PRACTICAL NATURE STUDY AND ELEMENTARY AGRICULTURE

A MANUAL FOR THE USE OF TEACHERS AND NORMAL STUDENTS

BY

JOHN M. COULTER
Director of the Department of Botany, University of Chicago

JOHN G. COULTER
Teacher of Biology, Illinois State Normal University

ALICE JEAN PATTERSON
Teacher of Nature Study, Illinois State Normal University

NEW YORK
D. APPLETON AND COMPANY
1909

CONTENTS

PART FOUR

PREFACE

Books about nature study have become numerous, perhaps more numerous than good teachers of it. These books deal with principles and methods and somewhat with material, so that the student or the teacher need be at no loss for suggestions. But the subject is so new and nature so extensive and the suggestions as to use of material often so general that the books seem to differ confusingly, and the honest seeker for help often becomes more mystified the more he reads. In fact, nature study is still in the period of suggestion, a period which may be trying to the experienced teacher, but which is a necessary antecedent to the period of experiment. The time has come for extensive experiment by trained teachers, putting to rigorous test the suggestions that seem hopeful. Teachers will always have the last word.

It is not with the hope that this confusion of suggestions will be cleared up that these pages are written. Their purpose is simply to state the situation in such a way that the teacher may become more independent in his work and thought and thereby better able to eliminate confusion from his own particular problem. We shall never reach general agreement in this matter until many good teachers have conducted careful experiments and their results have been sifted. Even when this is done, teachers themselves are such variable factors that no hard-and-fast schemes of nature study can be or ought to be constructed, but rather an approved body of principles, the details of whose application must be left to the individual teacher.

Part Two of this text contains a detailed topical outline by grades and seasons of the materials used in nature study in the training school at the Illinois State Normal University. Though this program has stood the test of repeated satisfactory use in practically all its parts, and represents the result of much sifting and rejection and rearrangement, it is by no means to be interpreted as fixed. It represents simply the present status of the work. Each season is certain to bring its quota of minor modifications, either of addition or subtraction.

The detailed outlines for work upon selected topics which, as models, follow the topical outline are believed to be rather more definite in character than many heretofore appearing, and are designed to be of service primarily to teachers who are called upon to handle the subject with slight previous training. They are not indicative of any belief on the part of the authors that all nature study material should be so prescribed as to manner of treatment. They represent simply an effort to fulfill the function suggested in the general title; to aid in making nature study practical, not so much under ideal conditions as under the conditions of teaching as we have them. In these outlines references to other books for necessary information is avoided, the design being to make each outline as nearly as possible complete in itself and ready for use.

Part Three contains a shorter outline for the work in the lower grades arranged according to seasons, and leading more directly to the agricultural studies of the seventh and eighth grades. It also contains suggestions for conducting certain studies without having any special place on the daily program for nature study, and in coördination with the other school subjects. But it is principally devoted to an outline course for elementary agriculture in the seventh and eighth grades with most of the lessons worked out in detail. This material and these lessons have all been used in regular class work and found efficient under conditions similar to those of the "average" rural school.

Part Four comprises certain chapters upon more general topics; material which has been found serviceable for teachers whose general science training has been slight or lacking entirely. The aim is to provide a scientific point of view of the materials and principles which are to be used in the work. Here also are chapters on method in bird study and garden management. It is a common observation that the usual college or normal school courses in science do not adequately prepare teachers of nature study. This appears to be due in large part to the absence of the nature study method from these courses; they are courses in "organized knowledge." Yet the obligation to meet county superintendents' examinations or university requirements for credit are obstacles at present to much alteration of the character of these courses. To meet this difficulty at Normal a course entitled Method in Nature Study and Elementary Agriculture is made prerequisite to the teaching of nature study in the training school and comes after the conventional courses in the sciences. In this course these chapters have been used as a text. In fact, this little book is somewhat an outgrowth of that course.

THE AUTHORS.

PRACTICAL NATURE STUDY AND ELEMENTARY AGRICULTURE

PART ONE

CHAPTER I

NATURE STUDY AND AGRICULTURE

NATURE study seeks to bring children into intelligent and sympathetic touch with their environment. The environment determines the material that is selected for the lessons. In an agricultural community, for example, the lessons must be primarily agricultural. In no other way can nature study fulfill its mission. *It makes no difference whether we call it elementary agriculture or agricultural nature study; it is the same thing and should be so understood.* It is study of plants and animals, of soils and weather, of natural forces and phenomena, of the interrelations and interdependence of natural objects, of the relation of all these to man, and of man's power in controlling them and making them work for his good.

The idea appears to be prevalent in some quarters that nature study is one thing and that elementary agriculture is another, and that the two are somewhat antagonistic. In fact this idea has gone far enough to elicit from one influential quarter the statement, in effect, that "nature study and school gardens" must be got out of the schools before elementary agriculture can be got in.

Such an idea is as unfortunate as it is erroneous. It appears to be based on the assertion that nature study is not "near to life," not "practical," as elementary agriculture is. Elementary agriculture can get no nearer to life than nature study should, and nature study aims to get near to a broader if not higher aspect of life than pertains to agriculture alone. These two things are one subject; they have a common educational value, or else none sufficient to make them worthy of a place in the schools. It is a case of "united they stand, divided they fall." If nature study fails to consider economic values and the best benefits which man may derive from nature, then it is not justified. If elementary agriculture fails to consider the response to all nature which may be aroused in us—the one thing which will make higher agriculture consistent with higher living —if it is purely utilitarian and "practical," then it, too, is not justified in a school system which aims to turn out a higher type of man as well as a higher type of farmer.

Instead of impeding agriculture in the schools, nature study must be there to make agriculture wholly successful. Agriculture is called for in some courses of study in the seventh and eighth grades, but it will never realize the success it should have in those grades if nature study is not taught in the lower ones. It does not take much insight into child psychology to realize that if boys and girls have not been trained to keep eyes and ears, mind and heart, open to nature, if they have not acquired a taste for cultivating plants and solving problems connected with them before they have reached the seventh and eighth grades, they are not so likely afterwards to acquire a permanent and enthusiastic interest in agriculture.

In planning the lessons, the children rather than the subject must be given first consideration. They, rather than the subject, are to be taught. There is evidence that the enthusiasm of some leaders in agricultural instruction has tended to obscure this principle. Children must be met upon their own ground, along lines of their own interests. The problems they are set to working out must be problems that appeal to them; not necessarily problems that appeal to adult farmers. Lacking this consideration, the very purpose for which agriculture is being introduced into the schools will be defeated. Instead of keeping boys on the farm we may drive them away from it.

The work should begin no later than the intermediate grades and should be guided along lines of investigation and problem solving as fully as the training of the teacher permits. Nor is such training difficult to attain if serious effort is made. It must be a study of real objects; not a study about objects. It must include doing things, working with hands and tools as well as minds. It should lead to familiar acquaintance with the important natural objects of the environment, to observation of relationships, to some knowledge of plant growth and propagation, to recognition of friends and foes among insects and birds, to some understanding of weather, etc.

By the time children have reached the seventh and eighth grades they are ready to take up the applied lessons in nature directly connected with agriculture as an industry. Thus the value of such preliminary training is twofold; the pupils gain a fund of useful knowledge as a foundation upon which to build the "practical" work, and they come to it with live interest and questioning minds. Then the work is educative from the outset; broadening, not narrowing. We do not want our country boys to become merely efficient farmers who have learned to do certain things that they may make more dollars. We want them to be men who realize the larger applications of the laws and principles they are following, men who see and discriminate, who grasp situations, who think for themselves, and who have an abiding interest and enthusiasm for their profession, looking upon their fields, orchards, and meadows somewhat as laboratories in which to work out experiments to the end that they may do their work more profitably and enjoyably. We would have them men who take a keen pleasure not only in making their soil more productive, and in raising better crops and stock, but quite as much in making the home and its surroundings and the life within it more comfortable, more interesting, and more beautiful. In so far as nature study does not contribute directly to these ends it is not justified, but if it does contribute to them, who shall say "it is not sufficiently related to life"?

CHAPTER II

THE TRAINING OF THE WORKING TEACHER

Need for Effective Execution.—The immediate task in the development of nature study is the training of teachers to use it. Principles are sufficiently agreed upon. The need is to put into actual effect what we already know. There is plenty of undigested inspiration on the subject, but not very much effective execution. There has been enough done in the way of pointing out the desirability of such work. Its right to a place on the programme is sufficiently conceded. But the potent argument which superintendents bring against allowing it that place is that teachers are not sufficiently well trained to make it effective.

The too ready answer to this objection is that teachers can become trained in the subject only by trying it. In some cases in which they have been allowed to try it the results have amply confirmed the original contention of the superintendent. But in all these cases, so far as known, the teachers themselves have had to bridge that large and troublesome gap between general inspiration and specific lessons. The most difficult part in the construction of a nature study scheme was left to them. It was very nearly a case of requiring "bricks without straw." The results, save with the exceptional teacher, should not surprise.

Specific Lessons.—The point appears to be that the "authorities" have failed to show inexperienced teachers *just how* to begin; just how, step by step, to give their first lessons. It may be argued that to outline specific lessons violates the ideals of nature study by making it rigid and formal. But rigidity and formality are not so characteristic of these lessons as is definiteness, and perhaps the most serious charge brought against nature study is that it is indefinite. It needs to be shown that it can be taught in a perfectly definite manner.

However, experience makes it plain that, with few exceptions, nature study cannot gain a footing in the schools on other and possibly more "ideal" terms. What the untrained teacher must have before she can make a real beginning is specific lesson plans about specific familiar things. These suggestive lesson plans must be grounded on good nature study principles, but they should lack nothing in definiteness as to steps to be taken and results to be achieved.

Rousing of Latent Interest.—To train in a new subject teachers already busily occupied with the old ones is a task beset with difficulties, but it is encouraging to find almost everywhere teachers eager to get light in the matter as opportunity is afforded. And, backed by such interest, the work is not at all difficult.

This interest, which appears to be persistent and increasing in most cases, finds some explanation in the fact that the subject takes a grip upon the teacher quite apart from her teaching capacity alone. The little laboratory course in outdoor work which constitutes a main part of the training appears to stimulate latent interests which frequently quite forget and run past the schoolroom. Perhaps that "latent interest" in outdoor things is the naturalistic spirit which some contend to be as universal in us as a stomach; but whatever it is, it gives rise to an enthusiasm for country conditions and to a vision of the attractiveness of nature which was not there before; a thing which few will dispute to be a valuable asset for anyone, and especially for the teacher.

Experimentation with Classes.—Also, we have found that working teachers make decidedly better progress in a course in nature study method than do students in the normal school who are not engaged in practice teaching. There is a great advantage in having one's own class for stimulus and, to some extent, as a means for experiment.

It may be argued that the usual country teacher is not to be trusted with "experiments" on her classes. Some superintendents object to nature study just on the ground that it is "experimental." They are willing to introduce it when more definite steps of procedure have been determined, but they seem reluctant to let their teachers help determine what these steps shall be. But nature study will never pass the "experimental" stage in one sense; at least never when it is a question of its introduction in a new locality. That must always involve some experimentation.

In the same connection, what shall we say of the growth in efficiency of teachers who are given no opportunity for some such educational experimentation? Is there any better means of growth than the trial of new material with successful results, results for which the teacher can take credit to herself rather than ascribe it to steps laid down by another?

However, it is not desired to make claims too large. It is not argued that nature study is alone among subjects in

2

affording opportunity for growth in efficiency, or that the teacher is to work out her plan for it by experimentation only. She must start on safe and certain ground, ground which has not yet been any too clearly mapped out, but she must soon arrive at the point of choosing her own path. Nature study is peculiar in requiring such divergence from a straight course. Its content must be as various as environments are various.

Encouragement of Initiative.—For some time we have sought to discover what method is most serviceable in training working teachers in this subject. We have dealt with average conditions and average teachers in city and country schools. The problem has been mainly one of fitting the subject to the teacher. The teacher has been the starting point and the subject the goal. The most effective part of a course so worked out has been a body of lesson outlines upon familiar and important materials of the environment. It has been the aim to make these lessons explicit enough to insure definite results, and yet not so explicit as to hinder the birth of the teacher's own initiative. In fact, the type lessons are designed as a means to insure properly controlled and sustained initiative rather than in any way to interfere with it.

It is a fact that the best nature study teachers we find are the most self-trained. It is well that this is so, for the subject will not wait for the next generation. The demand for ability to teach it, especially in its agricultural aspect, is too insistent and too widespread. The alert teacher perceives that such training is an important addition to her working capital, and to the capital from which she can draw for enjoyment of life as well. In so far as she gives thoughtful attention to the working out of lesson plans in her own school, she will be taking the best part of a course in nature study method. She may be following a rigid outline of steps at first, but initiative is soon born wherever real interest and persistence are present.

Nature Study and Biology.—The conventional elementary courses in the sciences are inadequate for training nature study teachers. County superintendents' examinations include botany and zoölogy, but all the rather miscellaneous information necessary for passing them helps but little in grade work. It is common to meet the teacher who says she has tried to make her high school or normal school science fit the case of nature study and has found that it does not fit at all. Students who have taken botany and zoölogy may be scarcely better prepared to teach nature study in the grades than those who have not. They have facts enough, but little conception of how to use them to fit the case; in fact, they are in constant danger of spoiling the whole lesson by making it too technical.

The difficulty appears to be that even high school botany and zoölogy are taught as complete sciences; as systematic courses reviewing large bodies of organized knowledge. But nature study is not concerned with such organization of its facts. It attempts no such bird's-eye view of the whole field. It does not squeeze its facts into a system, or study its objects according to a uniform laboratory plan. *Each object reveals a plan of its own.* It is science only as science may be defined as a certain common-sense method of coming to conclusions. Here, then, are two very different things, and training in one hardly prepares for the practice of the other.

Nature Study Method.—To meet this difficulty a course in nature study method appears to be desirable, and the following chapters are designed to furnish a guide to such a course. The essential part of the course itself, however, is not in a book, but is in the handling of the actual materials, outdoors or in the schoolroom, with actual classes, and by methods in which the immediate conditions, rather than the dictum of any book, will be taken as guide.

CHAPTER III

THE MISSION OF NATURE STUDY

The Purpose in View.—Before undertaking any actual teaching of nature study it is well to consider thoughtfully the purpose which it has in view. If this purpose seems desirable and attainable a stimulating motive for the work will be obtained. In the writings on this subject various statements as to its purpose are found, but there are no very essential discrepancies among them. The differences are rather in how much is included than in how much is excluded. The following conception of purpose is of the inclusive type, the opinion of the writer being that the mission of nature study is much larger than it seems to look to many who have written about it.

Interest in Men versus Interest in Nature.—One of the tendencies of modern civilization has been to increase interest in men and their affairs and to diminish intelligent interest in nature. The former is much to be desired, but the latter is to be deplored. It is an error to develop one at too great expense to the other. There is no necessary connection between increased interest in man and decreased interest in nature. This condition has come about from the fact that the affairs of men have thrust themselves upon our attention with increasing aggressiveness, while the affairs of nature have kept in the background. One mission of nature study is to induce people to include among their other interests an interest in the affairs of nature in addition to the mere dollars-and-cents interest. The result will be the introduction into life of an influence that is restful, pleasurable, stimulating, and educative. Conversely it is claimed that lives which do not include some intelligent observation of nature are denied something of the development of mind and of character which life offers, and are thereby more narrow.

Yet nature study is in no sense exclusive of man and his affairs; in fact a very large part of the material it uses falls in this category as roughly separable from "wild" nature, but its point of view is opposed to all that is exclusively utilitarian. It takes a view of nature from nature's own viewpoint rather than from that which excludes all but the cash and comfort values.

The Point of Attack.—It is easy to state the situation, but it is difficult to discover the methods that will bring about the desired change. The intelligent observation of nature seems very desirable, but to secure it under the ordinary limitations of the schools has proved to be one of the most elusive tasks that teachers have ever undertaken. It has been felt that the most hopeful and definite field of effort is with the children of the grades, for they are teachable, they are developing their intellectual tastes and habits, and they will presently form the bulk of the adult population.

It does look as though the problem would be solved if the majority of these children should discover a liking for nature, but to hope too much for such a result is visionary, for many things stand in the way.

Obstacles.—Conspicuous among these obstacles is the lack of teachers trained for such work or sufficiently interested in it, the lack of knowledge obtained from sufficient experience as to the most effective methods in using the materials of nature study with children, the overcrowding of classes, and a generally neutral attitude of parents with reference to it. Thus its fulfillment of the place in the educational programme which is sought for it means not merely the mandatory introduction of the subject into the grades, but also it means interesting adults, training teachers, and conducting numerous experiments as to methods and materials. The children may be expected to give the largest response to an educational effort to stimulate interest in nature, but also the appeal must be made to adults who may not have silenced completely the "call of the wild" or who may wish to hear it again. In these pages, therefore, while the presentation is to those who will teach nature study, the application is also to be extended to all who influence children or who wish valuable contact with nature for themselves.

A Local Study.—Nature study is necessarily restricted in the materials it uses to those which any particular environment affords. Hence the details of nature study courses must differ widely. The objects of nature which are of especial interest in one community may be entirely lacking in another. In one community the outdoor interest may center in the forest, in another in the prairie, in another in the fields and gardens, or in another in the seashore. But amid these widely different details as to the materials which nature study uses the same purpose runs and the same results are to be obtained. It is this great variety in the details that baffles many teachers who are more accustomed to follow directions than to formulate them.

But it is one of the strong arguments of the advocates of nature study that it is a subject whose very nature requires its teachers to be initiators rather than imitators. And a teacher's growth in efficiency depends in part upon the compulsion to initiate in some directions rather than to imitate.

Difficult to Teach.—Every teacher of nature study should have the comfort of knowing and every prospective teacher should have the warning that the subject is a difficult one to teach. It calls for more of originality than does the teaching of sciences in the high schools. It demands acquaintance with the local material, facility in using it, and flexibility of presentation to a degree not dreamed of in those orderly laboratories where the cut-and-dried "sciences" hold sway. To ask such work of unprepared teachers and to demand good results is unreasonable. It is not strange that failures in teaching nature study have been numerous; it is rather a wonder that successes have been so frequent. Yet this fact should not produce a feeling of unrest or discontent with the subject among its teachers; rather it should give confidence in the virtues of the subject itself and courage to continue the perplexing and ever-changing but fascinating task of its successful presentation. If teachers are working in the dark, they should know that this is still somewhat the condition of teachers of the subject everywhere. If they are eager for the light, they should know it will come chiefly by continuing to work patiently and thoughtfully. No one can rescue them except by stimulating their own persistent effort. There are still many stumbles to be made in nature study, but every fall shows what to avoid next time.

Variance in Definitions.—A clear definition of nature study and an adequate statement of its purpose have been long in coming, and perhaps have not yet arrived. But its very breadth of purpose and fundamental importance in education may be cited as causes of its non-definition quite as reasonably as vagueness or educational impracticability. A subject which some easy sentence will snugly define has limitations in education of equally easy definition. Protoplasm and creation and education itself are equally lacking in adequate definitions, but no one challenges their fundamental importance.

