and the consequent phenomena. It is perhaps better to begin with water. Bodies floating in water may be taken as a starting point. Why do they float? Why do some float with more of the mass above the water than others, while some sink? What happens to the same floating bodies in liquids of different densities, e. g., lighter or heavier liquids?

These questions may be made the guide to a series of experimental lessons with grades above the fourth.

The last of the above questions is a good one to begin with. For the lesson there will be necessary: A small wooden rod one-half inch or less in diameter, and about five inches in length; some small nails, and a piece of copper-wire for weighting one end of the rod; two fruit jars, one filled with water, the other with a strong solution of salt; some small blocks of wood; and some corks. The lesson may begin with the question of how the things will float in two liquids, water and salt solution. If the pupils can be led to invent an apparatus to test the difference, so much the better.

This may be done by first trying the blocks of wood or the corks. It will soon appear that from their awkward shapes and instability in the water, they can not give good results. Then some one will be sure to suggest a method good enough. Most likely the rod of wood loaded at one end will be invented by the class. If not, it may now be brought out, and will be appreciated. It is best not to have the rod loaded ready for the experiment, but reserve for the class the loading of the rod just right to make it float upright in the two liquids, and the marking of the scale on it. With this now ready, have them test the liquids. They find that

the rod floats higher in the heavier liquid. Now make the mixtures of the water and salt solution, and have them predict how the rod will stand, then verify the prediction.

Now other liquids may be tested and compared with water; e. g. milk, kerosene, or a solution of salts other than table salt.

The apparatus may be varied by preparing other forms of floats, e. g., a long, narrow test tube with sand, shot, or nails in the bottom to act as ballast. In the tube may be placed a paper scale. If a lactometer or alcoholometer, or other form of hydrometer (see text-book on physics) can be borrowed to show, and can be made use of, the value of the lesson will be greater. But the pupils will see that none of these instruments is anything more than their wooden rod with a scale.

An egg will float in strong brine and sink in water, and thus is used as a hydrometer. These experiments extended bring the phenomena of floating clearly before the pupils.

Next the question of what makes the bodies float may be taken up. At the start do not tell the pupils that it is "the weight of the water displaced." This is misleading, and, once given, seems to become a sort of cant phrase into which it is hard to put the real meaning. Later this truth may be seen and verified. While the whole mathematical explanation can not be gone into, the simple fact that floating is due to the *upward* pressure of the water may be clearly seen.

Show the pupils that when a body is placed in the water, the water presses against the whole surface. A bucket pushed down would show the pressure if holes were bored in the bottom and sides. A rubber boot placed in a bucket shows the pressure by the collapsing of the sides. A bottle filled with air thrust mouth down will show that the air is pressed upon by the water. In a floating body the pressure against the sides takes no part in holding the body up, but only the upward pressure does so.

The children will readily see that the pressure of a liquid is due to its weight, and consequently is greater in the heavier liquids. It will be very interesting to show a very light liquid, like gasoline (do not use it near a light), and the heavy mercury.

From liquids it is easy to pass to air. In previous lessons air has been shown to be "something," and consequently has weight and exerts pressure. Let the children devise means of showing this to be true.

Put experiments like this in the form of questions: A glass of water evenly full is covered with a piece of paper, and then suddenly inverted, the paper being held on by the palm of the hand. When the hand is removed, the water will be kept in the glass by the pressure of the air.

"Sucking" water up a tube is removing part of the pressure of the air above the water in the tube. The pressure of the air on the water outside of the tube pushes the water up the tube.

Enlarging the chest in respiration makes a larger space. The pressure of the outside air crowds in and inflates the lungs to fill that space.

The toy called a "sucker"—a leather disc with a string in the center—illustrates this further; the pump and the siphon also.

From pressure of air, we may pass to experiments on bodies floating in the air, as balloons,—toy balloons, either paper filled with hot air or rubber filled with a gas lighter than air. Next we may take up currents in the air and water.

It has been seen that heat expands water and air. These are then lighter. The warm water rises in the cold, and the warm air in the cooler. (The lessons on currents in air and water may now be referred to or they may be arranged to follow these lessons.)

How Insects Breathe.