Nature study seeks to supply a need that is evident enough, but whether it actually does supply it as yet is not so evident. We find statements of its purpose ranging all the way from the cultivation of a sentimental love for nature to training in habits of exact observation and inference. When there is added to this confused statement of purpose the fact that the subject has been thrust in many cases upon unwilling and unprepared teachers, it is no wonder that it has been regarded by many as an indefinite, inchoate thing, the despair of the grade teacher, and, till recently at least, somewhat of a joke among scientists. Yet, though its beginnings in the schools may not have been fortunate in the majority of cases, its mission is so distinct and valuable that it is certain to outlive many a bad start.

Helpful Contact with Nature.—The name nature study was perhaps not a happy selection, for it hardly expresses the idea as it is working out, but like many another name it has become conventional, and so will serve the purpose. It will be better to defer the selection of another name until the thing to be named develops more definite organization. But, whatever the name or the definition, what is entirely agreed upon in this connection is helpful contact with nature, and what finds much less agreement is what kind of nature contact is most helpful.

Nature Study a Sentiment?—The love of nature is a sentiment that seems to belong to all healthy minded people who revel in forest and stream and mountain and sea like children turned out for a holiday, and just as this sentiment is nurtured by experience the mind will retain its healthy, natural tone. But if this were all that is meant by "helpful contact with nature" the mission of nature study would be hardly more than a campaign for fresh-air outings. Yet the delight that comes from being immersed in nature as one is immersed in air is an essential condition and stimulus for nature study itself. Such love of nature must be awakened or nature study will have no vitality, and perhaps this is as far as some will go or can go. This is fine as far as it goes, but it is not nature study. It is only nature sentiment.

Nature Study a Science?—At the other extreme of opinion is the claim that nature study is science. Now if science is held to mean in this connection method rather than matter there might be no dispute with this claim, for science as a "method of problem solving" begins even in nature study. But science as ordinarily used means organized knowledge in reference to nature. Such claim would mean then that nature study is composed of bits of botany, and bits of zoölogy, physics, geology, etc., for these are the so-called sciences.

Any such organization of nature study would defeat its purpose, for it is knowledge without definite organization, nature as it presents itself unanalyzed, a composite picture of the sciences. Whenever the study of nature enters upon organization of the whole and the pigeon-holing of facts in some general system it becomes science, and in our usage of the term ceases to be nature study. The sciences are all bound up in the great bundle of nature, and their dissociation comes sometimes later in one's training, but in the training of most it does not and need not come at all. Where in our educational programmes nature study shall be said to stop and science study to begin is a question not primarily related to this topic. But the attitude toward nature which nature study seeks to engender would suggest that, with opportunity, nature study would pass into science as naturally as the boy into the man, and with as little innate need for a sharp line of demarcation.

Its True Place.—Between sentiment and science, therefore, nature study must find its place; the former is its atmosphere, the latter may be its successor. Its mission, or at least its opportunity, is nothing less than initial training in the scientific spirit, which when found in men who love and cultivate nature makes of them what were once called "naturalists." The old-time naturalist has almost disappeared with the development of modern science, but his spirit is the spirit of nature study. To cultivate the scientific spirit in contact with nature is to obtain a distinct and exceedingly valuable educative result, which makes of nature study much more than the cultivation of a sentiment.

Educative Result.—What this educative result means to us as a people may be indicated. The test of teaching is the result. As one examines the product of the schools to-day has he a right to feel satisfied? The essential feature of the test is not to be obtained from school records, but from the social order. Are the schools contributing to society men and women who will improve it; men and women who are not only sound morally but also intellectually, and who have wide interests? Have the schools given us men and women incapable of becoming victims of demagoguery, of superstition, of hallucinations of any kind? It has seemed to many that our educational schemes lack efficiency in just this direction; and that, judged by the results, we have not hit upon just the form of training that results in clear thinking and the prevalence of clean truth among the greatest number of adults.

The Opportunity.—Nature study has the opportunity to develop mental steadiness and clear thought at the very beginning of education. The chief troubles connected with doing this have not come from unprepared teachers so much as from self-appointed leaders whose books and addresses have somewhat befogged and belittled the situation. Nature study is much easier to talk about than to teach. It lends itself peculiarly to schemes which upon trial prove to be visionary. It represents one of the greatest problems of education, and it will not be solved by schemes imposed upon teachers, but by the teachers themselves attempting to work out in a practical way certain evident principles.

The Dominant Motive.—Before teaching nature study in the grades the teacher must determine its dominant motive; not merely its incidental advantages, which are numerous enough. In suggesting what seems the appropriate dominant motive that must determine the method, we are at the parting of the ways where opinions diverge. However, all these opinions must be tested in the furnace of experience before any one of them can be advocated with any boldness.

The place of nature study in elementary education is supplementary to what may be called the conventional education. The latter of necessity compels attention to certain abstractions of language and of numbers that are not of paramount interest to the pupil at the time. Any observation of young children shows that they reach out to the tangible things of nature about them with eager curiosity. The normal child is evidently born with what may be styled tentacles of inquiry by which he relates himself to the world about him. It has been observed that a strictly conventional education tends promptly to cause atrophy of these tentacles through disuse, and when later in life the opportunity for work in science presents itself there is no response, for loss of interest has followed loss of power.

Tentacles of Inquiry.—An actual test whose results are indicative of such atrophy of these native tentacles of inquiry and the substitution of artificial ones, if any, may be of interest. Spring twigs bearing buds were given to two groups of children. One group consisted of children just entering school, the average age being six. The other group consisted of children with six years of school experience, but with no nature study. Both groups were asked to sketch what they saw. The results were submitted to an outsider to separate the good from the bad. This was done without difficulty or even hesitation, for some were free and expressive, including all the conspicuous features, while others were stiff and conventional and omitted several of the conspicuous features. The satisfactory sketches were all by the six-year old pupils, while all those made by the twelve-year old pupils were deemed unsatisfactory. The latter had been mutilated for six years so far as their power of independent observation was concerned. They had become apparently so dependen upon outside authority as represented by teachers and books that when left alone they were at sea with neither chart nor compass. This happened to be an extreme case, for some pupils always retain their observing powers through their own initiative, but it is a real illustration of a general situation.

Later Effects.—This benumbing effect of the exclusively conventional education upon the natural interest in observation appears to have much to do with the small proportion of college students attracted to the laboratories. In colleges where some laboratory work is required of all students it is painful to see the complete inability of the majority to do anything at all without the most explicit and repeated directions, and this is naturally accompanied by a strong feeling of aversion for such work. It is really the worst kind of drudgery in such cases to develop any semblance of the initiative with which most of them were probably born.

Familiar to the Child.—Nature study is the most familiar face that greets the child upon the threshold of education. It, of all the subjects, should serve best to keep the tentacles of inquiry at least functional during the necessary, preliminary, conventional period of education. Perhaps it is asking too much at present to permit it to do more, for the pressure of work that seems more necessary to living is very great, but it must be given an opportunity to keep alive the powers of observation and of questioning. If this is not done, the door is closed upon one half of life, and later in education and later in life the pupil is found to have been robbed of both opportunity and enjoyment; the one-sided beginning continues its distorted development to the end. If this statement of purpose be sound, the methods of nature study are to be judged by their success in fulfilling it.

Additional Benefits.—In view of the rather modest claim for attention made in the preceding paragraph, the prediction may be ventured that when really tried nature study will be found perhaps more important in the preparation for living than some of the work now consuming a large amount of time in the grades. It is not a question of contrasting its educative value with that of other subjects, for they all are able to show good reason for their present place in the curriculum, and it has a stronger claim to place than could be established by any such process alone. But presently it comes to a choice among values, and we believe that nature study will not be found among the rejected values. It is too fundamental in its processes and too far reaching in its results to stay among the incidentals of elementary education. At present, however, it must demonstrate its value as compared with the accepted values, and must be content with only such an amount of time as will make the test a fair one.

The Test of Interest.—It is evident that the test of successful nature study is interest, shown by the child who is being taught, by the teacher, or by adults who are searching for the most helpful contact with nature. However, this is not all, for some teachers are able to interest children in anything, or the interest may be spasmodic. The interest must be shown in important things; that is in things worthy of interest, knowledge in reference to which is a valuable asset in one's equipment. Much of the material suggested for nature study is trivial. It may or may not be made interesting, but in any event it is valueless, and to study it means going through the motions rather than doing something. Merely to observe the many differences in the forms of leaves or in the colors of birds or butterflies is the observation of certain facts of nature truly enough, but such facts alone are as barren as a sand bank. It is like taking bricks and putting them into a meaningless pile rather than into a building that means something and abides. The test of interest, therefore, must mean interest in important things.

Continuity.—Another quality which must be apparent in the interest is continuity. Occasional interest is not the real thing, for it disappears as difficulties or even inconveniences are met. The interest that counts is willing to contribute time and labor and patience for the sake of what they bring. This is the difference between interest and entertainment; the former is willing to endure drudgery which would spoil the latter. The full statement of the test, therefore, is continuity of interest in important things.

It is almost instinctive among teachers with formal training in methodology to demand continuity of subject matter. They are very strenuous about one thing leading to another in logical sequence, so that the subject as a whole may have a beginning, a gradual unfolding, and a conclusion. It is felt that this is the only way to "complete a subject." This is really an indication of a thoughtful teacher and is to be commended and striven for. Too few teachers have any idea of sequence and progression for us to criticise those who do have. Yet while in most subjects this may be the effective method, it does not apply to the study of nature, which begins anywhere, continues in every direction, and never comes to any conclusion. Besides, the continuity we are after in nature study is continuity of interest, and that pertains to the pupil and not to the subject. The warning, then, is to watch the child rather than the subject.

Adaptability.—A teacher of nature study had secured from some source what seemed to her an admirable outline for her school. It made little difference whether it was prepared for her neighborhood or not, for to such a teacher an outline is something like a moral law, applicable anywhere. This logical outline was followed with inflexible faithfulness, and exercise followed exercise like the joints of an articulate. One day a small boy, who still retained some interest in nature in spite of his teacher, brought in a small land turtle. He was not merely interested, but excited and bubbling over with questions and a desire to show his prize. However, the outline called for an exercise on leaves that day, an exercise that fitted with precision into the previous exercise and into the one to follow. So the leaves were examined and the turtle went out of the window. The teacher had missed an important psychological moment so far as turtle study was concerned. She was watching the outline rather than the pupils.

3

The School Garden.—Wild nature is in many respects the ideal laboratory for nature study; the one that appeals most to those with the nature sentiment. It is a difficult laboratory, however, and it is perhaps best approached and interpreted by one that is simpler and more familiar. Besides, those who have not developed the nature sentiment, either through lack of its possession or lack of opportunity, cannot be drawn at once to wild nature with any feeling of interest. For these another introductory appeal is necessary and it is very likely to be through the near by and the useful.

The phrase wild nature implies its correlative cultivated nature, and here we touch human experience everywhere. The plants and animals that man has brought under cultivation are real exponents of nature, and as such furnish proper material for nature study. The observation of growing corn or sweet peas, for example, reveals the same truths in reference to plant structure and activity that are exhibited by their wild relatives. In fact they uncover an even wider range of knowledge and suggestion, for plants under cultivation teach impressively the most obvious needs of plants, since these must be supplied by the observer. Moreover, it has been found that a real knowledge of plants comes only in connection with their cultivation. For this reason the modern botanic garden is established in connection with universities, and the school garden is its representative in the schools. The care and observation of a few plants under cultivation open one's eyes to many essential things in the observation of wild plants. A well-organized school garden is not only a great but a necessary interpreter of nature as exhibited by wild plants.

Aside from the usefulness of plants and animals under cultivation as interpreters of those that are not, they also furnish the appeal that is strongest to many. To such persons a field of wheat or a bed of radishes stands for something worth while, and any knowledge that will help in their culture is prized. Nothing is to be gained by failing to recognize and reckon with this attitude of mind; in fact it has been called the genius of the age, and we must take people where we find them. Such a point of view must be laid hold of and used as a natural introduction to an interest that is larger and finer.

Besides, it is not discreditable to possess an exclusively utilitarian point of view; on the contrary, it is quite hopeful. To relate nature study to human interests is sound pedagogy, for intelligence in what relates to living should be a fundamental in education. When intelligent living has been established, there will come to many the leisure and the desire to enlarge the horizon, and to surround the circle of living with the larger circle of purely intellectual interests. This means that there is a field of nature study within the circle of living, and another beyond it; but the radius of the former is extended naturally into that of the latter.

Summary of Educative Results.—These results are in addition to the sentiment, the pleasure, and the enlarged interests that come from nature study and that would make it very worthy of attention for their own sake. They will not follow the study in many cases, and it remains to be seen through experience whether they follow it in any considerable number of cases. However, it is certain that nature study is capable of such results and that, too, without forfeiting any of the others. As they appear to be far the most important and definite results, it follows that they constitute the chief motive in instruction and determine the method. Such results are the more hopeful when they enter into the intellectual organization of children. Some of them will become more apparent when methods of study are considered.

A sustained interest in natural objects and the phenomena of nature. This is the most obvious educative result, and is really an opening of the world of nature to that kind of joyful appreciation that comes to students of the world of art, of music, or of literature. It makes life richer and far more varied and is a great offset to the narrowing and artificial tendencies of modern life. This is not merely the nature sentiment to which reference has been made; it is rather nature appreciation, which comes through a certain amount of knowledge as to the significance of things.

Independence in observation and inference. It is astonishing how few people think for themselves or perhaps think at all. The world is full of second-hand opinions, and almost any vagary seems to be able to get a following. Nearly everyone has learned to depend upon teachers or upon books for opinions, and "authority," although often unconsciously followed, is depended upon. It may be the authority of a person, of an organization, or of a convention, but it is always very real. The whole spirit of nature study is one constant protest against second-hand opinions, against any bondage of the book. The authority appealed to is direct observation, and the inference is very cautious until repeatedly tested. It is an attitude of mind that first demands the facts and then suspends judgment until they are all in. Such training is fundamental, for no one possessing it will be likely to lose his intellectual balance.

Some conception as to what an exact statement is. Very many people are unable to make an exact statement, chiefly because they are in no mental condition to do so. Their ideas are vague and hazy, their thinking illogical, and their expression wabbles. Nothing trains in clear thinking and expression so much as accurate observation and description, and here again we are in the very stronghold of nature study. To hew expression close to the line of fact may not be called for on all occasions, as in familiar conversation, which cannot degenerate into a series of formulas, but in statements of fact or of belief it is demanded. It is surprising and gratifying to see how rapidly young children learn to hold steadily to what they have seen, and to state it without exaggeration or verbiage. It is a good habit to learn, and to learn so early that it becomes involuntary.

Some conception of what constitutes proof. This is the crying need of the men and women of to-day who make and hold the most impossible connections between cause and effect. It is in this very broad field that charlatanism of every sort flourishes like a noxious weed, and unless this situation is changed through the schools the dupes will continue to multiply. They are already far too numerous for our good, and seem to be increasing in number in spite of increasing education. Nature study presents unrivaled opportunity for training in proof, for it is found that a single observation is rarely trustworthy, and that additional facts are apt to modify the conclusion. The spirit of nature study is necessarily conservative and is very slow to recognize a thing as proved, for it is compelled so often to change its conclusions. Whole systems of belief and lines of conduct have been constructed upon a basis of claimed fact which a child in the grades, trained in nature study, could he understand the terminology, would reject without hesitation. An injection of such children in large numbers into any metropolitan community would work a revolution.

Such are the results that appear possible from well-organized and well-conducted work in nature study, and, if so, its greatest mission is evident, for the production of independent and rational individuals is what society needs to-day more than anything else.

CHAPTER IV

THE DANGERS OF NATURE STUDY

Introductory.—Even when the purpose of nature study is clear in the mind of the teacher there are numerous pitfalls for the unwary. They may be very readily discerned by visiting schools or by reading books that are serving as guides to many teachers. The earnest work of teachers is fully appreciated, but if earnestness in certain things seems to be misdirected it is wise to call attention to that fact. Some of the following criticisms may develop differences of opinion and then the teacher is to be the judge; the justice of others is more evident, for the faults referred to are very far from the real purpose of nature study.

The Teacher.—Here lies the fundamental danger in all teaching. Methods and material may be well organized, but the teacher is able to make them ineffective. This is peculiarly true of nature study, for if it is not well done it is worse than useless. The studies long established in elementary schools are so well organized that even poor teaching may result in some progress, but nature study is in the experimental stage, and to experiment takes initiative and ideas. As a consequence, the results obtained from nature study have not encouraged its introduction or maintenance to so large an extent as it deserves. It has been decried as a fad that will die out, as a thing with no educative value, as an impractical and nerve-racking timekiller. All of these epithets have been applied to it by those in authority in the schools, and by parents; and it is interesting to trace the cause of such opinions. It is usually found that such criticism is founded upon the work of some teacher who was marking time rather than teaching. One is forced to the conclusion that among the worst foes of nature study must be counted many of its teachers.

It is often urged that this state of affairs will continue until teachers become trained for this particular work. It is very true that teachers should be trained in nature study, but this is not the principal thing. University representatives of the sciences have even urged an amount of general knowledge of the sciences that would stagger a university instructor. This is clearly impractical, for grade teachers cannot obtain so extensive a training, and if they can they will no longer consent to be grade teachers.

The principal thing is not formal training in teaching nature study, although this is very desirable; or a university course in all the sciences involved; but the principal thing is the spirit in which nature study is taught. This is the first thing, and training and knowledge will develop through experience and wise suggestion; without it, no amount of training and knowledge will make a successful teacher of the subject. There are teachers with no formal training and with no exact knowledge who have succeeded in developing almost ideal courses in nature study, judged by all the tests we know; and there are teachers with all the formal training of the schools who could not "make it go." To catch by observation the qualities of an effective teacher is like trying to catch a personality. For such a one no rules can be formulated; he is like an artist, born with a feeling for his work. We simply know that in our school machine, at the points of application, we sometimes get power and sometimes none. And yet there are certain obvious things about a successful teacher that can be observed and these ought to be helpful.

The most obvious thing in a successful teacher of nature study is an enthusiasm for the work, and enthusiasm is one of the most contagious things in the world. Moreover, the enthusiasm is not assumed, but real; the outward expression of a feeling that the work is important and delightful. Without this feeling, the work becomes a task rather than an inspiration, and in such an atmosphere nature study cannot live. Those who teach this subject, therefore, must feel abundantly encouraged if they have a real love for it, for all the other desirable things will follow; but if they look upon it as an unspeakable drudgery from which they long to be relieved, they should consider thoughtfully the purpose and principles of the subject, and see whether a fuller understanding of it may not generate a spark of enthusiasm that experience can fan into a flame.

Dead Work.—This means that insignificant and trivial things are selected for observation, and when the work is done there has been no real gain. This is a very common pitfall even for the enthusiastic teacher, but it is almost a sure indication of the perfunctory one. When the world is full of important things to be observed, and when observation should accumulate a body of useful knowledge, it is fatuous to waste time and energy upon trifles.

Just here comes a serious difficulty. How shall teachers select important things and reject trivial ones unless they have more training in the sciences? It does not take as much training to make such selection as may be supposed. A little reading, some experience, and a few questions directed to those who know and are glad to help will suffice. Besides, no one expects every selection of material to be wise; even in university laboratories we are doubtless giving much attention to certain things that will later turn out to be of trifling importance. The best that can be done is to avoid the obviously trivial whenever it becomes obvious to the teacher.

There are teachers honest enough to recognize and acknowledge that they have been dealing with trifles. They confessed that they were "marking time"; trying to fill the assigned period with anything that occurred to them. As a salve to conscience the exercise was called "busy work," instead of nature study, and that is a capital name for all dead work in nature study; work which keeps the pupils busy even if they are neither interested nor profited. Classes are many in which leaves brought in day after day are used in such work, presumably because they are abundant and varied and can fill in more periods than any other material; but classes are still rare in which the really important things about leaves are observed.

There seems to be an impression with some teachers that the most important things to observe even about familiar objects are those things most unusual to the pupil's experience. The fact is that the most important things are the most obvious, so obvious that it almost seems foolish to call attention to them. They are so common to the experience of everyone that they do not seem to need consideration. For example, who does not know that leaves are green? But why? This is the question that so universal a phenomenon should suggest, even if it remains unanswered for the present. Who does not know of spring flowers? But what does this very common habit of spring flowering mean? Nothing is more obvious than that stems grow upward and roots downward; but why? The seedling multiplies its bulk an hundredfold; but whence and how have come the materials for this increase? It may be almost taken as a rule that important things in nature are those which are so common that people seem to know about them without observation. Some teachers have taken a whole course in nature study, and so common were the phenomena considered and so simple was the presentation that they claimed to have learned nothing, when they were really dealing with the most important materials of nature study. They demanded difficulty, rarity, obscurity, terminology; and getting none of these things they were as disappointed as is a hypochondriac whose physician refuses to give some nauseous medicine.

Terminology.—There appears to be common confusion between "terminology" and "knowledge." To learn the technical name of an object seems to satisfy the intellectual desire of most people in reference to it. As a well-known botanist said in reference to the naming of plants, once so much in vogue as botany: "It is like chasing a woodchuck into his hole; one has only the hole to show for his effort." A technical name explains nothing, and is merely a necessary evil and necessary only to specialists. To introduce technical terminology into nature study is as much out of place as to introduce professional training.

With observation of leaves, which seem to be favorite objects with many teachers, the frequent result is merely an ability to apply the terms lanceolate, ovate, cordate, etc., to the proper forms; serrate, dentate, etc., to the proper toothing; and palmate, pinnate, etc., to the proper veining. Such work is often done seriously and with the idea that a knowledge of these names means a knowledge of the leaf. If a technical name is used at all it should be used like the name of an individual; useful to distinguish the individual upon introduction, but by no means implying acquaintance. What we want in nature study is not a series of introductions merely, but an increasing acquaintance and fellowship.

It may be claimed that we know little more about most things than the names we have given them. This is very true, but we can learn to ask intelligent questions, which is far more important in this work than being supplied simply with answers to questions. The method is more important than the matter. This is the attitude of mind that nature study should cultivate, rather than the idea that a name is the end-all. That leaves vary in form, toothing, and venation is very evident; and it is a good thing to impress this fact and the range of variation. The end of all this, however, is not to apply names to the variations, but to suggest the question as to what all this variation means in the life-work of the plants. To be able to ask intelligent questions is after all about the best we can do in the present state of knowledge in reference to nature.

Factitious Interest.—This means that use of playful and imaginative devices for securing an interest that the real object is supposed to lack. Here is where the majority of books on nature study get in their deadly work, with their personifications and romances. We sometimes find so-called nature-study exercises which consist of the exhibition of a flower or even a bird and the quotation of poetry about it. This may be a charming way of making literature more realistic, but it does not hold relationship with the nature study here in mind. We may find this process called the correlation of nature study and literature. But such devices repel rather than attract strong children, just as does the foolish and forced sprightliness of manner of many primary teachers. The truth itself, when discerned clearly, is always attractive, and we cannot afford to play fast and loose with it.

Just here we find large diversity of opinion, for this kind of instruction has become so engrafted upon nature study that to many it seems to be essential. Besides, the method referred to obtains results that are really desirable, for it interests and stimulates many and certainly feeds the imagination. The only criticism is that it is not nature study. It is simply using the facts of nature as starting points for flights of fancy. It shifts the interest from nature to a figment of the imagination which does not and cannot exist in nature. It introduces points of view that result in deceptions and even hallucinations, and it is improperly labeled nature study. Rather it is "nature fancy," and perfectly unobjectionable when rightly named.

The race of so-called "nature fakirs" thrives in this atmosphere. They weave their nature fancies with great skill, and their writings are very seductive. We acknowledge and enjoy their charm, but when they pose as interpreters of nature they are to be denounced as frauds. Let it be understood that all this criticism has to do only with a proper label—a label that shall fairly represent the content.

Does this mean that instruction in nature study must be as exact and colorless as a mathematical formula? By no means; but it does mean that no teaching device shall divert attention from the real truths. Every bit of color and glow that can be made to play about these truths is not only legitimate but extremely desirable. This, however, is merely good teaching, and comes naturally to teachers who have the ability to interest children. To make nature live is one thing; to make the imagination lively and even wild is quite another. We may contrast the actual cases of two teachers, each telling the story of the winter bud and its awakening in the spring, and each holding the rapt attention of the class. One told of a sleeping princess guarded by wonderful coverings, of the coming of the spring fairy, of the gradual awakening, and of the unfolding into full beauty. The other introduced no princess or fairy, but spoke of the bud as a part of the plant, of the danger that comes with the winter, of the way the danger is met, of the new conditions that come with the spring, of the unfolding leaves, and of the preparation for a season of service. The pupils of the former were attracted by the princess and the fairy; those of the latter by the structure and significance of the bud. No one should hesitate to decide which of these two teachers was teaching nature.

Unwarranted Inferences.—It is astonishing how many teachers feel under compulsion to explain everything, when as yet most things cannot be explained. Perhaps this arises from an anxiety lest their pupils regard them unfit for their work. The inferences heard and read in connection with nature study are wonderful. The wildest guesses as to the meaning of things are made, when the teacher or writer must be conscious of utter ignorance in reference to the matter, or is singularly self-deluded.

The "nature fakir" is the prince of nature explainers. Even if his observations are to be relied upon, which is far from true in every case, his explanations are usually beyond all reason. Especially deceptive is the explanation that involves attributing to plants and to the lower animals the consciousness, and motives, and methods of human beings. More or less of this idea is implied in the terminology we use, for we have developed no other for common use; but it is not used with the deliberate intention of attributing human powers to low organisms. The spines on a cactus are very serviceable in protecting it from grazing animals, but to teach that the cactus invented spines to use for this purpose is to teach an untruth. In this case it happens that the cactus grows chiefly where there are no grazing animals to molest it, and that its spines were produced of necessity and not from choice; and this may be taken as a fair sample of all the wonderful and deliberate "inventions" of plants.

There is an opinion current that everything in nature is perfectly adapted to its surroundings, and perhaps this belief explains the feeling of compulsion to explain. Evidently many have not thoughtfully considered what perfect adaptation would mean. It would mean absolute stagnation; while lack of adaptation means progress. Plants and animals are doing as well as possible under the circumstances in which they are placed, but in general they are changing and are far from being perfectly adapted to environment. In fact the whole question of adaptation is to-day an open one among biologists and no weaker point has been found in certain theories of evolution than the assumption that all things in nature have or have had a use and we need be but sufficiently clever in order to discover it. Since we are agreed that a child's interest should not be bought by trifling with truth, all statements that plants or animals have certain structures or habits for certain specific purposes are to be avoided as dangerous. Such, for example, would be the statement that flowers have odors and colors and nectar in order to attract insects. These characteristics may attract insects truly enough, but the form of statement should be rather that flowers do have such characteristics and that insects do come to them. The purpose idea has been greatly overemphasized. Such instances come up in nearly every lesson, and the continuous attribution of design as behind and precedent to the facts observed will form a fundamentally misleading habit of thought. The teacher, therefore, must be content to observe, to explain what is evident, to leave most things unexplained, to ask questions, to find failures; in short, to take nature as a great book of truths and of puzzles. To leave the impression that all things are understood would be the worst possible result.

Sentimentality.—This has been referred to in the previous chapter, but, as a danger, it needs additional emphasis. It is hard to make this criticism clear, for a certain kind of sentiment in reference to nature is not only desirable but necessary if there is to be success. But sentimentality is something quite different; it is a state of feeling rather than a state of intelligence. It has the effect of blunting keen observation, for it responds to the total effect of wild nature as to a general stimulus, rather than as a book to be read.

Such feeling is delightful, and the possessor is fortunate in having an additional attraction to nature study. What we are after, however, is not so much a feeling as a state of mind that compels observation, that is interested in the meanings of things, that is cautious in drawing conclusions, that is making continual progress. Sentimentality may degenerate into mawkishness, a kind of dreamy, unreal association of ideas that is ineffective and mentally enervating. There is probably too much sentimentality in education now, or, perhaps better, too little of its converse. If nature study is to intensify this tendency it had better not be introduced, but if it can be used to correct it, it had better be introduced at once everywhere.

It has been attempted to show that nature study can produce clarity of vision, exactness of statement, definiteness of conclusion; in short, the most practical qualities for successful living. If it can do all this it would seem a perversion to use it to increase the materials for mawkish sentimentality. The association of nature study with poetic literature is probably largely responsible for fostering sentimentality as opposed to knowledge. Because a great poet has mentioned a yellow primrose, does the quotation from him illuminate any fact of nature? The primrose might illuminate the quotation, but that is a study of literature, not of nature. The introduction of this method was natural, for it seemed to give to nature study a very powerful ally, but the relations have been developed in such a way that it looks like an alliance between a lion and a lamb. This is no criticism of poetic literature, nor of the attempt to make it live by seeing the objects it mentions; both appeal to the finest that is in us; but it is a criticism of the attempt to make it engulf nature study which has a very distinct mission of its own. The advice is, therefore, to change the atmosphere in passing from such literature to nature study, like the physician when passing from the joys of social life to the study of some difficult case. The former gives the emotions play, the latter demands mental poise. This does not mean coldness, for it involves enthusiasm; but it does mean a totally different attitude of mind. It is the cultivation of both of these sides of life that is sought. Each needs the other as its complement, and neither alone makes the most effective life. Let literature continue to do what it has been doing most effectively, but let nature study also show what it is able to do.

Book Dependence.—Under this title I mean to include all dependence upon authority, whether it is literally a book or some teacher. Respect for the opinions of those who are in a better position to know should be enforced strongly at every stage of education, but this does not mean the suppression of all initiative, the possession of only second-hand opinions. It is not difficult to perceive that ordinary school methods enforce intellectual dependence upon many teachers as well as pupils. Leaning upon authority is a deadly habit, easily acquired and broken with great difficulty. If an offset for it can be discovered, it is certainly desirable.

Such an offset may be provided by nature study, unless it is used to enforce still more the habit of dependence. Does it not furnish the main opportunity in early education to break the shackles of the book? When observations are being made, the things seen are to be recorded and not the things that ought to be seen as stated by book or teacher.

The variations in nature are so endless that no record has kept track of them, and this is one of the beauties of nature study, for it can be told easily whether one is really observing or only following. As an instance may be cited an exercise in which the teacher had distributed some seeds for examination. Among other directions was one calling for the observation of the two coats (the directions said "integuments"!). All found them except one boy, and the teacher informed the visitor that he was always giving her trouble, repeatedly failing to see according to directions. In this case the boy could find only one coat, and insisted that to get two coats this one would have to be split. It happened that the boy was right. The teacher had learned from some book that seeds have two integuments, and therefore two must be observed. This is not an example of a useful exercise, but merely an instance of misplaced use of authority.

The fact is that technical exactness in observation is not necessary in nature study. It demands such observations as are obvious to eyes and minds interested in nature, but not the observations of those professionally trained. Technical exactness at this stage of one's contact with nature kills interest; the chief thing is to secure genuine observation, and it is better to give this free rein, quite independent of authority. The habit of looking into the facts for oneself is one that cannot be acquired too early, and it should be cultivated steadily, as an offset to the intellectual dependence inevitably developed in the teaching of certain other subjects.

Outlines.—There is a very general demand from teachers for outlines. This point has been previously touched upon but it needs to be included again in any category of dangers. As a rule the inexperienced teacher feels more or less at a loss and grasps at every straw of help; books, magazines, lectures, or summer courses; and running through it all appears to be the hope of securing a precise outline of the work to be done.

All outlines and all uses of outlines are not to be included in one sweeping condemnation, but they introduce a danger that may be fatal. It is rare to find a proper outline or an outline used properly.

Yet a plan is deemed necessary for the most effective work. But an effective outline must be very flexible. It should be a series of suggested possibilities rather than of rigid prescriptions. It must adjust itself to seasonal fluctuations, to daily changes of weather, to the chance find in the field or material brought in, and always it must be specially written for the local conditions. And so it becomes amorphous to the degree that it nearly ceases to be an outline at all. It has few definite lines of structure and many alternative lessons. It nominates more topics than can be covered, for many may not be available in certain seasons. It provides on the same days lessons for rain and lessons for shine, and just so surely as the teacher approaches the ideal the need for any such outline vanishes save only to prevent the trespass of one grade upon the general premises of another. But withal it must be admitted that with things as they are with teachers' preparation good outlines sanely used are altogether useful in practical nature study.

An outline constructed by the teacher is a good thing. It may not be a good outline, but it is the organized expression of the teacher's thought as to the possibility of the subject in that particular school. It is an evidence of independence, which means that the outline will be modified for the better as experience increases.

An outline obtained from a successful teacher is also a good thing. It will be a good outline, not to follow, but to study. One may catch from it the principles involved, the spirit, the methods, and the sort of material that has proved successful. It will probably enable another teacher to make his own outline better, but there is always the temptation to "crib bodily" and be done with the trouble.

No outline is altogether good except one that is made with special reference to the particular teacher and to the neighborhood of the particular school. That nature study is peculiarly a local study cannot be emphasized too frequently. It is for this reason that any outline must be constructed by the individual teacher and not for teachers in general. But when this home-constructed outline has been completed, even it becomes a danger if it is followed too rigidly. It is a general guide, but it cannot be a day-by-day guide. It is impossible to foresee all the shifts that good teaching will demand. There will come the especially appropriate moments for different material or for arousing new interests of the pupils or for new methods of presentation, any one of which may for the moment cast the outline to the winds. Just as to certain speakers there come moments of inspiration through the act of speaking, so to teachers there come sudden inspirations in the act of teaching. These should be seized upon at once, used without reference to a programme, and recorded for future use.

When an outline becomes filled up with the records of such experiences, it becomes very much more valuable.

The worst phase of the outline danger, however, is the use of a borrowed one. This means that a scheme of work constructed for one neighborhood is applied to another, and it can hardly fail to be somewhat a misfit. The school of a teacher in the Central West was visited. The town was small and surrounded almost completely by a magnificent forest. In her eager search for instruction and an outline for nature study, the teacher had gone far afield, attending a summer course given on the Atlantic coast and securing an Atlantic coast outline. On the day of the visit the class was observing seaweeds! They had been obtained, with great trouble, from the fish market of a neighboring city, being the sad and broken sort of seaweeds that come as packing. They were slimy and formless masses, entirely foreign to the experience of every child in the class, or of any fortunate child anywhere. But seaweeds were in the outline and so they must be observed; and in this same outline there was not a single tree or forest study, the most conspicuous material of the neighborhood! This is an extreme illustration, but it is a true one. The contrast of regions may not be so striking in every case, but the same lack of fitness may easily appear when a borrowed outline is used.

Conclusions.—All the dangers enumerated above cannot be avoided at every moment of one's progress. The chief thing is to recognize them as dangers, and to eliminate them as rapidly as possible. A thoroughly good course in nature study, one that includes all the advantages and avoids all the dangers, is a thing of slow construction; and perhaps it is impossible of construction as yet. It is not a question only of what material is available, it is a question also of what material has valuable significance and of what appeals to the children. To select appropriate material from available material is the work of the teacher who is experimenting with the children. No earnest teacher of nature study need feel discouraged, for those who write and lecture and suggest are more dependent upon the teachers than the teachers are upon the "authorities."

CHAPTER V

THE PRINCIPLES OF NATURE STUDY

Introductory.—The title of this chapter may be misleading, but it is a convenient one to cover certain general suggestions which deal with principles as contrasted with details, and are applicable to any detail of location and material. Such principles are of course more clearly developed in connection with details, and these general statements lack something of force until they are applied in the series of suggestive studies in Part Two.

In the preceding chapter the reader was left with a series of things forbidden, which to some may have seemed to include everything done in nature study. Unless something can be substituted only damage has been done; criticism is of no avail unless it includes constructive suggestion. Of course things forbidden imply that the converse is desirable, and what is said in the following pages has been implied in the preceding ones. However, there is advantage in a series of positive statements. It must be kept in mind that these are only suggestions, but they are derived from long experience in teaching observational subjects, and effective methods for securing independent observation find general application at every educational level.

Objects of Common Experience.—Often the greatest puzzle to the inexperienced teacher is the selection of material. Since this must be done for each neighborhood, direction must take the form of general principles applicable to any region. The fundamental principle is to select the natural objects of most common experience—those that thrust themselves upon the observation of everyone. For example, in a wooded region no natural object is more common than a tree, and in every region trees are at least associated with parks, or streets, or dwellings. It happens that tree studies call for somewhat special treatment, especially with lower grades, but they are not to be avoided on that account. Tree studies are discussed as a topic in Part Two. In an agricultural region the prominent crops are most conspicuous, and in every region the common garden plants, useful and ornamental, are available. Everywhere there are the insects, and domestic animals, and some birds, and simple physical materials in abundance. It is often useful to discover the experiences of the pupils, making a list of the natural objects that have attracted their attention, and taking advantage of these contacts for a beginning. Naturally the conspicuous objects in many neighborhoods are much alike in a general way, and an outline for one school may be fairly applicable for a neighboring school, but there are always differences in detail to be provided for. For example, while trees will doubtless be included in most outlines, the conspicuous and easily available trees of different regions are apt to differ widely.

In addition to neighborhood differences in material, there are neighborhood differences in the experiences of pupils. The country child or village child is apt to have cultivated a considerable acquaintance with certain plants and animals, both wild and domestic, while the city child is apt to be in a state of great ignorance in reference to such things. To give to both of these experiences the same work would result either in commonplaces to the country child or mysteries to the city child. The average city child labors under a great handicap in reference to nature study, and is in peculiar need of it in its most elementary form.

All this means an adaptable teacher, one who is very sensitive to differences of experience among pupils, who can lay hold of any material, and who can vary the presentation according to the need. This last point is often lost sight of and is very important. Truth is many-sided, and it is always a question as to which side will make the most effective first impression. This is a very real problem which is to be solved only by the teacher. For example, is it the individual tree that has interest, or trees massed in a forest? Is it the general habit of a tree that impresses or the wonderful work it is doing? Or do trees impress some children at all? Quick shifts must often be made in points of view when an effective one is stumbled upon.