The familiar grasshoppers, or locusts as they are better called, can be found along roadsides, and in pastures and meadows. Have some energetic and interested small boy catch alive and bring to the school as many live locusts as there are children in the nature study class. Any species of locust will do, the specimens need not all be of the same species even. The locust hunter should carry a small closed wooden or paste-board box with a hole in the top just large enough to admit a single locust. If he can take with him a butterfly net he may be able to get his specimens in shorter time, tho the usual small boy can catch the most active sort of locust without artificial equipment.

Let each child of the class have a live locust. It should be held so that the long, strong hind legs are kept quiet. When the locust has stopped struggling to free itself and is apparently motionless, let all look sharply for any signs of movement. Give especial attention to the hinder half of the body.

Is there any movement here? Yes, a distinct tho slight, regularly-recurring contracting and swelling of the body. What is the locust doing? Breathing. Notice this movement of the body very carefully in all its details. What parts of the body surface move the most? Of what is this part of the locust's body composed? Of a series of rings or segments with distinct lines separating them. Note that the under surface of the body is separated from the lateral and upper parts of the body by a little longitudinal furrow on each side. It is at these furrows that the breathing motion is most pronounced. Feel the surface of the body; it is rather hard. The outer skin, or surface of the grasshopper's body is composed of a thin layer of a horny substance which serves as a sort of coat of armor and protects the soft parts inside. But just at the furrows the body wall is thin and soft.

The furrows are in fact, a sort of long soft hinge by means of which the hard lower wall of the body can be moved away from or towards the hard upper wall, and the size of the body thus made larger or smaller. This making the body larger or smaller is the breathing motion.

Does the air which the locust breathes pass in thru the mouth? If not, where does the air pass in and out of the body? Unfortunately the children will not be able to prove that the locust does not breathe thru its mouth—it does not: nor that the air does pass in and out of the body thru a series of tiny holes on each side of the body—which it does. It may be readily seen, however, that on each side of each body ring or segment there is just above the long lateral furrow, and near the front edge of the segment, a small spot. This is a minute opening in the body wall, and is a breathing pore or spiracle. Thru these holes, each time the body expands, the air passes into the body, and out of them the air comes each time the body contracts. On the inside of the body leading from these breathing openings are small tubes which carry the air into two air trunks, which run longitudinally along each side of the body and extend in most insects for almost the entire length of the body. From these main trunks arise many subordinate trunks, these in turn subdivide into numerous finer branches which branch again and again, so that every part of the body is reached by these air tubes, and all the organs and tissues of the body thus directly supplied with oxygen.

These air tubes or trachea, can be readily shown to the class. The teacher should prepare a simple dissection of some large insect—a caterpillar makes an especially good object—revealing the main longitudinal trunks and some of the branches. Make the dissection as follows: Glue, with water proof glue, a piece of sheet cork to the bottom of a small, shallow tin dish or earthenware saucer. Pin the caterpillar, which has been killed by chloroform, outstretched with back uppermost to the cork. With

fine scissors or sharp scalpel or knife cut open the skin along the median line of the back from end to end of the body. Spread the skin out on each side of the body and pin the cut edges down. Then pour into the dish enough clear water to cover the specimen, and with needles and forceps pull apart the white masses of fat until the conspicuous dark longitudinal tracheal trunks are exposed. The air tubes will appear either dark or shining silvery. All air tubes (tracheæ) are finely transversely lined or striated. These fine transverse striæ are really a continuous elastic thread which runs spirally around on the inner surface of the air tube and which by its elasticity, holds the tube open. A bit of one of these large air tubes cut out, and mounted in a drop of water or glycerine on a glass slide, should be examined with a magnifier, so as to see this characteristic transversely striated appearance.

In the case of other animals, not insects, the air which is breathed in is carried by short tubes to an organ (the lungs) where it meets the blood and gives up its oxygen to it. The blood then carries thru the blood tubes (arteries) this oxygen to all parts of the body. But with insects, as we have seen, the air is carried in tubes of its own all over the body. This is one of the most important physiological peculiarities of insects.

All insects which live in the air, i. e., which do not live in water, breathe as the locust does. That is, they breathe thru small holes which are situated in a single row on each side of the body. But many insects live in water. How do they breathe?