Activity Rather than Structure.—Children seem to be most interested in observing things that are doing something, and fortunately this activity represents the most important fact in reference to any organism, for structure finds its most important significance in the work it does. For this reason children watch with more interest the behavior of animals than that of plants; their activity is so much more in evidence. However, it is not difficult to show that plants also are very active. It is fundamental that all studies with plants and animals should rest upon the idea that organisms are at work; that life compels work. This does not mean that the study of structure is to be omitted; far from it! It means simply that all structure must be interpreted as to function so far as possible. Activity is to be the dominant idea. For example, the general structure of leaves ought to be observed, but only as leading to interpretation of their exceedingly important work. This dominating idea determines the structures to be observed, and eliminates all dead work. The general habits of trees ought to be observed in relation to their scheme for the position of branches and the display of foliage. The structure of bird feathers or of insect mouth parts or of gastropod shells should be studied, but always in terms of the part they play in the economy of the animal's daily existence.

This is not to be confused with the habit of assigning a designed purpose, often more or less obscure and forced, to every structure met. Warning has already been given as to the dangers in wholesale claims of adaptations. Where the structures observed have an obvious use that use is to be brought out, always by the children rather than the teacher, but the form of statement that things are thus and so *because* of such a need of the organism is a form of statement whose assumption is usually unwarranted by the facts and is to be avoided.

To show that plants as well as animals are busily at work simple experiments are valuable and usually arouse decided interest. Seeds are commonly germinated in the schoolroom in connection with nature study. Pupils in upper grades have been heard to complain that they "had beans in every room." The loss of interest and time in repetition has been pointed out, but the value and interest of germination work are enhanced by the use of various seeds and by experiments. Germination studies should always make clear by experiment the conditions essential to this process, and the varying habits of different seeds. Simple experiments demonstrating the ascent of sap, the evaporation of water from the leaves, the rate of growth, and the turning of roots toward water can be arranged with home-made apparatus. One cannot see the sap ascending in a tree, but after experimenting with the movement of water in a stem he can appreciate what is going on in countless tree trunks. One cannot see water vapor arising from leaves, but after measuring transpiration he can appreciate the great volume of water given out by forests, and their value as water reservoirs.

Definiteness.—To work effectively, the teacher must work to some definite purpose. To place material before children, or to send them out to observe anything, without definite knowledge on the part of the teacher as to the things to be done and some plan of action suggested to the children is never effective. Children have been set to observe a tree, with no suggestion whatsoever, and without the faintest idea as to the important points. As an experiment to discover what facts about a tree impress children the most, this is sometimes worth while, but as an ordinary method it results in confusion. No material should be assigned that has not been traversed previously by the teacher, so that she knows that there are some very definite facts in plain sight. Even in the university the laboratory instructor must work over his material and his experiments before each exercise, so as to be sure that what he wants is there in good condition or that his experiment will work. Quite as much is this needed in nature study, for young pupils must not be made to search long or to obtain poor results. Lack of definiteness results in work that is confusing, discouraging, and disastrous.

It is just here that the teacher's greatest skill is called for. To give enough suggestion to make observation definite and not to give enough to interfere with independence is sailing between Scylla and Charybdis. Either extreme is disastrous, and the decision as to just what to suggest and what to leave to suggest itself must always be dependent upon the immediate circumstances both as to material and as to pupils.

Sketching.—In connection with the observational work there is no question as to the value of sketching; it can hardly be called drawing. The purpose is not to make a good sketch, but to insure accurate observation, and it is the best teaching device known to secure this result. Usually no one sees an object with exactness or fastens it in his memory clearly until he attempts to reproduce it. Any artistic skill possessed by a pupil is apt to be a danger, for the tendency then is to make a picture rather than to record the facts. And yet the exercise incidentally teaches one to make lines represent facts with exactness. The pedagogical value of sketching in nature study, however, lies in the effort to reproduce rather than in the accurate reproduction. A pupil whose sketch does not represent the object, and who recognizes the fact, may have received as much benefit from the exercise as the pupil who sketches better. This is important to remember in criticising and in grading pupils. In using such a device, the temptation is to make the device the end in itself rather than its effect upon the pupils. Sketching should measure the thought behind it no more than does handwriting; both ought to be as good as possible, but both are subordinate.

Individual Work.—Observation must be made as independent as possible and this means individual work rather than general class exercises. It is hardly necessary to argue for this method, for it lies at the very center of the idea of the laboratory method which has penetrated and revolutionized all education. To lean upon anyone else for an observation is to make it ineffective, and the majority of pupils will lean if permitted to do so. General exercises are often conducted in which some object is held up before the class, different things about it pointed out and named, and an occasional question asked. Under these conditions the pupils fall into four categories: those who do not listen, those who do not observe, those who do not answer, and a few eager ones who do all the listening, observing, and answering.

Individual work means individual responsibility, a most important lesson to learn early and to learn thoroughly. It takes those who do not listen, or observe, or answer out of the class of drones and makes of them workers. This sort of work means more effort by the teacher than a general exercise, but its results are worth much more than the difference in trouble. To individualize material or experiments in the classroom is simple enough, even if it is laborious, but to individualize work in the open is often regarded as impractical. The school garden work should be based upon this idea of individual responsibility just as soon as the maturity of the pupils permits; in fact, a school garden would hardly be justified if it were made a general exercise throughout.

Although individual work is spoken of in contrast with general exercises, this need not necessarily mean each pupil working alone. In fact, it is often a great advantage to break the class up into groups of two or three in the conduct of observations and experiments. A companion or two in work is a great stimulus to effort, to interest, to exactness. A pupil working alone may be careless, inexact, or even untruthful; but two or three working together will be almost sure to bring in honest results. Even in the primary grades this group system appears to be desirable in the garden work. Such separation into groups also often arouses a desirable spirit of competition. It is interesting and instructive to see and hear one of these groups properly at work. The observation by one pair of sharp young eyes is checked or supplemented by the observation of another pair equally sharp; then the discussion comes; then repeated observation is made to settle dispute; and finally the conclusion is reached. This working over of the problem before the result is presented gives admirable results.

Unprejudiced Observation.—The danger which lies in the teacher's telling too much, and the difficulty in avoiding this without telling too little have been mentioned. But the telling too much is perhaps the more serious fault, for it leaves no effort for the pupil, while telling too little leaves the effort, even if it results in no very definite observation.

Children in school are remarkably docile, and if told to see a thing, the majority of them will confess to seeing it. In the preceding chapter reference was made to a troublesome boy who would not see the two coats of a seed which the teacher called for. In that particular instance the class was almost unanimous in professing to see something that did not exist, simply because they thought they ought to see it. It must be evident that this result is as far as possible from the one sought. It is just this kind of docility that must be broken up, or the child will become a confirmed dependent.

This kind of dependence appears even among university students, whose observations are not prejudiced in this case by instructors, but by well-illustrated text-books. This flinching from doing the one really essential thing, when it comes to observation, is to be observed in many ways and is to be checked at all hazards. In nature study, text-book, or chart illustrations are not likely to prejudice, and the teacher properly on his guard will not commit such a blunder, but even then there are ways of dodging the issue. There are sketches of fellow pupils that may be used as a substitute for one's own observation; this of course is palpable dependence. A more subtle form of prejudiced observation is the careless or hasty look, followed by a record made to fit general impressions rather than the actual facts.

It is very helpful to discover the tendencies of individual pupils in a variety of ways, trying to discover the personal equations and then attempting to correct them. A bad case needs to be isolated from every form of temptation, a sort of solitary confinement, until real observation is secured. In other cases, whose symptoms are not so serious, occasional traps will probably bring caution and honesty. Some cases will be found hopeless, for they are born dependents, or they may be even persistently dishonest. But the majority will respond and will presently stand any test of independent, honest observation, feeling free to contradict book, teacher, or any other authority that does not agree with their own observations. This is really the ideal result; but it is rather surprising to find that the "spirit of contradiction" distresses many teachers and angers some. Honest contradiction based on honest observation means an alert, independent mind, and when such a result is reached in the case of any pupil, then teacher and pupil may enter into comradeship in observation, and the further progress of both is assured.

Comparison of Results.—This deserves special attention. It ties up the bundle of observations in such a way that they lead to a much larger outlook and the intellectual result is of the greatest importance. In fact, observations conducted in accordance with all the previous suggestions seem to end somewhat blindly without the culminating process of comparison. It would resemble reading a story so as to become acquainted with the characters and even interested in them and in the dramatic situations, and then omitting the concluding pages that record the final results and give meaning to all that has been done. It would resemble the tracing of a series of converging lines and stopping before they meet at some point. The intellectual results obtained from the process of comparison follow one another in a series so swift that one seems to compress into a brief effort more results than have been obtained from everything that has gone before. This point needs somewhat close analysis to see what a rich content of results comparison contains.

Let us suppose that various plants or animals have been examined by different pupils or small groups of pupils. The exercise may have dealt with such details that only one kind was used, individual specimens having been assigned to individual pupils or small groups. Or the exercise may have been a general one, applying to a group of types, as woodpeckers or evergreen trees. In either case each pupil or group has made and recorded observations that are presumably independent and honest. When all these sets of observations are brought together and compared, it will soon become apparent that there are differences. Far the most interesting way of comparing results is to take them up item by item in a class meeting and call for an oral statement in reference to them. Some of the differences of statement will be so great as to appear like contradictions. The chances are that a general oral exercise of this kind will develop discussion and perhaps dispute, and the more interested and eager the dispute can become the better, for it means momentum for what must follow, and clinches things in memory when agreement is reached.

The next step comes so naturally that it is likely to be proposed by the pupils themselves. Differences and even contradictions in the results demand a reëxamination of the material, each claimant undertaking to make his claim good to the class as a whole. This will certainly detect and so eliminate careless observations and dishonest claims, and will stiffen the moral backbone in future exercises. This phase of the result, however, is only incidental, for the exercise is not meant to be a trap for the careless and the dishonest. What we have in mind are sets of honest and good observations that show differences of varying degrees up to contradiction, and that are confirmed upon reëxamination. This is the useful situation to develop, and it is the usual one if the work has been well done.

Confronted with the fact that many differences in evidence are not due to mistakes but are real, the pupil has reached an experience that is very important. He must see for himself or be shown that while certain observed features are different, others are similar. The result is recognition of the facts that the characters in common are the important ones, and that the characters which differ are not so important, being only individual differences. For example, a number of maples may have been under observation, and the result will be sets of observations that will show characters in common and characters that vary. Those in common will be found to be the features that distinguish maples in general from other trees, while those that vary will prove to be variations in individual maples, or the variations which indicate the different species. Not only will the difference between essentials and variations be determined in this way, but the possible amount of individual variation will often be quite impressive. It will be realized, for example, how much maples may vary and still be maples. Here, again, it is not a specific exercise which is recommended, but merely an illustration given which applies to almost any material.

A few experiences of the kind suggested certainly have a tendency to develop caution. When differences in the results of observation develop in connection with some subsequent exercise, there is more toleration shown, the tone of discussion or dispute is not so confident, and the appeal to reëxamination is more immediate. To recognize the fact that other people may be right even though they seem to differ from one is making progress. Disputes may be frequently heard among adults which children, trained in comparisons as just indicated, would make short work of. Herein lies a way to the attainment of the scientific spirit, which is more important in education than ten thousand mere facts of science.

The crowning result of this exercise, when repeated often enough, is to teach the need and nature of adequate proof before a statement can be insisted upon very strenuously. For example, a boy claimed that oak leaves have five lobes; he knew it because he had seen an oak leaf and counted its lobes. Another boy, who has been through the mill described above, knows that this is not proof; that many more oak leaves must be examined; and that very likely the lobes will be found to vary in number. Yet the statement of the first boy represents by far the most common form of statement, and many people even base important beliefs upon testimony no more critically examined than the testimony of the oak leaves by the confident boy who examined one.

This tendency to confidence in conclusion based upon few or even single observations is so general that it needs serious attention, and any exercise that helps to correct it cannot be repeated too frequently. One of the hardest things in teaching experience has been to check the tendency of many students to use one fact for a starting point for a flight of fancy that is surprising. Such a tendency is corrected when facts accumulate somewhat, and flight in one direction is checked by a pull in some other direction.

But most of us have the tendency, and the majority are so unhampered by facts that flight is free.

There seems to be also a notion current that one may start with a single fact of nature and by some logical machinery construct an elaborate system and reach an authentic conclusion, much as the world has imagined for more than a century that Cuvier could construct a skeleton if a single bone were furnished him. Facts are like stepping-stones; so long as one can get a reasonably close series of them he can make some progress in a given direction, but when he steps beyond them he flounders. As one travels away from a fact its significance in any conclusion becomes more and more attenuated, until presently the vanishing point is reached and its power of illumination fades like the rays of light from a candle. A fact is really only influential in its own immediate vicinity, but the whole structure of many a system lies in the region beyond the vanishing point. When life and conduct are shaped by such observation and reasoning the result is disastrous.

This dangerous tendency is so serious and fundamental that that exercise deserves special emphasis which more than any other single one in nature study will be found useful in correcting it.

The suggestions just made in this chapter are intended to be a statement of the methods by which the important results which were mentioned at the close of the first chapter may be obtained. It remains to apply the principles to actual studies. If the results are important, and the practice of certain principles can secure them, and simple exercises can include these principles, then there would seem to be no reason for hesitation in making the experiment.

CHAPTER VI

THE SPIRIT OF NATURE STUDY

Introductory.—The spirit that dominates successful work in nature study has been distinctly implied in the preceding chapters, but it may be helpful to assemble definite statements in regard to it into a continuous presentation. It is important for the teacher or the adult student to appreciate what may be called the atmosphere that vitalizes the subject. This will enable one to distinguish between the genuine and the spurious, just as one learns to distinguish between genuine and spurious art. This will bring critical judgment to bear not only upon one's own work as a teacher or a student, but also upon the literature of the subject and the claims made by public lecturers. Nature study has been defined as a certain "attitude toward nature."

The ability to pass intelligent judgment upon the increasing body of the literature of this subject is very important to teachers and is not difficult to acquire if one catches the spirit. It is much like judging individuals, who for the most part soon arouse a feeling of confidence or of distrust; it is difficult to describe just how, but the judgment comes. Very frequent inquiries come from teachers of nature study asking opinions concerning books, and it is certain that the majority of teachers are often victims to the plausible representations of agents. To such this chapter may prove helpful, for to know the spirit of nature study is to recognize those who really represent it.

To describe an "atmosphere" is not easy, at least in exact terms. Although real it is elusive, and can be brought to the appreciation of anyone only through experience or suggestion; and yet it includes certain very definite things which may be taken to represent it as its natural expression.

Enthusiasm.—It is always characterized by enthusiasm, which is the motive power. This is a feeling of attraction for nature and for natural objects that compels attention. It may be born with one or it may be acquired, but without it nature study is as lifeless as a graven image. There is an enthusiasm that is exuberant and fitful, now blazing out, now dead; but the enthusiasm that counts is steady and sustained.

It is far from safe to use enthusiasm as the only test of an effective nature study spirit, for it may be irrational and hence ineffective. Having been found in a person or in a book, it is taken as the first count toward a favorable judgment; if it is found to be lacking, no further investigation is necessary, for nothing else can take its place.

It is just at this point that differences of opinion often arise. Enthusiasm sometimes inclines one to slur over facts rather than to analyze them with exactness. This is bad if carried too far, to the point of securing false results; but up to a certain point it is far better than deadly exactness. Much of the criticism by scientific men is justified, but when it demands an exactness that belongs to the university laboratory, it misses the mark. There is a kind of exactness that is essential in nature study, and there is another kind that kills it. For example, it is necessary to observe the exact sequence of events in a germinating seed, but it is entirely out of place to insist that a seed does not "germinate" because this function is restricted to spores. It is essential to see that most stems turn toward the light and most roots turn toward the earth, if a curve is necessary to secure these directions, but to insist upon a form of statement that describes with exactness the response to the stimulus of light and of gravity is a useless analysis at this stage of education. Total results are to be considered primarily, and the factors which contribute to them cannot be analyzed too critically, else teachers acquire so much deadly dullness that they destroy all enthusiasm.

This demand for exactness that kills enthusiasm appears more in connection with terminology, perhaps, than in a needlessly close analysis of the facts. Technical terms are used to secure exactness, and in study of the sciences they are absolutely necessary, but in nature study they have small place, for the accuracy they imply is not demanded. To elaborate, for example, the differences between a rhizome and a tuber is perhaps necessary at some stage of progress, but all the student of nature study needs to know is that they are both thickened, underground parts of plants, to be called by whatever name happens to be convenient.

This is not a plea for inaccuracy either in observation or in terminology, but a plea for the salvation of enthusiasm. Anything that would diminish it must be avoided, and experience has shown that technical exactness does this very thing for the first contacts with nature. General ideas, impressions if you please, come first, and when they have been established their analysis with its terminology may follow. This guarding of enthusiasm constantly suggests points of danger. For example, in addition to the dangers already referred to, the repetition of similar exercises beyond the point of interest is a frequent menace to continuous enthusiasm. Insistence in carrying through an exercise that has been thought useful, but has proved otherwise at the very outset, is similarly of dubious value. In short, when interest is guarded, which has been shown to be essential, enthusiasm is guarded.

It is a mistake to suppose that enthusiasm any more than interest lives on excitement. Such enthusiasm is unhealthy and cannot be sustained. It is like attempting a continuous Fourth of July. Pupils need different treatment; the exuberance of some must be toned down to a safer level; the sluggishness of others must be stimulated into effectiveness. It is apparent that it is no simple thing to secure enthusiasm of the right kind and of the right amount, but it is essential.

The questions to ask oneself, if a teacher or a student, or to answer for one's pupils, are as follows: Has nature any real attraction for me? Is it so attractive that I will not be rebuffed easily? Is my enthusiasm in danger of sweeping me off my intellectual balance and submerging me in mere feeling? Must things be exciting to be interesting? Am I looking at nature as a dry book of details and terminology, which it is my duty to read? Honest answers to these questions will go far toward determining whether any effective enthusiasm exists.

An Open Mind.—This means a teachable mind, one with no prejudices, and ready to receive impressions freely. To come into contact with nature with any preconceived opinions as to what it should be is to court rebuff and perhaps blindness. There was once a time when botanists conceived the idea that each kind of plant represented a definite type, and this type was carefully described and named. When they visited plants in nature, they carefully selected those individuals which represented the preconceived type, and disregarded all the others, which others happened to be in the large majority. In fact, one ardent botanist called these individuals that would not come true to type "devices of the devil." This distinct prejudice blinded botanists to the great fact that was thrusting itself upon their attention persistently that no such types exist, but that variation exists everywhere. In this case prejudice was sufficient to introduce into nature, for these observers, a figment of their own imagination; and it will do just the same thing for anyone who observes only what he thinks he ought to observe.

Here comes the danger in books and teachers, for must one not read or hear before he can observe? This is true, in a sense, but not in the literal way in which it is often taken. The books and teachers must not be taken to direct and enforce the details of observation, but simply to emphasize the record of things that have been observed. They suggest the things to examine, but should never determine the things seen. A botanist may describe a plant or a zoölogist an animal in considerable detail, and yet no one may be able to find forms just like the descriptions. The result of observation should be, not that no such forms could be found, but that the forms seen differed in several particulars.

The beauty of the open mind is that it sees what is to be seen, and is continually encountering facts that it never saw in a book or heard from a teacher. The records of nature are very meager as compared with the facts of nature, and it is the latter that the student is exploring. To select a few cut-and-dried things beforehand and then to go out into nature to find them is like matching a pattern in a great department store rather than looking at its wealth of offering. Experience is a good guide, but not if it keeps one in a narrow path between high walls; its use in nature study is to show that there are no boundary walls.

Teachers may be troubled by the freedom which this spirit produces. They have laboriously familiarized themselves with certain observations, and when the boundaries are disregarded they are at a loss. Questions are asked, material is introduced, observations are made, which are out of bounds and hence perplexing. But the spirit is vital, and must not be suppressed, for it is the very freedom of nature. The wise teacher, who does not feel compelled to know everything, can guide and use it, and is most fortunate if his work has permitted its expression.

A Spirit of Inquiry.—This is an attitude of mind essential to nature study, and is also one of the most valuable assets in life. The need of this in life may serve to illustrate its place in nature study. In our experience we encounter a vast body of established belief in reference to all important subjects. Not only do we encounter this in others, but we find ourselves cherishing beliefs, often called hereditary, but really the result of early association. Nothing seems more evident than that all this established belief belongs to one or the other of two categories; to wit, the priceless results of generations of experience, and heirloom rubbish. The spirit of inquiry impels one to examine the foundations of belief. The childhood of the race accumulated much which its manhood is compelled to lay aside, and our mental stock in trade needs going over and revising continually. This is the only way to keep the true from being covered over by the false.

Every part of this description applies to the need of a spirit of inquiry in nature study. We find that there are many cherished beliefs about nature that people have grown up with and many of them may be on record. They may be recited to us by friends, by teachers, or by books. We can be sure that some of them are founded on the truth, and that others are nonsense; and so far as opportunity permits us, the spirit of inquiry urges us to put them to the test. Under the last topic it was indicated that the open mind comes into a larger and freer contact with nature than instruction can anticipate, but the spirit of inquiry finds part of its mission in looking into the foundation of instruction. Old ideas of nature became crystallized into statements, and these statements have been passed on from one book to another, and they reappear in the instruction of to-day. Some of these statements stand the test of new observation and others do not.

The spirit of inquiry, therefore, leads one to take the statements of books and of teachers as things to be tested before they are believed. It distinguishes clearly between beliefs that must be taken on faith and those that need to be accepted only after the evidence is examined. If the teacher states that all clovers fold their leaflets toward evening, and suggests that the observation be made, the pupil need not believe it until seen, and then he will probably conclude that the teacher made too sweeping a statement. It is a current belief, expressed by the name, that all sunflowers face the sun and follow its path, and the very first sunflower met may contradict this notion. It is an interesting thing to collect neighborhood beliefs in reference to nature and to check them up by a little exact observation. It is not only interesting, but it is an exceedingly valuable exercise, and develops an attitude of mind that is really scientific. Especially do these unfounded beliefs prevail in connection with the cultivation of plants, and we have seen children deliberately set to violating every known superstition in the case of plants and proving them worthless.

The spirit of inquiry not only compels one to examine the foundation of current statements in reference to nature, but it pushes observation into investigation. An open mind sees, but the spirit of inquiry wants to know why. The open mind sees the veins of a leaf and is not hampered by any preconceived plan for them, but the spirit of inquiry wants to know what the veins mean. It is always converting the *what* into *why*, and is an endless series of interrogation marks. This does not mean an endless series of answers, for that is impossible, but it will mean an answer now and then, and a most valuable attitude of mind.

Do teachers encourage this sort of thing, or are they inclined to suppress questions and to resent any hesitation to believe? We have seen this tendency, but can hardly believe that it is general. There is no surer evidence of an awakened mind than the questioning which follows observation.

The Desire for Truth.—This topic may seem to overlap the last one, but it has a different application. We have touched upon the prevailing sentimentality that infects nature study, sentimentality that sometimes may be called gush. It always raises a fog over the facts, and they appear unnatural and distorted. Any real desire for truth resents this and insists that the fog be cleared away so that things may be seen as they really are. It is just here that the imagination becomes dangerous. This does not mean that it is to be eliminated, but that it is to be kept within bounds. Imagination may make facts glow or it may conceal them.

An actual experience illustrates this point. A teacher with a delightful power of story-telling had entertained a class in nature study most successfully, but she had set free her imagination in such a way that fact and fancy were all in a jumble. Only one who knew the facts could pick them out, and the whole description was as seductive as one of Jules Verne's romances. Fortunately, at the close of the exercise, questions were called for, and the proper spirit of nature study came into evidence. A boy, whose restlessness was in sharp contrast with the general breathless attention, began to free his mind, and never was a witness subjected to a more searching and persistent cross-examination than was that teacher. That boy wanted to know just what was true and what "made up" in the account, and he did not propose to rest until the truth had been freed from its wrappings. This attitude toward truth appears to be general among boys unless it has been unfortunately suppressed.

The honest desire for truth not only seeks to free it from a fog bank of imagination, but also compels honest work. Work that is part observation and part guess does not satisfy. Of course if interest does not prompt, there is no desire for the truth in reference to any particular exercise, but, given enthusiasm, the real facts are discovered if they are attainable. The same desire not only prompts to honest work, but mounts over all sorts of obstacles to secure it. It is not necessary to make things easy, but only to assure that they are really there. A boy became interested in the length of time a certain bird sat on its nest to hatch eggs. He might have asked some one who knew, or possibly he might have found the information in some book, but he wanted the truth, and thought he was able to discover it for himself. That involved daily trips to the nest until the truth was discovered. Some would say that the boy's time and energy might have been better employed, but that is very doubtful. That particular fact at that particular time was the most important thing for that boy, and he labored to discover the truth in a perfectly scientific way. The illustration is an extreme one, for the boy was exceptional, but it illustrates the compelling power of the desire for truth.

There is reason to believe that such definite problems can be used to great advantage at certain stages. This does not mean problems in the university sense, but in the school sense. It means the suggestion of a truth that may be discovered by using a reasonable amount of time, effort, and initiative. Children who have given symptoms of an ability of this sort may well have problems of this kind on hand, to be followed up on their own initiative. It is a higher stretch of observation, for it substitutes for the single study a continuous series of observations that are related to one another. Some problems of this kind are included among the suggestive studies in Part Two.

Persistence.—While this quality is most desirable in children, and is welcome when it appears, one cannot expect them to show it very strongly developed. Nor is it desirable with them to insist too much upon persistence, for such driving will transform what ought to be kept attractive into a hated task. But the teacher is in much need of persistence, for the temptation is very great to do the easier thing rather than the desirable thing.

A field trip or a park trip is often troublesome to arrange. It takes time and planning and a control of children under difficult conditions. To keep such a trip from being merely an outdoor frolic, and to hold it to anything like a class exercise is a problem that makes many a teacher flinch, and perhaps argue herself into the belief that it is not worth the trouble. And yet it is the ideal exercise in nature study when well done. It is when confronting such trouble that persistence comes into play. It sees that a field trip is the thing to do, and it compels the undertaking. Even though the first trip seems to be a failure, persistence tries another one, and so on until the problem is solved. It is in such things that persistence means all the difference between success and failure.

The teacher also knows that material must be carefully selected and examined, that some of it is a little troublesome to secure, that solitary trips ought to be made in advance of the class, and the temptation is to use inferior material, to take the chances that it will show what it ought to, and to trust to luck for the trips. This shrinking from a little sacrifice of comfort is very common, and makes nature study so unsatisfactory that it becomes an increasing burden to the teacher and to the pupil.

Persistence is needed also in the successful formulation of many exercises. They must be repeated over and over in different ways before they become satisfactory, and some of them call for no little ingenuity, especially those that call for experimental work. Suggestions from books and from other teachers never meet all the perplexities, and one must persistently devise things for oneself.

There are teachers of no experience or training in nature study, but with enthusiasm and persistence, who have worked over their local material until they are perfectly familiar with its possibilities, who have devised all sorts of useful schemes for interesting the children in uncovering it, and who have accumulated a stock of most suggestive experiments. In short, they are exceedingly successful; perhaps more so than if their opportunities for training had been greater. There are other teachers of high training whose lack of persistence makes them shrink at every trouble, even the trouble of devising something that they had not learned. It is not the training nearly so much as the spirit that makes for success in this work, and since it *is* still experimental work, all the teachers who can think and devise should feel compelled to do so.

In many of the most useful problems in nature study it is necessary to carry on observations throughout the year or through successive years. The observation of the same plant or bird or insect at different seasons develops the conception of life histories, which is far more important than scattered observations and should be a dominant idea. This is especially true of tree and insect studies which really demand such periodic observations in order to be most successful. Observation through successive years develops some idea of the differences in time of development and in appearance in different years.

To carry forward the same ideas over such intervals of time demands persistence of the first order. But the teacher who depends upon one season to be repeated by every other season, and has the once-for-all idea, is sure to run on to the rocks. It may not be encouraging to teachers to know they can never complete their equipment, and that each succeeding year must witness the casting aside of much that was done in the preceding one, but the growth and the sense of satisfaction that this brings is its own compensation, and nature responds with such attraction that she will be studied afresh each season for her own sake.

A Special Subject.—This may not belong strictly to the spirit of nature study, but it is a natural expression of it. The teacher in conducting class exercises must traverse broadly the materials at hand. This range of material is so large and varied that the view must be very superficial. It is like walking through a huge picture gallery without stopping to study some one painting or some one master. This first general view is just what is wanted for children, but it is too superficial for the teacher or for the adult student. They must look deeper for the sake of their own development, which will bear upon their teaching, their standing, and their happiness. No one can give more than a superficial look at very many things, nor is the deeper look to be obtained through reading, although this is a part of the process. The wise thing is to select some special subject for individual study, which will include much observation and some reading. The development of a special region of the great field is a very common characteristic of the most successful teachers. Books and addresses on nature study show the same tendency, and those who really represent an experience and a knowledge that is helpful to teachers stand for some restricted field for work. One stands for plants in general, another for trees, another for birds, another for insects, another for amphibians, and so on to the end of the list. Upon listening to the instruction of these various representatives of nature study, it would seem as if each one was working with the only material worth while. But no such conclusion is warranted, for this variety of material presented only means that these individuals have become representatives of nature study by selecting some special material for special study. They are very familiar with it, and so can present it effectively. These special fields are used simply to illustrate the principles of the general field, principles that may apply to any material. There has been a very successful summer school of nature study in which only trees and birds were studied; another in which insects were the objects of chief attention. In any of these cases it was never intended that the materials used by these teachers with their classes should be so restricted, and it certainly should not be. But a teacher who has learned how to use trees and birds ought to be in a position to include other plants and other animals in the work in similar manner. The material used in the summer-school classes referred to simply represented that which was most favorable for the place and most familiar to the instructor.

Therefore every teacher of nature study is earnestly advised to select some particular subject and to become thoroughly acquainted with it. It may be wild plants, or trees, or birds, or different groups of insects, or fish, or reptiles, or domestic animals, or cultivated plants, or plant communities, or any of the score of subjects that might be mentioned, but let it be a choice thoughtfully made and persistently followed. This may bring a definite preference for a certain kind of material in teaching, but this will not hurt; it is far better than no preference at all. We have any number of teachers of biology, but not one of them is good who is not biased either as a botanist or a zoölogist, and his work shows it. The same thing is true of teachers of nature study; for the good ones show a decided preference for certain kinds of material—a preference that is determined by familiarity.

Also this following of a specialty is more certain than any other method to arouse a real and abiding interest in nature, for such interest is quite sure to accompany the acquirement of a precise and somewhat thorough knowledge of any particular field. What field is chosen matters not at all. As depth of knowledge of nature is acquired one passes through essentially the same rich experiences whatever the field.

CHAPTER VII

THE CHILD AND NATURE STUDY

Introductory.—In the foregoing chapters many of the principles that should govern the teaching of nature study have been named and emphasized. While all of them are well worth careful consideration, none is more important than the suggestion that a recognition of the principle of child study should determine what we shall teach in the different grades of the elementary schools. Without this recognition we are likely to defeat our own ends. Instead of bringing the children into closer, more intelligent touch with nature we may drive them further away from it.

Children live in a world all their own. They do not see things as adults do, neither do they appreciate the things that adults care for. In order that we may act intelligently in arranging a course in nature study for children we must catch at least a glimpse of the world in which they live and move. We must know something of what they are, and what they know at the different periods in their development. At the same time we ought to have some definite notion of what we wish them to be when they go forth from the influence of the schools.

It is not difficult to set up an ideal of what we desire the boys and girls to become. We would have them strong in character, independent in thought, reliable, honest, courteous, with faces turned toward the best things in life. Nature study if properly taught will aid in bringing about these results. It is exceptionally adapted to lead boys and girls to become inquirers after truth and the true relations of things, to acquire a reverence for life and living things, to gain patience and self-control in the performance of duties, a genuine respect for labor, and skill in handling tools. Besides these things nature brings the children into possession of numerous interesting and useful facts that will be of value to them after they leave the grades whether they pursue their education further in high schools and colleges, or whether they go out at once into the world of business to earn their living.

It is far easier, however, to declare what we desire the children to become than it is to form any accurate conception of what the children really are at any period in their school life, and what nature study has to offer that fits their needs at this particular stage of their development. Individual children of the same age or in the same grade differ greatly from one another in natural powers, in ability to grasp new ideas, and in quickness of thought and action. In spite of these differences children have certain characteristics which for the most part are common to all and which make possible a workable course in nature study.

Primary grades. — Primary children are interested chiefly in activities, especially those activities in which they may participate. In fact, it is by this participation that most of their ideas are gained and fixed. They are interested in whole objects, not in parts; in large things rather than small ones; in the useful rather than in those objects that seem to be of no service. Their interest in activities and objects is short lived. They do not relate their experiences to the past, or project them into the future. They live in the present—either in their own real experiences or in a world of fancy built by their active imaginations. As to their knowledge, it has been acquired largely in connection with their home environment. They are acquainted with the activities of the members of their own family, the keeping of the home in order, and the providing for the needs of the household. They know the animals about the home and, perhaps, a few of the plants of yard and garden.

When we consider what primary children know, in the light of what they are, it seems that we have something tangible on which to base an intelligent outline for their nature work. At the same time we have an excellent opportunity to keep the home life and the school life in close touch with each other and thus prevent forming the gap that so often exists between those two great factors in the education of children.

In carrying out the above principles we may begin our work by directing the children's attention to those things which nature contributes toward their needs and the needs of the family. This brings about a visit to the garden with a simple study of vegetables, of fruits and grains used for food, and of the methods of gathering, storing, and preserving these. It suggests a better acquaintance with the animals that aid in the preparation of foods. This in turn leads to a study of the care of domestic animals and household pets. In much the same way shelter and clothing may be studied as well as trees, birds, and other wild nature that appeals to children of this age. All the while the activities of the children are brought into play in the actual gathering and storing of vegetables, fruits, and seeds, in planting seeds, and caring for their plants, clay modeling, making playhouses, sewing, etc.

As children grow older their outlook upon the world becomes broader. They begin to see interrelations and interdependence among objects in the nature world. They see themselves as a part of this living, working universe. As a result new relations are established between them and their environment. They feel a consciousness of power in the midst of their surroundings. They are interested in the life of the community as well as in the family, in the industries going on around them, in machinery, how it works and how things are made. They are anxious to make things themselves, to try new projects, to handle tools. They are restless both in mind and body and are desirous of working out the problems that come to them, not by abstract reasoning so much as by manipulating concrete objects. They do not mind hard tasks, but they must feel the desirability of doing the things they are asked to do.

Nature study, if wisely and judiciously handled, may guide these impulses and desires of the child so that the results will be healthy, vigorous growth and development. The garden, orchard, farm crop, and forest, with all their accompanying wealth of animal life, as well as simple physical phenomena and appliances encountered about the home and school, offer abundant materials that seem to fit the needs of the intermediate grades. This material gives the children an opportunity not only to work with hands as well as minds, a thing which appeals greatly to them at this age, but to acquire habits of careful, thoughtful application, and a sense of responsibility which results in the trustworthiness we would have every boy and girl possess. It is doubtful whether there is any other period in the life of the child when the feeling of responsibility can be as well and as permanently developed as in the intermediate grades.

Grammar grades.—When the children have reached the grammar grades their experiences are becoming more unified; their knowledge grouped into larger wholes. They have discovered something of the laws that govern life and living things. They realize that to a certain degree they may control natural processes. They have become to some extent investigators desiring to search out the truth of things for themselves. They recognize more than ever before that they are a part of the social order in which they live and work, and begin to appreciate the necessity of coöperation with their fellows.

Because of the above characteristics certain phases of the nature work will appeal strongly to children of grammar-school age. They will enjoy working out some of the more intricate problems that the nature world presents. They are ready to try some simple experiments in plant breeding, to test some of the fundamental relations which exist between soil conditions and plant life, to plan original designs for the artistic arrangement of plants for ornamental purposes. They are prepared also to group together, according to common characteristics, the plants and animals they have become acquainted with.

Progressive work.—Throughout the entire course the material selected gives ample opportunity to plan the work along lines of certain fundamental principles so that it will not be desultory, but progressive and cumulative. To illustrate, the study of plant propagation is begun in the primary grades where the children plant large, easily grown seeds, water and care for the plants. In the intermediate grades seed propagation is continued, but here the children work out some of the principles upon which germination and plant growth depend. Other methods of propagation are taken up by the respective grades with reference to the difficulties they present. Plants are grown from bulbs, soft-wood cuttings, tuber and root cuttings, runners, layers, taproots, buds, and finally in the grammar grades by grafts and hard-wood cuttings.

While adaptability to the child should always be the first consideration in the choice of material and the method of its presentation, the natural relations which exist among objects and phenomena should not be lost sight of in arranging an outline.

Instead of studying weeds, insects, mammals, etc., as isolated topics, they should be taken up in connection with special plants or animals with which they are closely associated ecologically or economically. This organization of material unifies the work and makes it much more valuable from an educative standpoint.

While the hope of fitting the nature work to the exact needs of the child at every step in his development will, perhaps, never be fully realized, yet, if the work is planned and carried out along lines of the growing intelligence and sympathies, it will fulfill its mission. It will leave the child better equipped to meet the exigencies of life, better disciplined, physically, mentally, and morally to do work in the world, and it will leave an abiding interest in nature which stimulates self-resourcefulness, and makes the world in every aspect always a most interesting and enjoyable place of residence.

PART TWO

CHAPTER VIII

TOPICAL OUTLINE BY GRADES AND SEASONS

[*Course used in the Training School of the Illinois State Normal University.*]

The course is based primarily on the relation of the child to its environment. In the following outline of material the repetition of topics is avoided in the intermediate and grammar grades, but topics used in the primary grades are sometimes used again in the higher grades, the manner of treatment being of course very different. Except for the seasonal divisions no attempt at chronological order is made.