An account of the manner of breathing of several water insects is given in the chapter "Some Water Insects."

Birds.

Get from the market a freshly killed fowl or pigeon. Have the pupils examine the various parts of the bird, especially the bill and feet and feathers. (For a lesson on feathers see pp.141-4). Note the different kinds of feathers, namely, down, contour feathers, and quill feathers, and note the distribution and arrangement of the different kinds. The quill feathers are in the wings and tail only. Note the third eyelid (nictitating membrane). This can be especially well seen in a live bird, preferably a large eyed bird. This third eyelid instead of working vertically sweeps horizontally or obliquely across the eyeball from the side next to the beak to the opposite. If you menace the eye of a live bird with finger or pencil this nictitating membrane rushes across the ball to protect it. Examine the bill. Note the absence of teeth. The earliest birds, now known to us only as fossils, had teeth. The bills or beaks of birds vary a great deal as we shall see when we come to examine other kinds of birds. The two parts of the bill are the upper and lower mandibles or jaws, and both jaws are movable. With us the upper jaw is immovable. The motion of the upper jaw is freest and most extensive in the parrots. Note the horny character and the evident strength of the bill. In the pigeon there is a soft swollen part on the upper mandible, in which the nostrils are situated. Examine the feet. How many toes are there? Some birds have only three toes (the plovers, certain woodpeckers, and others). The ostrich has only two toes. Note the arrangement of the toes, and their shape. The arrangement and the shape and appearance of the toes varies much among birds (see later). Note the hard nails; they are horny like the bill.

With this simple knowledge of some of the parts of the chicken or pigeon, have the children watch the live chickens or

pigeons at home. If in a city, have a live fowl or pigeon in a cage in the schoolroom. Have them see how the bird uses its bill and feet. Let them find out how the structure of the bird fits it for its special kind of life.

To study birds further it will be well to have a small set or collection of prepared skins of some of the common birds of various families. In order to see how the general structure and the special character of the wings, tail, bill, legs and feet of various birds vary in correlation with the various habits and living conditions of the birds it will be necessary to be able to examine, in hand, different birds. "Bird-skins" which can be bought for about twenty-five cents each (the common birds) are better than mounted or stuffed birds which are expensive and are very rarely true to life in shape and attitude. The skins can be got, perhaps, from some boy collector of the neighborhood. These skins can be conveniently kept, can be handled readily without harming them, and do not pretend to imitate the bird's shape or attitude. But they do allow us to see the exact character of the various external parts.

Make the pupils acquainted by out-of-door lessons with the common birds of the school yard and neighborhood. Try to get acquainted with birds representing some of the different orders and families so that various kinds of food habits and physiological characters will be represented. Try to have prepared skins of most of the birds selected for study. Good birds to begin with are the robin, some swallow, the English sparrow, a blackbird, a jay, the bee-martin, a humming bird, a common woodpecker, a hawk, an owl, a mourning dove, a quail, a sandpiper or snipe a mud-hen or rail, a duck and a gull. The prepared skins of twenty different kinds of birds selected so as to represent different large groups present an extremely varied and interesting lot of bills and feet and colors and patterns, and these same birds observed alive out-of-doors will make the pupils acquainted with

a host of different habits of food-getting, flight, song, nesting, perching, walking and swimming, etc. The teacher should constantly strive to lead the pupils to see the correlation of the structure of bills and feet and other parts of the body with the special kinds of uses to which these parts are put.

Have the children observe the running and scratching and seed eating habits of the quail and domestic fowl, and note that the structure of legs and feet and bill fits these parts for such habits. The hawk and owl are raptorial birds, or birds of prey. They catch small animals alive, and tear and rend them with bill and feet and feed on their bodies. Examine the great hooked beak and the strong talons of the hawk and owl. The woodpecker bores into hard wood in search of insect grubs for food; note its chisel-like bill. It uses its tail as a sort of prop to help support its body when clinging vertically to the limb of a tree. Note the very stiff sharp-pointed tail feathers. How are the toes of the woodpecker arranged? Of what use to it is this unusual arrangement? If a freshly killed woodpecker can be examined, note especially the structure of the tongue; it is so constructed and set that it can be darted far out with great force to pierce (it is sharply pointed) and capture insects. The swallow rarely walks; its only mode of locomotion is its swift flight. Note its short, small weak feet, ill adapted to secure foothold and very badly formed for walking. Its food is small insects caught while flying in the air. Note its very wide mouth, and tiny weak bill. Note its long, narrow, powerful wings. The sandpipers and snipe wade about in marshy places or on the muddy banks of small ponds. Their food is found in the mud and has to be probed for. Note the long slender featherless legs adapted for wading, and the long slender bill fit for probing the mud. The duck swims, and gets its food by taking into its mouth water and thin mud in which there may be tiny water animals. The duck's bill is broad and scoop-like and provided with a strainer at each side which