FIRST GRADE

Fall.—*Food:* Observation and some participation in the gathering and storage of beans, beets, tomatoes, potatoes, and squash; the flowers and seeds of nasturtium, balsam, and four-o'clock are also gathered in the garden; visit to a farm; the gathering and storage of corn; visit barn, granary, and corncrib to observe storage of crops; observe condition of fields after removal of crops; fall plowing; care of cows, horses, and chickens; turkey in connection with Thanksgiving.

Clothing: Father's work in buying; mother's work in making; changes of clothing as related to weather; care.

Shelter: Care of the school desk; of the room by committees; of the home; sweeping and dusting without raising dust; care of tools and toys; cleaning shoes before going into the house.

Miscellaneous: Migration of robins and grackles; study of individual trees, especially norway maple, oak, and tulip tree; uses of them made by man; observe leaves and general contour of tree; the coloring and fall of the leaves; such changes in the vegetation and landscape as appeal to the children's interest; keep a calendar noting condition of sky, direction of wind, and temperature from day to day.

Correlate work with clay molding and drawing especially in connection with vegetables, flowers, and trees; with sewing in connection with clothing; with construction work by shaping houses in sand.

Winter.—*Food:* Visit a cellar; note stored foods and the manner of keeping; the effects of freezing on fruits and vegetables; visit grocery store; observe common foods in the store and how they are kept; use, care, and habits of the cow; make butter and cheese; the milkman, his work and his relation to the community, suggesting social relationships wider than the family ones; cook apples and cranberries; make candy.

Clothing: Adjustment to new weather conditions; visit dry goods store as the source of materials from which clothes are made; distinguish between wool, cotton, and silk; sew articles for actual use; visit shoemaker at work; consider source of leather.

Shelter: Heating of houses, with emphasis on fuel rather than methods of heating; the local supply and home storage and preparation of fuel and kindling; candles, lamps, gas, and electric lights as different means of lighting homes; molding of candles; uses of water in our homes; distinguish between well and cistern water; cleanliness of house, clothing, and body; the carpenter's work; lumber yard and hardware store as sources of his materials; make and furnish a doll's house.

Miscellaneous: Squirrel, his home, habits, and relations to man; same of bluejay and cat, with observations of all three; wild relatives of the cat; observation of pine tree on campus; consideration of its uses; trim a Christmas tree, using if possible candles made by class and decorations prepared in hand work.

Spring.—*Food:* Plant seeds in eggshells to take to home or school garden and transplant; participation in the preparation of the class garden beds, which are not assigned to individual children in this grade but to groups; plant four-o'clocks, nasturtiums, radish, lettuce, and beans; care of the growing plants; spring work of the farmer; visit to fields; plowing and sowing; preparation of the radishes and lettuce for the home table.

Clothing: The putting off of heavy clothing and its storage for the summer; care of the new spring clothes.

Shelter: Removal of storm doors; putting up of screens and awnings; housecleaning; special cleaning of desks, chairs, and blackboards; make some new furnishings for the dollhouse.

Miscellaneous: Arrival of birds, especially robin, redhead, grackle, flicker, bluebird, and others which especially attract the children; watch feeding and nest-building as circumstances permit; listen for song; the leafing of the trees, especially of those observed in the fall; dandelion; violet; observation in the class wild-flower patch; raise a brood of chickens; observe Arbor Day; plant a class tree.

SECOND GRADE

Fall.—*Food:* Continue the observation of plants started in school garden in previous spring, gathering fruits and seeds; gather seeds of balsam, phlox, and sunflower for next spring's planting; storage of seeds for winter; squashes and pumpkins in connection with Thanksgiving, saving seeds for spring planting; fall marketing of farm crops; visit an elevator; cornmeal, hominy, breakfast foods, and cornstarch as corn products; use of corn in stock feeding; similar study of wheat and oats products; make simplest form of bread by mixing meal or flour with water and salt and baking; preparation of meal or flour by grinding grains.

Clothing: Cotton; study of the plant in the garden, gathering bolls, picking out seeds, and observing the fibers of raw cotton; the story of cotton told with pictures; spinning, weaving, and dyeing; children weave on a primitive loom and use dyes; wool; observation of sheep; food; manner of cropping; care; habits; compare with cows; how is the wool obtained? story of shearing with pictures; observation of the preparation of wool for spinning and weaving; children weave.

Shelter: Materials used in making homes; lumber, nails, brick, and stone; observe the construction of a building or a carpenter at work; children make small bricks, mix mortar, and build a wall of their brick.

Miscellaneous: Review of trees studied in first grade; add soft maple, chestnut, and basswood; robin, bluebird, and bluejay, and other conspicuous birds which may especially attract attention on excursions.

Winter.—*Food:* Study of Eskimo; compare food of Eskimo with our food; uses of refrigerator; make ice cream; food of Indians.

Clothing: Eskimo clothing; materials used; how sewed; dress an Eskimo doll; Indian clothing; weave a small blanket; dress Indian doll.

Shelter: Eskimo house; materials; how lighted? how heated? comparison with our own homes; make an Eskimo house out of salt; make an Eskimo lamp out of clay; snow as shelter to vegetation in our own climate; make Indian wigwam.

Miscellaneous: Make Indian cradleboard, quiver, canoe, and simple basket; simple pottery work; Eskimo dog, its use and place in the home; our dog, his relations to us, his habits, and our care of him; wild relatives of the dog; winter birds, especially chickadee and nuthatch; place suet on trees near schoolhouse for them; rabbit, its winter home, habits, and relation to man; observation of tame rabbits; tap soft maple trees near schoolhouse; make syrup and sugar.

Spring.—*Food, clothing, and shelter* of Arab; compare with ours and those of Eskimo and Indian; make Arab tent; dress Arab doll; place of the horse in the Arab's home.

Horse: What it does for us; habits of feeding, resting, and exercising; different kinds of horses; our care of the horse.

Garden: Children help in the preparation of beds, but individual beds are not assigned until the third grade; plant phlox, sunflower, balsam, peas, squash or pumpkin, and onions; also repeat plants of first year if the children show a desire to do so; peas and squash seeds planted in egg-shells or small pots to transplant into home or school garden; preparation of the early vegetables for the market; visit to spring vegetable market.

Birds: Note arrival of common birds; special study of bluejay with reference to color markings; study of robin's nest removed from tree after brood has been raised; the duck; raise a brood of ducks.

Trees: Soft maple; flowers, fruit, and leaves, noting time of appearance as compared with other trees; plant some of the seeds to find whether they germinate the first season or not; horse-chestnut; basswood.

THIRD GRADE

Fall.—*Garden:* Continue study of plants started in previous spring; select the best tomatoes for seed and prepare seed for planting next spring; gather seeds of aster, sweet corn, and sweet peas; study of sweet pea plants, having in view especially how they scatter their seed and how they climb; plant hyacinth bulbs in pots for forcing and plant out of doors in home and school gardens for spring blooming; start geranium cuttings from plants on the campus to be transplanted and taken home for winter blooming; observe wild asters and wild sunflowers in comparison with the cultivated varieties.

In this and all later grades the children visit the school garden in the early fall, when it is at its best, to choose as *they like and gather under direction flower and vegetable seeds for planting in the following spring in the home gardens.*

Birds: Note especially those studied in the previous spring; determine how late into the fall they may be seen; pigeon; home; habits of feeding; nesting; observation of the pigeons around the building; the kinds of pigeons; their relation to man; caged pigeons for a time in the schoolroom.

Trees: Study of the nut trees in Normal; walnut, butternut, and chestnut; observe polished walnut and consider its uses in furniture and finishings; nut trees in the woods in this part of Illinois, especially the hickory nut; what animals eat nuts? plant nuts; visit grocery store to observe imported nuts; uses of the cocoanut, the largest of nuts.

Insects: Observation of insects in connection with the tree and garden studies; blister beetles on asters; what are they doing? butterflies on garden flowers and in campus; what are they doing? are there many different kinds? watch the woolly bear caterpillar and the tiger caterpillar feeding on plants; place a few of these in a terrarium; feed and watch them spin their cocoons, and preserve these for next spring; open one cocoon to see what change has taken place in the caterpillar; study cecropia moth in same way; ants; note their homes on the campus; watch for the swarms of flying ants that come out of their homes on warm days in October; arrange an ant colony in the schoolroom.

Miscellaneous: Care of the yards in fall; the raking and burning of leaves; observe the leaf mold under the pines; what becomes of the leaves which are not raked and burned? observe the final work in the garden in clearing off and preparing the ground for spring; observe frost effects on plants in the garden and on the campus; what shall be done with valuable plants which are slightly frosted? what can be done to prevent the killing of plants by fall frosts? observe the broom corn and winter wheat growing in the garden in connection with these topics in geography.

Winter.—*Biological:* English sparrow; goldfish in aquarium in schoolroom; consider in connection with the topic "fish as food" in the geography work; observe activities, manner of feeding, and gross structure; Easter lily bulbs planted in the greenhouse; trees, especially poplars, willows, and evergreens in connection with the effects of heavy snows and frost.

In this and in all succeeding grades during the winter term preliminary work in the greenhouse is done in connection with the plants to be studied in the spring. Cuttings are made, seeds planted, and some transplanting is done. A garden and greenhouse calendar is furnished to show when all such work is due.

Physical: Thermometer; burning of wood and coal consuming both volatile and solid matter; construction of stoves, noting especially the air currents and the use of dampers; use of chimneys; the two systems of heating used in the schoolroom; ventilation of the room; heating and ventilating system of the main building; the evaporation of water in a few very simple quantitative experiments showing the effects of extent of surface, temperature, and air currents upon the rate; the effect of wind upon the rate of drying of clothes, muddy walks, etc.; observations of wind, clouds, rain, floods, snow, hail, and frost especially in relation to man and his activities, such as the various effects produced by these agencies upon transportation and crops, using local instances as examples; as storms occur, comment and observation upon their destructive effects on trees, etc. For one month, beginning with the day the new moon is first to be observed, each pupil sketches its appearance about sunset in the first half of the month and about sunrise in the second half. The sketches are made about every other day. When the observations are completed an explanation is brought out by the teacher, new moon, first quarter, full moon, and third quarter being taken into consideration. Observation of the Great Dipper, Little Dipper, Orion, the Pleiades, and the Polestar. The apparent diurnal motion of the stars in relation to the Polestar is observed.

Spring.—*Garden:* Indoors the children decide upon the arrangement of the flowers in their gardens; simple plats are drawn by the children upon which the arrangement is indicated; the same is done with plats of the home gardens which are brought; it is not attempted to draw these plats exact to scale; plant sweet pea, pansy, china aster, morning glory; tomato, sweet corn, leeks, and chives; simple indoor experiments are made to determine the conditions under which sweet peas will germinate and begin their growth to best advantage, bringing out therewith what physical conditions are essential to germination and continued growth; frequent visits to the school wild flower garden, noting the changes in appearance from one week until the next, and the effects of weather upon the rate of development; mandrake, bloodroot, buttercup, and spring beauty are especially watched; in connection with mandrake and bloodroot observation is made of the division of the plant body into root, stem, leaves, flowers, and fruit; sketches of these are made and their general functions brought out in so far as can be done, using only the observations of the children as a basis; Easter lily, started in greenhouse in winter, is continued, being observed from time to time throughout its development; the flower of this plant is used to introduce the observation of petals, stamens, pollen, and pistil without any attempt as yet at explanation of their functions.

Trees: Indoor work on twigs of willow and peach early in the season; observe the spring aspect of the nut trees studied in the fall; watch for the growth of seedlings; become acquainted with box-elder, sassafras, redbud, and mulberry, relating the last to work with silkworm indicated below.

Birds: Flicker, redhead, sapsucker, and any other woodpeckers seen; special study of the flicker, comparing other woodpeckers with this one; note where it is found, its habits of moving about, feeding, and nesting; its value to man; keep bird calendar; learn to recognize bird notes of the birds known by sight.

A few minutes are taken every day or two in this and succeeding grades to discuss what new bird activities have been lately noted by pupils or teacher.

Insects: As in the fall, they are here considered informally as they are encountered in connection with plant study; observation of the ant colonies on the campus; cocoons and chrysalids put away in the fall are watched for the emergence of moths and butterflies; study of the silkworm; development from the eggs, occasional visits to the large pond on the campus and observation of the insect life there; dragon fly larvæ brought into the schoolroom and observed in an aquarium.

Observation of oats in the garden in connection with the geography work upon this topic.

FOURTH GRADE

Fall.—*Garden:* Continue the study of the plants started in the previous spring; harvest tomatoes; decide which varieties are preferable for food; gather seeds of aster, pansy, and sweet pea; in anticipation of the work of the following spring, observe the dahlia roots and the method of storing them for the winter; gather seeds of petunia, ten-weeks'-stock, wishbone flower (torenia), and marigold; morning glory as a type of annual climber; compare with sweet pea as to methods of climbing; cuttings of coleus to pot and take home for winter; plant tulip and narcissus bulbs at home and school; appearance of currant and gooseberry in fall; propagate by layering.

Birds: Continue study of woodpeckers, adding nuthatches and brown creepers; note the different methods of these birds in climbing the trunks of trees; determine which of these migrate in the fall.

Trees: Continue study of those begun in the spring; add locust and larch.

Insects: Tomato worm if found on the tomatoes grown by the class; work out life history; ladybugs as found in the garden; what are they doing? bees as honeymakers; specially constructed beehive with swarm in the schoolroom.

Miscellaneous: Observe flax and sorghum in the garden in connection with the geography work on these topics; burdock as a type of weed; compare thistle and wild carrot; the methods of exterminating them.

Winter.—*Biological:* Crow; habits; detailed study of the feathers; relation to man; evergreen trees on the campus, observation to be continued in the early spring when the new cones are ripe.

Physical: Water supply of the school; pump connections; observation of differences in pressure at basement and third story; basement connections; air cushions; faucets; city water system; pumping station; gauge; standpipe; the laying of mains, if available; connections; cutoffs; fire plugs; city fire limits; water heating cylinders and water fronts in stoves; Normal and Bloomington fire departments; city sewer system; house drainage; sinks; traps; vents; catch-basins; wells; the water plane; percolation of soil moisture; suction forces and lift pumps; the siphon; buoyancy of liquids.

Spring.—*Garden:* Potato; indoor study of the parts of the tuber; the cutting of tubers for planting; discussion of methods of planting; measure the amount to be planted; potato scab observed if present and the method of combating it discussed; experiments in connection with potato culture; plant carrot, salsify, onions, seeds, and bulblets, lima beans, petunia, torenia, ten-weeks'-stock, marigold, and dahlia; garden plats drawn as indicated for preceding grade; continue studies of tulip, gooseberry, and currant started in the fall.

Wild Flowers: How do these plants succeed in sending up their leaves and flowers so early? continue observations and discussions upon the general functions of the different parts of the plants, limiting this work to points observable by the children and readily appreciable deductions made by them from observed facts; note the various devices shown for securing the light relation as indicated by variations in leaf pattern and position; observation of the parts of the flowers; discussion of preservation of wild flowers and discouragement of reckless picking; hepatica, Indian turnip, violet, and trillium; observation of the two kinds of flowers in the Indian turnip; what are flowers for? what becomes of the pollen? irregularity of flower parts in the violet.

Soil: Observation of clay, sand, gravel, humus, and garden soil; what things are found in garden soil? plant seeds in different kinds of soil and note effect on growth; careful observation of relation of roots to soil; experiments showing the turning of roots toward moisture; root hairs; observation of root tip under microscope.

Trees: American elm; general form; flower, fruit, and leaves, noting time of appearance and maturity of each; how long does it take to mature the fruit? adaptation for dissemination of seeds; plant seeds; make acquaintance of other elms on campus, English, Scotch, and Camperdown; hackberry; sumach; haws; learn to recognize elm seedlings and look for them along walks and fences; why should they occur here?

Insects: Continue observation of ladybugs; how have they spent the winter? potato beetle; relation of ladybugs to these; sawfly larvæ on gooseberry and currant; work out their life history; look for the natural foes of these insects; observe aphids on cockscomb galls on elm leaves.

Birds: Continue study of crow; oriole, rose-breasted grosbeak, cardinal grosbeak, and wood thrush; excursions on the campus outside of school hours may be necessary for the observation of these; note habits of feeding and nesting; relation of rose-breasted grosbeak to the potato beetle; indoor study of nests of the birds observed.

In this as in other grades the effort is made to make detailed study of certain birds, but the teacher must be governed in this part of the work primarily by circumstances. Any bird not previously studied is to be studied at any time that conditions for such study are especially favorable.

FIFTH GRADE

Fall.—*Garden:* Continue study of potato; harvest the crop; measure and compare with the amount planted in the spring; check up on the experiments started at that time; determine what hills have given the greatest yield and which potatoes are desirable to save for "seed"; dig dahlia roots and put away for winter; gather seeds for home garden as indicated in earlier grades; in preparation for next spring, gather beet seeds and preserve a few roots from which to obtain seeds the next year; gather seeds of salvia, lobelia, and snapdragon and put away for next spring's planting; raspberry and blackberry; condition of the plants in the fall, especially the canes that bore fruit in the summer just ended; the need for pruning; the appearance of new stems; the number on each plant; propagation by tip rooting; observe strawberry plants, noting the habits of growth and propagation; cover strawberry beds.

Trees: Ash trees on the campus; the oaks of the campus with study of the fruit; compare with the native oaks in neighboring woods; distinguish white from red oak by leaf characteristics; compare acorns from several different oaks, noting the different sizes and shapes of cup and nut; the uses of oak for furniture and finishings, observing the polished wood; observation of the white birch; review of the trees studied in fourth grade; plant peach seeds to get seedlings to bud in the following fall; leaf coloration and fall; why do not the evergreens shed their leaves? what trees with needle-shaped leaves do shed them? (larches); in what parts of the leaves does the green color remain longest? what weather conditions give us the best leaf coloration? does a sharp frost produce better coloration? does the loss of the leaf leave a wound which must be healed?

Birds: Continue observation of those studied in the previous spring; report of summer observations of these birds; the thrushes to be seen in Normal during the fall migration, hermit, olive-backed, and gray-cheeked; keep a list of the birds seen during this term; study of nests after the leaves have fallen; determine the total number to be seen in the trees of the campus; what trees are favorite nesting places? what trees appear to be avoided? how far from the ground are the majority of the nests? report on nests seen in other parts of the town, or in hedges along the roads.

Insects: Grasshoppers found in the garden and on the campus; how many different kinds? what do they eat? how do they move about? how do they eat? place a few in a terrarium in the schoolroom for observation; determine by experiment the amounts of grass eaten; determine how the meadow grasshopper makes its music; the snowy tree cricket found on raspberry bushes; compare with the black cricket; consider, as relatives of the grasshopper, the cockroach and methods of exterminating them in houses; arrange a few breeding cages to obtain eggs of the grasshopper and cricket.

Winter.—*Biological:* Preparation for garden work by planting seeds in greenhouse; study of the winter woodpeckers, the hairy and the downy.

Physical: Simple experiments in magnetism and electricity; construction of galvanic cell; electro-magnets; electroplating.

Spring.—*Garden:* Measure the fifth grade garden accurately and draw to scale; different methods of propagating flowering plants; plant salvia, lobelia, snapdragon, gladiolus, and tuberose; beets; plant seeds and set out roots; a type of biennial; plant rutabagas, turnip, parsnip, navy beans, mangoes, parsley; continue the study of raspberry and blackberry; strawberry; uncover beds; note propagation by runners; flower; fruit; culture; marketing.

Trees: The gray birch and the paper birch studied at intervals during the term; the fruit; the seeds; the wood in furniture making; the uses of the bark; flowers and fruit of beech and ash; dig up a few of the peach seedlings planted the previous fall to determine how the young plants get out of the stone.

Lawns: Bluegrass; observation of its condition at the beginning of spring; its habits of growth; the characteristics that make it a good lawn former; the care of lawns; how to make a good lawn; the selection of grass seed; test of grass seed obtained in local market; dandelion as a lawn weed; habits of growth; root; flower; fruit; what characteristics make it a successful weed? how should it be combated? its competition with the bluegrass; what advantages does each possess over the other? to what great plant family does it belong? what are the characteristics of this family? examine a flower head under the dissecting microscope, making out the external appearance of the individual flower; observe centrifugal maturing of flowers; mark dandelion plants to determine rate of maturation of floral heads and fruit; determine rate of growth in length of the scape after floral maturity; determine effect of environment upon length of scapes; plantain, crabgrass, and other lawn weeds which may be encountered in abundance; the mole as an enemy of the lawn; its habits; its special adaptations for its mode of life. See also grubworm below.

Birds: Brown thrasher; wren; catbird; make and put up boxes for the wrens.

Encourage the pupils to continue observation upon these birds especially during the summer months. This applies to summer studies of the respective birds in each grade and under proper stimulus the interest appears to be well maintained through the long vacation.

Insects: Grubworms and May beetles; the grubworm an enemy of the lawn; recall grasshopper and cricket study in this connection; roll worms on strawberries; watch for these moth larvæ early and remove, keeping a few in a jar in order to work out the life history; it is the second brood that does the greatest damage.

SIXTH GRADE

Fall.—*Garden:* Continue the study of the plants set out in the spring; dig and house bulbs; especial attention to gladiolus and tuberose, noting the growth that the bulbs have made during the season; flowers of torenia and salvia; correlate the structure of these with the insects which visit them and consider in general the service which insects render to plants as agents in cross pollination, cross pollination itself being touched upon only incidentally to floral structure and insect activities; complete life history of the beet; observe the entire root system; compare with the sugar beet; show by experiment that sugar is present in beet roots; gather seeds as usual for next spring's planting; make soft-wood cuttings of any plants desired to take home for winter blooming; as weeds, pigweed, purslane, and ragweed.

Trees: Bud the peach seedlings started the fall before; peach tree culture; comparative study of cherry and plum; sycamore, poplars, purple beech, Kentucky coffee tree, mountain ash.

Birds: Continue the observation of those studied in the spring; report on summer observations, especially as to wren and catbird; add goldfinch and junco.

Insects: Peach tree borer; flies found on the garden plants as to habits and food; soldier beetles on the garden plants and on goldenrod; the goldenrod gall gnat; larvæ of butterflies on borage and sassafras; keep these in a terrarium and observe their life histories; spiders as to habits, homes, and food.

Sky Studies: The movements and phases of the moon;

its physical condition; changes in measured noonday altitude and in the length of day and night; the ecliptic and the zodiac; the apparent annual motion of the sun; the rotation of the star sphere; the poles and the equator; the autumn constellations; the milky way; the planets, noting their changes of position; the general plan of the solar system; eclipses if one occurs.

Winter.—*Physical:* Systems of lighting in common use; construction and principles involved; incandescent light; arc light; kerosene lamp; gasoline lamp; gasoline carbureter; acetylene lamp. Study of petroleum; crude petroleum; production; refinement into commercial products. Coal gas; manufacture and combustion of coal gas; kinds or grades of coal; peat, lignite, bituminous, cannel and anthracite. Sources of coal and petroleum. Chemistry of combustion; kindling temperature and burning point. Application of these facts to lighting studied above. Brief reference to the history of the production of fire and its influence upon civilization.

Spring.—*Garden:* Plant sweet scabious, gaillardia, cosmos, several varieties of poppy, California poppy; cabbage, broccoli, cauliflower, Brussels sprouts, kohl-rabi, kale, endive; coldframe work in preparing members of the cabbage family for transplanting; continue the study of the annual field and garden weeds begun in the fall; complete the work on the budded peaches; study the flower of the peach, cherry, and the plum as representatives of the rose family and compare with the flowers of other members of the rose family in bloom at this time of year; consider the formation of the fruit from the flower in these fruit trees; note the effects of weather on the flower and fruit crops, noting especially the effects of severe frost on the fruit if one occurs.

Trees: The trees of the campus; general survey; history of the planting of the trees on the campus which fifty years ago was a perfectly treeless piece of prairie; which of these trees are natives of Illinois? group the principal trees into their botanical families; a special study of catalpa, planting the seeds, and considering its value as a tree to be set out on prairie soil; the planting of catalpa for railroad ties in Illinois; study of its flower; the ways in which forests are destroyed; what is being done to renew the forests? consider the causes of the treeless prairies of this region and note their distribution; the natural groves of the county; compare three trees of different kinds as to the growth which they make in one season; using poplar, willow catalpa, and oak; compare rates of growth by measurements of year-old twigs showing the large differences in growth rate between "hard" and "soft" woods.

Birds: Meadow lark, bobolink, purple martin, swifts; the value of the meadow lark and the bobolink in the fields; the value of the martins and the swifts as mosquito and fly destroyers, observing habits before drawing conclusions.

Insects: Housefly; its habits and relations to man; work out the life history of the mosquito in an aquarium; study the water beetles as enemies of the mosquito, watching them in an aquarium which is also stocked with mosquitoes; study any insects found on the fruit trees as to their relation to these trees.

Other Animals: Snails and slugs in relation to garden plants; toads, frogs, and salamanders as to habits, food, life history, and relations to man.

SEVENTH GRADE

Fall.—*Garden:* Continue the study of the cabbage family, noting the parts used for food in each kind; the methods of storing for winter use; special characteristics of the flowers started in the spring, considering the plant families which they represent and individual adaptations of structure; observation and study of the uses of the various medicinal plants and kitchen herbs grown in the garden; select seed corn from home and school garden, noting the desirable points in stalk and ear; the methods of storing seed corn for winter; make grape cuttings and store for winter; the common field weeds, especially cocklebur, butter-print, and mustard; consider as to structure of plant body, floral characteristics, and botanical relationships; students work out the special characteristics which make these successful weeds.

Insects: The insect enemies of the cabbage family; work out the life history of the cabbage butterfly in the schoolroom; the braconid and chalcis flies as enemies of the cabbage butterfly; aphids found on the garden plants and on trees and shrubs of the campus, the winter eggs of aphids being frequently found in abundance on white pine needles; the lacewing fly, the syrphus fly, and the ladybug as enemies of the aphids.

Birds: Phœbe, pewee, great-crested flycatcher, least flycatcher, and kingbird as members of the flycatcher family; their habits and value to man.

Weather: Daily observation of the weather conditions, at first mainly non-instrumental, and later, when the reading of the instruments is learned, with fuller instrumental data; this work finally includes barometric pressure, dry and wet bulb reading, maximum and minimum reading, wind direction and estimated velocity, clouds as to amount and kind, precipitation, and the recording of dew-point and relative humidity; in connection with the interpretation of observations and in explaining instruments, the mechanics of liquids and gases is experimentally studied; study of the weather maps, monthly weather reports, and mechanics of Weather Bureau; a notebook is kept.

Winter.—The human body.

Spring.—*Garden:* Corn; germination tests of the ears gathered the previous fall; study of corn kernels as to structure and food content; corn culture with experiments in school and home gardens; study of corn as a plant type; its commercial value; means of improvement of the crop; sweet potato culture; raise plants in coldframe or greenhouse; melon family; watermelon, muskmelon, citron, and cucumber; take home for trial seeds of various varieties of melon family; plant vinca, euphorbia, zinnia, calliopsis, centaurea, blue sage; grape; habits of growth; flower; fruit; methods of pruning and spraying; transplant grape cuttings made in the previous fall; comparative study of relatives of the grape, the five-leaved ivy, the Boston ivy, and the wild grape; continue study of weeds begun in the fall as to their spring aspect.

Soil Physics: Ground water; ground air; experiments to show the conservation of moisture, porosity, capillarity, and air spaces; show the relation of plants to soil; uses of fertilizers.

Animals: Earthworm in connection with soil study; beetles found on the melon vines and methods of combating them; corn root aphis; plum curculio, and any other insects found on the garden plants; ground squirrel; groundhog; coon; skunk; gopher; field mouse; the groups of mammals, emphasizing the study of domestic types whenever possible.

Birds: Review the flycatchers studied in previous fall; shrike; native sparrows; the value of these to man; note the characteristics of the sparrow family; group other well-known birds into their families, such as thrushes, mocking-bird, blackbird, woodpecker; individual field work following outlines given by teacher and reports on same.

EIGHTH GRADE

Fall.—*Garden:* Continue corn; check up on the experiments worked out in the home and school gardens; observation of kaffir corn in the garden; uses, and comparison of structure of ear with other varieties; continue study of melon family; reports on those grown from special seeds at home; comparative study of the habits, flowers, and fruits of the members of this family; sum up the characteristics of the family; harvest the sweet potatoes, measure, and determine the yield per acre; make cuttings of roses; make the acquaintance of some of the desirable varieties of apples and pears; observation of these trees and study of general character; study the clovers, soy beans, cowpeas, and alfalfa grown in the garden with special reference to their effects upon soil fertility; elements of soil chemistry with experiments.

Insects: Insect enemies of the apple and pear; the pear-slug, the cankerworm, scale insects, and coddling moth; the insect enemies of other trees; white-marked tussock moth, working out the life history; tent caterpillar; fall web worm; any insects found on the corn or melons and the methods of combating; look for their natural foes, as parasites, predaceous insects, and birds; division of labor and care of young among insects; mud-dauber, polistes, hornets; bumblebee as related to the pollination of red clover.

Birds: Special attention to the fall migrants from the north, especially warblers and kinglets; quail and other local game birds; their protection; the game laws of Illinois.

Fungi: The common mushrooms; the smut on corn and other grains; blight on pear and apple; mildew on lilac or other plants; mold on fruit; tree fungi; study of the methods of combating these when injurious.

Wild Plants: Study of remnants of the prairie flora; the special characteristics of these plants.

Winter.—The human body; some simple experiments in plant life in the greenhouse, and in bacteriology in the biology laboratory.

Spring.—*Garden:* Plant alternanthera, lantana, heliotrope, verbena, other flowers selected by the pupils; okra, celery, eggplant, spinach, asparagus; experimental work in the garden to determine methods of culture best suited to the local conditions of soil and climate; oats; test seed for purity and vitality; experiments to determine the desirable depth of planting, and the amount of seed to be used per acre; different varieties are sown by different pupils in the home gardens; graft apple trees and set out in nursery rows; study the culture of apple trees and the history of their amelioration; apple culture used to exemplify the general principles of horticulture; acquaintance with the more successful varieties of apples; a comparative study of the pear; apple and pear industry in Illinois; visits to a nursery.

Insects: Any insect pests encountered in connection with the plant studies.

Birds: The birds of prey; owls, sparrow hawk, red-tailed hawk, sharp-shinned hawk, and others; the value of birds of prey to the farmer; characteristics of these birds as a group; special study of the migration of birds; continue the study of warblers.

Botany: The great plant groups; observation of the gross anatomy of types of algæ, fungi, liverworts, mosses, fern, conifers, monocots, and dicots.

CHAPTER IX

TYPICAL LESSON PLANS

THE COW.—First Grade

LITTLE children are interested in domestic animals both because of their large size and their familiarity in the home environment. In developing lessons for this grade the children have been led during the fall term, as indicated in the outline, to observe something of the food, shelter, and care of domestic animals. In the winter the cow is taken up for a more detailed study, especially in relation to food supply. The central thoughts are what does the cow do for us and what should we do for the cow? If any observation of cows was made during the fall they were found feeding in pastures. What were they eating? How were they eating? Where are cows kept during the winter? Draw upon the experiences and observations of the children for answers. If practicable, visit a barn where a cow is kept and let the children see how it is cared for.

What do cows eat in winter? Recall the fall study of storing food for animals. If a barn is visited note all the different kinds of food stored here. Country children will know that sometimes the cows are allowed to roam about through the corn fields in winter days, eating the dry leaves and stalks, and are sheltered only at night. Watch a cow eat. Does she eat slowly or rapidly? Do you ever see her chewing when she is standing still or lying down? She really chews her food over again. How does a cow drink? They like plenty of clean, fresh water. Notice the thick coat of hair. Do you think this would be as warm as your own coats and jackets?

Circumstances will determine procedure in the study of milk as the thing which the cow gives us. In cities where milk is delivered in bottles the study is necessarily more limited than in the country. The different prices of milk and cream may be considered; the times of delivery; the habits of the milkman; how soon must he begin his work in the morning and where does he load his wagon? See how the milk is kept in the wagon. If possible observe milk trains and the cans in which milk is shipped in from the country. Note the difference in the appearance of milk after standing in bottles overnight. In smaller towns where many people keep cows some of the children will have experience in carrying milk to the neighbors. Who does the milking? What is done with the milk after it is brought into the house? Is it strained and put away or measured and sent out to customers? What care is taken to keep the milk clean?

What are the uses of milk? Let the children name all they know. How is butter made? Have the children make butter by stirring some sour cream rapidly. This may be done by placing the cream in a quart jar and stirring with a cake spoon, or it may be accomplished by shaking the jar vigorously, in which case the jar should not be more than two thirds full. Cheese may also be made in the schoolroom. Heat sweet milk to about 84° F. Put a little rennet in the milk to curdle it. (Rennet may be obtained at any drug store.) Drain off the whey. Cut the curd into small pieces and stir gently for a short time, draining off the whey occasionally. Now heat the curd slowly to about 92° F. It should be heated till it will string a little. Turn over and over to get the moisture out. Salt and mix or grind thoroughly. It is now ready to press, after which it may be eaten immediately or allowed to stand in a cool, well-ventilated room to ripen. Dutch cheese or cottage cheese may also be made.

Spend some time in talking about what we may do for cows. We should see always that they have plenty of food and pure water, a warm shelter from storms, and clean stalls in which to lie. And we must always take great pains to see that the milk is kept perfectly clean.

SOFT MAPLE.—Second Grade

Since a special study of the Norway maple is made in the first grade, this tree is revisited for the purpose of recalling the facts previously observed. Then, as in the first grade, the work begins with the study of an individual tree rather than with soft maples in general. Compare the general shape with that of the Norway. Is it as round? Has it as many branches? Does it make as good a shade? Is the bark smooth or rough? You can always tell the soft maple by its scaly, light-colored bark. Examine the leaves. Are they the same color on both sides? Can you see why this is sometimes called the white or silver-leafed maple? How many points do the leaves have? Compare with the leaf of the Norway.

As an indoor exercise, have the children sketch a leaf.

Examine the twigs. Is there any way of telling how much they have grown in the last year? How are the leaves arranged on the twigs? Are they closer together at the lower end or at the tip? Where are the buds? Do you find anything else on the twig? When you feel confident that the children know the individual tree which has been observed, take them around to see if they can find other soft maples. Ask them to look in yards and along the streets for them. Be sure to call for reports upon such observations the next day.

Watch carefully for the beginning of change in leaf color. The children will be able to find many beautifully colored leaves on the ground. Let them collect and press a number of these. (They may be preserved for decorative purposes by scattering a little powdered rosin over the surface and ironing with an ordinary hot flatiron. This makes the leaves shine and preserves their color. The children are usually much interested. An attractive border above a blackboard may be made with these leaves.)

When does your soft maple finally become bare? Are there any leaves left on the Norway at this time? Note the effect of a heavy rain or wind on the falling of the leaves. Spend a little time on observing the tree after the leaves are all off, giving special attention to the clusters of buds near the ends of the twigs and the single buds on the sides. Make a sketch of a twig with a memorandum of the date. Early in the spring or latter part of the winter tap some of the soft maples. Bore a hole through the bark and a short distance into the wood. Place a spile to drain the sap into a receptacle. The spile may be whittled out of soft wood, being simply hollowed out a little to form a trough. When does the sap run more vigorously? On cloudy days or during sunshine? Boil the sap down until you have a little syrup or sugar. While the soft maple will not yield as much sugar as the sugar maple, it yields enough to make the process worth while from the standpoint of the children.

Watch the bud clusters in the early spring. What is happening to them? Place a few twigs in a bottle of water in a schoolroom window until the buds open and the dainty little flowers are revealed. Watch for the appearance of the flowers out of doors also. Have the smaller buds developed into flowers? These must be watched a little longer to see what comes of them. Watch their unfolding and the growth of the leaves. This can be well studied in the schoolroom if the twigs are kept in fresh water and in the light. Outdoor observations upon the same point should also be made. The best results will be gained by taking a few moments each day for a number of days to note the changes that are taking place. When these observations are finished the children will know that a bud develops into a twig with many leaves. Leave with them the question as to whether leaves continue to open up at the end of the twig. Toward the end of the term examine the twigs again with this in mind. Encourage them to watch some particular tree during the summer to see how long new leaves continue to appear or what other changes may be noted.

After the flowers have disappeared watch the rapid development of the fruit. Have three sketches made, each at a different time, showing the growth of the seeds and the wings. Do you find that the paired seeds are always about the same in size? When do the seeds begin to fall? Watch them flying down from the trees, whirling around, fluttering like butterflies. In what way are the wings of any help to the seeds? How far away from the tree do the winged seeds travel?

Gather a number of the seeds and plant them in the school garden or in flower pots or boxes in your window garden. Suggest to the children that they also plant some at home. How long after the planting is it that the young plants begin to appear? How many leaves has the little tree at first? Do these look at all like maple leaves? Watch for the appearance of the next leaves. Where do they appear? What becomes of the two long, slender leaves which appeared first? Can you find any young maple trees that have planted themselves? Where are they?

Some time should be given to a discussion of the value of the maple. Find what uses the children can name, such as shade, nesting and feeding places for birds, fuel, and furniture. Are there any objections to the soft maple as a shade and ornamental tree about the house?

THE FLICKER.—Third Grade

The flicker is one of our most common birds. Because of its large size, striking characteristics, and habit of nesting near our dwellings it is an excellent bird to study in detail in the lower grades. The first lesson should be an outdoor observation for the purpose of identifying it. Have the children note the size (a little larger than a robin), the color of the back (grayish-brown barred with black), the red spot on the back of the head, and the black crescent on the breast. Note where the bird is and what it is doing. When you are sure that the children know the bird tell them you want them to watch the flickers about their homes to see how many things they can find out about these birds. Have them note especially all the different places where the birds are seen, and what they are doing. How does the bird's flight differ from that of a robin? What marks aid in identifying it when flying? (The white spot in front of the tail and the golden yellow lining of the wings.) At the end of a week, during which the interest has been kept up by occasional reference to the bird, have an indoor lesson. This should be a free expression of the observations made by the children; good pictures of the bird may aid in settling some points in which there is a difference of opinion. Some points may well be left to be settled by further outdoor observation.