lets the water run out but retains the food. Its feet are webbed to make swimming paddles of them. Similarly the teacher should lead the pupils to look for something in the make-up of each bird that especially fits it for its particular kind of life.

The colors and patterning of birds are very beautiful and interesting. Note that in many birds the males are more brightly colored and strikingly marked than the females. The orioles and tanagers and red-winged blackbirds and quail are good examples of this. The colors and markings of birds are believed to serve as ornaments and also as recognition marks so that others of the kind can recognize their comrades. The colors and pattern often harmonize so well with the usual surroundings of the bird that they serve to conceal the bird when at rest and thus protect it from its enemies. A quail crouching on the ground is almost indistinguishable from the brown leaves and soil about it. The colors are produced in two ways, namely, by the presence of pigment, and by the reflection and interference of the light rays. In this latter way are produced the metallic or iridescent colors, which change as the angle of the light is changed.

The nesting of birds and the number and patterning of the eggs are interesting subjects for observation. The mourning dove makes a very slight nest of a few twigs; the robin makes a strong deep cup, rough outside, but softly lined within; the oriole builds an elaborate hanging cradle. Among some birds only the female works at nest building; among others both sexes take part in the nest building. Some birds lay but two or three eggs in a clutch, some a dozen or more. Some birds rear but one brood a year, some several broods. In most birds it is the female only who sits on the nest to incubate the eggs. With some, however, the male takes its turn in "setting." Have those children who have opportunity to watch pigeons while nesting find out that this is true in the case of the pigeon. With some of the plovers the males do all the incubating. A strange bird called the hornbill

makes its nest in a hollow in a tree. The female sits on the eggs, and the male walls up the opening to the nest, nearly completely. He leaves only a small opening thru which he feeds her. The female and the eggs are thus protected from enemies during the nesting time. There is much difference in the time of nesting of different birds. Most of the hawks and owls lay eggs very early in the year, in January or February even, while many of the song birds do not nest until late in the spring or until summer. The children should find out as much as possible about the nesting of some of the common and readily observed birds.

The songs of birds offer an interesting field of observation. What birds have songs? What one calls or cries? Some birds which have only sharp cries during most of the year have varied and elaborate songs during the mating season. What are the cries and songs for? Note cries to warn mates or young of the approach of enemies, and cries to call the young.

The bird fauna of any locality is made up of (a) all year residents, or kinds of birds which live there permanently, (b) summer residents, or birds which come in the spring, mate and breed there and leave in the autumn, (c) winter residents or birds which come in the fall and stay thru the winter, going elsewhere in the spring to breed, (d) migrants, or birds which pass thru in the spring and again in the autumn making but a short stay at either of these seasons, and finally (e) stragglers or birds which normally always live elsewhere but occasionally straggle into the region. Of the many kinds of birds which may be observed to occur in any locality usually about a fifth are really all-year residents in the region. The summer residents (as opposed to all-year residents) will include enough more to bring the total of birds which breed in a certain region to about half the total number of birds which may occur in the region. The other half of the total number is composed principally of migrants.

Older children can be got to keep a little note-book, or the

school as a whole might keep a note-book containing records of the various times of the year when individuals of those kinds of birds are seen which are known to the children. Keep a list of all the kinds of birds (which the teacher knows) which make nests, with the times of their nesting. When are the times of the first appearance of the migrants with which teacher and children can get acquainted?

Other good fields of observations on birds are the moulting, the care and feeding of the nestlings, the manner of flight, the sleep, etc.

A suggestive book about birds is Baskett's "The Story of the Birds" (Appleton). Keeler's "Bird Notes Afield" (Elder & Shephard, San Francisco) contains much information, popularly told, about California birds. It also contains a key for determining the land birds of California. Coues' Key to North American Birds, is the best book for teachers who wish to make a more serious study of birds.

APPENDIX

A Provisional Course in Nature Study Arranged by Grades.

It is with great hesitation that an outline of a course of nature study is presented. The fear is that such a course might be considered as being regarded by the authors of this book as having any virtue in it as such. A course agreed upon and adopted is often apt to have its form of arrangement clothed with an importance, or even a certain authority, which its mere form in no way possesses. It is emphatically insisted upon that many other arrangements of the subjects which follow here would seem to be equally good, or even better than this suggested course, and further, that no special arrangement is essential or should long persist.

However, it is a matter of convenience in execution, where there is a large community of schools of many grades, to arrange subjects to be taken up by the various grades at various times. Such an arrangement renders aid in choice of subjects, prevents confusion and undue repetition, and secures to all the schools provision for the work.

The arrangement given below is based on the experience of the teachers of the various schools of Oakland for the past two years, under the suggestions of one of the authors and under the supervision of Miss E. B. McFadden. It includes only what has been proved by actual trial can be accomplished in each grade easily.

What has succeeded in this community of schools should be equally suggestive in single schools.

To secure a somewhat systematic planning and supervision of the field of work, and at the same time the great liberty in choice to the teacher so absolutely essential in this work, the subjects are arranged under two heads: (1) Prescribed; (2) Elective.

Both the Prescribed and Elective subjects are selected from what experience has taught can be handled in the grades to which they are assigned, and the material for which it is known can be obtained at the time at which it is placed.

The whole amount of work required in each grade consists of all the subjects falling under the head of Prescribed, and a given number of those under the head of Elective.

The subjects placed under the head of Prescribed are not chosen because they are thought to be the more important ones. They represent those which the experience of the past two years of a free selection on the part of the teachers from a fairly extensive list shows are more usually chosen by the teachers. They are those with which the greater majority have been successful. Future experience on the part of teachers would, no doubt, very much modify this list. Indeed, it would be inadvisable to retain this list long unchanged, on account of a certain formality which might soon become attached to it.

The subjects placed under the head of Elective allow a range of choice on the part of the teachers, which permits the taking advantage of preferences on the part of teachers and pupils, and of favorable occasions and conditions. This list could be indefinitely extended with profit. It is here simply limited to subjects which have already been used in the schools, and for which material can be readily obtained.

To avoid too much repetition of work in different grades, it is advisable to confine selections to the list as provided, unless subjects are taken which are not in the whole course. Teachers should be encouraged to introduce, as time and opportunity may permit, as many lessons as possible on subjects not specifically given in this course, and to make note of their experience and report their success. The subjects outlined need not be taken in their order, but selected according to season, or as class needs dictate.

First Grade.

PRESCRIBED.

SEEDS. Dispersal. Most common forms as in lesson on Dandelion. Arrangement in seed-case. Apparatus for dispersal. Collection of seeds to show method of dispersal.

Germination and growth in several forms of seeds. Conditions necessary for germination and growth. How the plant breaks out of the seed; how it gets out of the ground. Growth of roots; of leaves,—the one seeking food from earth, the others from air. Growth of roots from cuttings,—air-roots.

All the phenomena of plant life easily understood by the children of this grade.

MOTHS, BUTTERFLIES, CATERPILLARS. Breeding-cages and food; egg, size and development; growth of caterpillars; feeding and moulting; cocoons, or chrysalides, — how made, of what. Life habits of adult moth or butterfly.

DEVELOPMENT of eggs of toads, frogs, or salamanders.

DEVELOPMENT of mosquito from egg to adult.

ELECTIVE.

SELECT two subjects from the Elective List No. 1 (see *postea*).

SELECT one subject from an outside source.

Second Grade.

PRESCRIBED.

Use the same topics given for the First Grade, extending the observations, and varying the problems given to be solved. Add to this list:—

FUNGI. Their manner of growth; the various forms as given in the lessons; positions in which found; their spore surfaces; discharge of spores; growth of spores, etc.

ANTS. Life history and habits studied from a nest kept in the school-room, also by observations in the field.

ELECTIVE.

SELECT two subjects from the Elective List No. 1.

SELECT one subject from an outside source.

Third Grade.

PRESCRIBED.

GRAPHITE. Properties, uses, comparison with lead and a few other minerals.

LEAD PENCILS. Structure, grades, account of the making, use.

POND LIFE. Jar aquaria, with some of the water insects; life, habits, motions, etc.

COVERINGS OF ANIMALS. Feathers, — structure, form, uses; scales; hoofs; claws; fur of different animals. All to be seen as adapted to the conditions of the life of the different animals.

DURING SEED-GROWING time, plant seeds not before studied, such as sunflower, castor-oil bean, buckeye, walnut, acorn, almond, or any other seeds brought in by the pupils for their study. Use the directions given under the same subject for the first grade.

ELECTIVE.

SELECT two subjects from Elective List No. 1.

SELECT one subject from an outside source.

Fourth Grade.

PRESCRIBED.

EVAPORATION. Liquids. Compare water, alcohol, gasoline, glycerine, molasses.

Show existence of vapor by use of ether, alcohol, chloroform.

Show that heat is used up during evaporation.

Evaporation of solids, such as camphor and iodine.

Condensation.

Show sources of vapor of water by condensation from breath, surface of skin, under surface of leaf, etc.

Distill water from a flask.

SOLUTION. Solution of various common substances that will readily dissolve in water, such as salt; those that will not dissolve readily, as camphor, potassium bichromate, copper sulphate, and the like; those that do not dissolve perceptibly, such as whiting, starch, etc.

Evaporation of water to regain substance, formation of crystals, in part.

Use of funnel and filter-paper to show dissolved substances.

Application of these phenomena to fogs, clouds, snow, rain, formation of soils, erosion, etc.

THE FUNGI GROUP, including mushrooms and the like, puff-balls, geasters, moulds, lichens. Place of growth, spore surfaces, discharge of spores, etc. Collect as many varieties as possible. Compare the various forms studied.

Examples of parasitic plants, such as mistletoe and dodder; their life history.

PINE TREE. (In season of casting pollen.)

MOSQUITO. Care of eggs; larvæ and pupæ, general appearance in each stage; movements of larvæ, how accomplished; feeding, molting, movements of pupæ, breathing, change to adult mosquito.

ELECTIVE.

SELECT any two subjects from Elective list No. 2. (see *postea*).

SELECT one subject from an outside source.

Fifth Grade.

PRESCRIBED.

GROWTH of pistil to the fruit in dandelion, burr clover, geranium, poppy, sweet pea. At least any other five may be substituted for these at the convenience of the teacher.

THE MAGNET. Properties and uses.

MARINE LIFE. Crabs and shrimps (or lobsters). Observation of motions, by what parts and how accomplished. Study of appendages, attachment to body; the joints, their forms and uses. Study of body, its divisions and segments which compose it. Comparison of the two. Comparison with some insect already studied.

FRUITS. Use of edible parts.

Change in fruit by cultivation and selection.

Structure of the fruit, its parts, their arrangement in reference to each other.

How green fruit becomes ripe.

Digestion of starch in the human body.

Use of sugar in plant life; in animal life.

FLOWERING PLANTS. Work of the flower.

Parts of the flowers seen in as many forms as possible.

Place of minute beginnings of seeds in ovary; extension of the ovary into style and stigma; stamens with pollen; corolla; calyx.

Provision for fertilization as seen in lupine, locust tree, peas, beans, clovers, or any plant of the Leguminosæ.

Use of corolla, calyx, honey, perfume, color, etc., to the plant.

Provision for fertilization as seen in petunia, morning glory, and the like.

SPIDERS. Collection and care of living spiders in jars and schoolrooms.
Food.

Web. What kind of a spider made it, how did it weave it, what use is made of it ?

Spinning organs, position, structure, how used.

General appearance of spiders.

Different families of spiders with characteristics.

ELECTIVE.

SELECT two subjects from Elective List No. 2.

SELECT one subject from any outside source.

Sixth Grade.

PRESCRIBED.

PENDULUM. Construction.

Length of a pendulum that vibrates once in one second.

Pendulum with same length but different weights.

Construction of pendulum that vibrates once in two seconds, once in three seconds, three times in one second.

Use of pendulum as a time instrument.

POND LIFE. The green scum of Ponds.

Diatoms.

AQUATIC INSECTS. Dragon flies; water beetles; caddis worms; pond skaters, or water striders; water boatmen; whirligig beetles.

Collection, care and study of life history of three kinds, or substitute any other three kinds of water insects.

METALS. Collection of metals, such as copper, lead, zinc, iron, aluminum, platinum, etc.

Properties, as relative hardness, flexibility, ease of welding, etc.

Alloys.

Uses.

How metals are taken from their ores.

Application to mining.

CRYSTALS. Formation of, to illustrate, occurrence in minerals.

ELECTIVE.

SELECT two subjects from Elective List No. 2.

SELECT one subject from any outside source.

Seventh Grade.

PRESCRIBED.

DISTILLATION of water.**FROST AND ICE.** Formation of frost.

Temperature melting ice.

Temperature freezing mixtures.

Why ice floats.

Manufacture of artificial ice.

Application to geographical features.

LIFE HISTORY OF FERNS.**OXYGEN AND CARBONIC ACID.** Preparation.

Properties.

Uses.

Application to human life, plant life, etc.

DIFFUSION OF GASES.**STUDY of the candle flame.** Parts of the flame.

How the flame is produced.

Use of different material for producing flame.

ILLUMINATING GAS. Preparation of gas in the schoolroom.

Process of burning in coal and wood.

Preparation of gas for use in city.

Visit to gas works.

PLANT PHYSIOLOGY. Growth and use of root hairs.

The plant's food.

Show that plants take up water.

Show that water escapes from plants' leaves.

Trace course of water absorbed by roots.

Examination of stomata.

Material of soil dissolved in water and used by plants.

Making, using and storing starch in the plant.

Food of mushrooms, moulds and the like.

Food of lichens.

Food of mistletoe, dodder, etc.

ELECTIVE.

SELECT one subject from Elective List No. 2.

SELECT one subject from any outside source.

PRESCRIBED. Each member of the class is to select an experiment or a lesson on some plant or animal which he is to present to the class, using his own apparatus or material that he himself has prepared.

Eighth Grade.

PRESCRIBED.

BIRDS. Part of the work, if not all, given in the notes.

CAPILLARY ATTRACTION. Illustration of capillary attraction by means of set of tubes, sheets of glass, a sponge, cloth, lump of sugar, etc.

Capillary attraction in gravel, sand, clay.

Application to plant life in California.

Reason for cultivation of orchards.

SOILS. Structure.

Kinds of soil.

Relation of soil to growing roots.

Relation of soil to percolating water.

PRESSURE of liquids and air.

Why bodies float.

Why some bodies float more above the water than others.

Why some bodies sink.

Effect of some floating bodies in lighter or heavier liquids.

Application to ventilation and winds.

Construction and use of barometer.

CURRENTS in water.

Currents in boiling water.

Currents in vessels of different shapes.

Effect of unequal heating on currents.

CURRENTS in air.

Exploration of schoolroom for currents of air.

Construction of hot air balloon.

Application to winds and to ventilation.

ELECTIVE.

SELECT one subject from any outside source.

Elective List No. 1.*For Primary Grades (1st, 2d and 3rd).*

Caterpillars.	Common minerals.
Bees.	Lead pencil.
Ants.	Fish in an aquarium.
Crabs, shrimps, lobsters and clams.	Spiders.
Earthworms.	Ferns, mosses.
Coverings of animals.	Mushrooms, moulds, lichens, etc.
Snails and slugs.	

Elective List No. 2.*For Grammar Grades.*

Germination and growth of seeds.	Fruits.
Distribution of seeds.	Effect of heat on gases, liquids and solids, or any of the
Moths, butterflies and caterpillars.	Physical experiments.
Development of frogs and salamander's eggs.	The fungi group.
Development of mosquitoes.	Marine life such as crabs, shrimps, etc.
Breathing of insects.	Flowering plants.
Ants.	Oxygen.
Bees and wasps.	Carbonic acid.
Pond life including aquatic insects.	Birds.
Coverings of animals.	

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