In the discussion of what the children have seen, new problems will certainly arise. For example, how does the flicker manage to walk up a tree trunk? The children will readily see that the short, stiff tail feathers aid the bird in climbing, and in resting on the sides of trees and posts. By means of pictures the teacher may bring out the special adaptations of the toes, two pointing forward and two backward, that enable the bird to cling securely to vertical surfaces.

The question of the flicker's food will come up. No doubt some of the children will report that they have seen the birds feeding while on the ground. What were they eating? The answer to this may or may not be found by observation. Some child may be fortunate enough to find a flicker sitting on an ant-hill eating ants. But whether the children are able to make out for themselves that flickers eat ants or not, it is well to have them know that during the summer and fall months more than two thirds of the food of the flickers consists of ants.

When does the flicker make its nest? Some of the children will have a chance to watch them digging holes for their nests. What tools do they use in chipping out the wood? Their strong chisellike bills. Do both birds work in making the nest? Tell the children that if they have very sharp eyes they can distinguish the male from the female by looking at the sides of the throat. The male has a black stripe on each side of the throat. How far from the ground are the nests made? Compare different ones. Watch the birds caring for the young. Listen for the loud hissing sound made by the young while they are still in the nest. Watch them come forth from the nest. Can they fly well? Few young birds can fly farther than young flickers. Do the parents continue to feed the young after they have left the nest? This will be easily determined, since the young beg in such a noisy manner for just another bite that the children will be sure to hear them.

Have the children decide whether the flickers are of any use to us. The fact that they eat so many ants and other injurious insects places them among our most beneficial birds. Leave unanswered the problems whether flickers use the same nest year after year, and whether they stay with us all winter or go away in the fall as robins and bluebirds do. A few flickers remain here over winter. They often excavate holes in trees or buildings and remain under shelter during the nights and very cold days. On warm days they sally forth to feed upon tree borers and whatever they can find.

While a detailed study is made of the flicker the other woodpeckers seen by the children should come in for a share of the discussions. Even in the third grade something may be done with a simple comparative study of the woodpeckers. The children will be able to point out a few characteristics that are similar in all the birds. In localities where the red-headed woodpecker is abundant it will be found fully as good for a detailed study as the flicker. Other woodpeckers that are likely to be seen are the hairy, downy, and sap sucker.

ANTS.—Third Grade

Almost all third-grade children have seen ants. Ask where they have seen them and what they were doing. The discussion will raise the question where do ants live, and how do they care for their home and young? If you know of an ant's nest accessible to the school building, by all means let the first lesson include a visit to this home. Nests of small black and brown ants are often found under sticks, boards, and stones. Some are found in the ground, while others make mounds or hills which are often several inches above the surface of the soil and several feet in diameter. If a mound is found have the children note whether there are any openings leading down into the ground. How many? Watch to see whether the ants go in and out of these openings. Are any ants carrying things? With a trowel dig up a small portion of the mound. How do the ants behave when disturbed? Is there anything in the nest besides ants? You will probably find a number of white bodies like tiny grains of rice. These are young ants in the condition in which they are called pupæ. They are asleep and perfectly helpless. They look like little bags tied with a string at one end. Some day the bags will split open and a grown-up ant will come forth. What do the ants do with the white pupæ when you stir up a nest? These ants that you see racing around and carrying the pupæ are known as workers.

You may easily make an artificial ants' nest and keep a few ants for observation in your schoolroom. There are many ways of making these nests. The field nest is easily made and is very satisfactory. Procure a piece of window glass twelve inches long and six inches wide. Build a wall around it about a fourth of an inch high and half an inch wide by sticking together strips of glass. Divide the space into three apartments by means of partitions made in the same way as the wall. Leave a passage between the rooms. Have a separate cover for each apartment. The covers should be dark glass or boards. Another simple ant's nest that answers the purpose is an ordinary school slate. Cut a couple of passages in the frame, get a pane of glass and a board or shingle the size of the slate. Set the slate on two blocks of wood in a shallow pan of water. (An ordinary baking pan will do.) To get your ants for the nest, find an ant's home and scoop up with a trowel a number of workers and put them quickly into a glass jar. Collect some of the pupæ. You may also find some wriggling wormlike creatures; the very young ants or larvæ. Get as little soil as possible. When you return to the schoolroom dump the contents of the jar into your nest, cover it up with glass and board. If you succeed in getting a queen you may have a permanent colony. You can tell the queen from the workers by her large size. Without a queen, however, you can keep the ants for several weeks; long enough for the children to find out many interesting things about them. If you start your nest in the afternoon, by morning the ants will probably be well established in their new home. You may watch them at any time by removing the board and looking through the glass. The air must be kept moist in the home or the ants will die. This may be managed by keeping a piece of moist blotting paper or sponge in the home. Have the children feed the ants different things; cake crumbs, bread, bits of fruit, sugar, meat, etc. Place the food near one of the passages and the ants will carry it into the home. Do the ants show any preference for special kinds of food? Watch how they care for the pupæ. You will probably find that they move these from one place to another. What effect does the light have on the workers?

Besides the observation in the schoolroom, encourage the children to watch ants they may find outside. Give them some simple problems to solve. How many different kinds of ants can you find? How many feet has an ant? How does it carry things? Do you ever find two or three carrying the same object? What does an ant do when it comes to something that blocks its way, as a stick or stone; does it crawl over or go around? When ants get into your pantry or cupboard do they have a definite path that they follow as they come and go? Watch two ants that meet; what do they do? You will often find that they touch each other with their feelers as if this were their way of greeting each other. In the fall you may find a great many ants with wings. These are the queens and drones. The workers never have any wings.

TOMATO.—Third Grade

Fall.—*Purpose: To interest children in preparing seeds for next spring's planting.*

Have the children visit the school or home garden and select some of the smoothest, finest tomatoes they can find; just the kind they would like to have on their own plants next summer. Cut these tomatoes in two crosswise, and notice where the seeds are borne, and how they are arranged. Some of the fruit have many more seeds than others. Have the children decide which kind they prefer. The more seeds, the less room for the thick, juicy meat. Remove the seeds and spread them out on a sheet of paper. When dry place them in an envelope, label, and put away for the winter.

Spring.—The spring work with the tomato should begin the latter part of March, or early in April. Have the children bring into the schoolroom some good garden soil. Put this into a shallow box and sow the seeds, covering them lightly with not more than half an inch of soil. Have the children decide where the box must be kept and what care must be given to it. Let them decide that moisture and warmth are essential, and light after the plants are up. Watch for the first appearance of the plants. How long did it take the seeds to sprout? Compare with sweet pea in this respect. How many leaves has the little plant?

Watch to see where the second pair of leaves appear. Are these leaves the same shape as the first ones?

When the plants are three or four inches high they may be transplanted into small flower pots, old berry boxes, or tin cans. If the last are used, be sure that a hole is made in the bottom of each can for drainage. However, if the plants are not allowed to crowd one another too much, they may be left in the large box until time to set them out in the garden.

The plants should be set out the first or second week in May. Have an indoor lesson to decide how and where this is to be done. This decided, the children should do the work of setting the plants, watering, and cultivating them. The plants should be set in rows four or five feet apart. Encourage the children to set out some of the plants in their own home garden. Watch the growth of the plant and note when the first blossoms appear. What is the color of the tomato flowers? When does the fruit begin to ripen? Can the plants stand up straight when they are loaded with fruit? It will be a good plan to use a support to help keep the fruit up in the light and air so it will ripen more evenly. How many tomatoes will one plant produce?

What is the fruit good for? Think of all the different dishes made from tomatoes; stews, soups, cream tomatoes, salads, scallops, etc. How are they put away for winter use? Our mothers can them, or they are canned in the factories and we may buy them from the grocer.

Suggestion.—The entire fruit of the tomato as well as the cross section are good objects for water-color work.

SWEET PEA.—Third Grade

Fall.—*Problems: How does the plant hold itself up and how does it scatter its seeds?*

How tall are the sweet-pea plants? Are the stems large around or not? What is the shape of the stem? Can one of these stems stand upright without a support? How does it hold on to the support? How have the tendrils succeeded in taking hold of the support? Where are the tendrils? How many can you find on one plant? Where are the pods; near the lower part of the plant or near the top? How long is a pod? Find some pods that are green and some that are ripe. Note how they differ from one another. How many seeds in one pod? Find a pod that has no seeds left in it. Notice that the two parts are twisted. Watch other pods to see if you can find out why they curl up like this. When the seeds are ripe the pod begins to dry. At night the dew moistens it, and in the morning the warm sun dries it out again and it becomes warped. All at once some day it splits open, and the two parts curl up and fling the seeds in every direction. If you should leave the seeds lying on the ground over winter some of them might grow. But if you want to be sure of a crop of sweet peas next summer you must gather the seeds and put them away.

Spring.—*Problem: What must we do in order to have many beautiful sweet pea blossoms this summer?*

Indoor work. Decide where, when, and how to plant sweet peas. These plants do well anywhere in rich mellow soil, and in plenty of sunshine. They may be planted along a fence, or close to a building, or out in the open garden. We must make a drill at least six inches deep, just as early as the soil is fit to work; the earlier the better. Sow the seeds in the trench and cover with about two inches of soil. When the plants have grown about two or three inches in height fill the trench almost to the top with soil leaving a slight depression to catch water. After the soil is thoroughly soaked, fill to the top with loose soil, or place a layer of straw on the top to hold the moisture. When the plants have grown about four inches high have the children decide what supports they will use for the plants to climb. Strings fastened to a few strands of wire, wire netting, or simply sticks from a brush pile will answer the purpose.

Watch the growth of the plants; are they slow or rapid growers? Watch for the first tendrils. How do they take hold of the support? Do they all curl in the same direction? When do the first flowers appear? We must learn how to remove the flowers without injuring the plants. We must cut them with a pair of scissors, not pull them off. Cut the stems as long as possible. It is very essential that you keep the flowers cut if you wish to have an abundance of flowers all summer. This flower is a good one to study. The children may be interested to know that it is called the butterfly flower. The two large petals at the sides are called wings, the one at the top the banner or standard, and the two that are grown together forming a little boat are called the keel.

Recall the pods in which the children found the peas last fall. See if they can find the part of the flower that will make the pod. Have the children watch the sweet peas to see if any insects visit them. What are the bees and flies doing?

Do not try to force the study of pollination here. It is enough for these children to see that the insects are getting something to eat out of the flowers.

Experiments.—No seeds are better than sweet peas for making some simple experiments in germination. If the peas grow and work we shall try to find out under what conditions they can do their work best.

Plant a few in dry soil; others in moist soil.

Moisten some blotting paper, put it in a tin cup, then place on it three or four seeds that have been soaked in water for twenty-four hours. Cover the cup so that no light can reach the peas and keep warm and moist.

Place the same number in a glass with other conditions exactly the same. From these the children will see that the seeds germinate just as well in the dark as in the light, but that they will not grow without moisture. In the same way show that moisture and warmth are necessary for germination.

Have the children select some of the most beautiful flowers and allow these to mature their seeds. Keep these as choice seeds for next year's planting.

Suggestion.—Sweet peas may be successfully grown in window boxes in the schoolroom.

ENGLISH SPARROW.—Third Grade

No time is better for the study of the English sparrow than the winter.

Problem.—How does the sparrow care for itself during the winter months?

Tell the children that you and they are going to talk about a bird that lives around our homes. What is it? The English sparrow. Do not let the children say just "sparrow," for they should know that we have many native sparrows, and that the English sparrow is only one of a large group. Make a field trip with the children to observe a flock of sparrows. Have them note especially where the birds are and what they are doing.

Tell the children to watch the sparrows around their homes. Where are they seen? What are they doing? Are they found singly or in flocks? How many can you count in one flock? What do they eat? You will have to be careful here or the children will say all sorts of things without having really seen any of them. Tell them to watch for two days and then call for reports of actual observations. How do they eat? Do they ever quarrel over bits of food? Do they like to drink water? How do they move about on the ground? Do they walk or hop? How do they hold their tails when they fly?

How do they keep warm in the cold weather? Discuss the coat of feathers. Do they exercise? Do they seek sheltered places? Where do they sleep at night? Watch to see if you can find out. Do they ever creep into sheltered places about your home?

Look closely at the sparrows you see. Are they all the same color? The ones with the black patches on the breasts are males, the others females. What other differences in color between males and females?

Do the sparrows sing? How many different sounds do they make? Do both males and females make sounds?

Where do sparrows like to build their nests? What are their nests made of?

One of their nests may be easily obtained from a corner in a barn or elsewhere, and kept in the schoolroom for study. Why do they have so many feathers in their nests? The children will be interested to know that after the mother bird lays the eggs the father bird carries feathers and covers up the eggs to keep them warm.

Why are the birds called English sparrows? Tell the story of how they were brought here from England with the hope that they would eat injurious insects. Instead of proving a blessing they have become a real nuisance in some places. Their real name is "house sparrow." Why is this a good name for them?

This lesson should not be finished up in a day or two. Time should be given for the children to make actual observations which may be reported occasionally. A few minutes may be taken for this once or twice a week just to keep up the interest. At the end of two or three weeks a whole period may be taken in summing up all that has been seen and heard.

TOMATO WORM.—Fourth Grade

Fall.—*Problem: To find out what the tomato worm does, and what it becomes when it is grown up.*

The tomato worm, a larva of a moth and an enemy of the tomato, is frequently found on the tomato plants in the summer and fall. Place about four inches of soil in the bottom of a quart fruit jar. Break off a spray of the plant on which the tomato worm is resting and place this upright in the jar. A piece of wire screening may be placed over the mouth.

How does the worm manage to cling so securely to the stem? The children will be able to make out the sixteen clamplike feet. What does it eat? When does it eat more, during the day or night? Put some fresh tomato leaves into the jar in the evening. Count the number put in and determine how many it eats.

Some day the children will find the worm not on the stem, but crawling around on the surface of the soil. If they watch closely they may see it begin to push its way down into the soil. Why does it bury itself alive? What is it doing? Wait about two weeks and then very carefully remove the soil from the jar and disclose the tomato worm no longer a green worm, but a brown pupa. If the children look closely they will be able to find the dry crinkled skin that the worm shed when it changed its form. Is the pupa alive? Can it move about? Can it eat anything? The wriggling of the back part of the body shows that it is alive, but it does not eat or move about. Put the soil back into the jar. Make a little furrow in the surface. Place the pupa in this and cover lightly with soil. Place the jar in a cool room. A basement not heated with a furnace is a good place. The study should be completed in the spring, when the jar may be brought back to the schoolroom. This should be done in the latter part of May. Place a small twig of some sort in the jar. When the brown pupa case breaks open the moth will crawl up the twig, and remain clinging to this while its wings dry. Have the children note the number of wings and feet, and the large beautiful eyes of the moth. When the wings are thoroughly dry, put the moth into your terrarium, to let the children see how the wings are used.

Have the children watch for other moths of this kind. They are frequently found flitting about the flower beds during the summer evenings. What are they doing? If the children watch closely they may be able to see the long sucking tubes thrust into the flowers to sip the sweet nectar.

GOOSEBERRY.—Fourth Grade

General Problems.—What are the characteristics of the gooseberry shrub, and what methods of propagation and culture are employed in making it productive?

The study should begin early in the spring before the leaves begin to appear. Note general forms of the plant. Is it straight and tall or round and bushy? Is there a main stem with branches or many stems growing out close to the ground? Are all the stems of the same size and age? Is there any difference in color between the old wood and the new?

Bring some twigs into the schoolroom. Can you tell what part of the twig grew last season? How many things can you find on a twig? What is the color of the buds? Are they opposite or alternate in arrangement? How do buds on the older portion of the stems differ from those on last year's twig? Where are the largest buds? What will all of these buds become? Leave this as a problem to solve when the buds have opened. Where are the thorns or spines with reference to the buds? How many spines in a group? Are they all the same size? Do you find any spines on the older parts of the twigs? Are there any not arranged in groups?

Watch for appearance of the first leaves. Compare with other shrubs and trees as to time of opening the buds. Does frost hurt these leaves? What is your opinion as to the hardiness of the plant? What is the shape of the leaves? How are they arranged, singly or in clusters? What is the end bud becoming? The side buds? Are there any spines on the new, growing twigs? Where are they with reference to the leaves?

Watch for the opening of the flowers. Are they more numerous on the old wood or on last year's wood? Do not decide this too hastily. Examine a number before coming to a conclusion. What is the position of the flowers on the twig on the upper or lower side? Make out the parts of the flower. What part of the flower becomes the berry? Watch development from week to week. What part becomes the dry, brown tuft that must be taken off before the berry is ready to use? Do we have to wait for this fruit to get ripe before we can eat it? This is a good type of the true berry. Cut one in two across the middle. What parts can you see? Is the skin thick or thin? What is the color of the meat or pulp? Where are the seeds? Is the plan of this berry anything like that of a tomato? From this the children will conclude that the tomato is also a berry. How about the currant? When does the gooseberry ripen? Have children note time of ripening during the vacation and report in the fall. They will find that all the berries do not ripen at once, but that they continue to ripen a few at a time for several weeks. What changes occur in color as the berries mature?

How may we produce new gooseberry plants? It will be interesting to have the children save some of the seeds from the ripe fruit. The seeds should be taken from the berries, washed, and thoroughly dried. While some of the seeds will grow, this method of producing new plants is a slow one and sometimes the seeds do not come true; that is, they do not produce a new plant that has as good fruit as the old one. In the fall plant the seeds in pots. Keep some in the schoolroom, the others out of doors. Watch for the appearance of the plants.

Another method used in propagating gooseberries is by layering. This should be done in the latter part of the summer or early fall. It may be done the first of the fall term. A vigorous branch is bent down and laid upon the ground, or in a shallow furrow. This is covered with moist earth, well firmed about it. On top a mound of soil is sometimes placed, or mulching of some sort to keep the ground moist. The layer may be held down by a weight or by means of a forked stick. In the spring the stem of the layer may be severed from the parent plant and the new shoot with its roots set out. The plants should be set from three to four feet apart in rich, rather moist soil. They will be ready to bear in a few years. To keep the plants bearing well the oldest stems should be cut out occasionally and the soil dug up around the plants once every two or three years.

The currant should be studied in connection with the gooseberry, noting the features in which the two plants resemble each other, and in which they differ.

What enemies have the currant and gooseberry? The children may find some of the gooseberries covered with a layer of rough, yellowish material. This is a fungous growth that in some places is quite destructive. All affected berries should be burned to prevent the spread of the disease. By spraying, this disease may be almost wholly prevented. Another enemy of the plants is the gooseberry or currant worm.

CURRANT OR GOOSEBERRY WORM.—Fourth Grade

General Problem.—What are the characteristics that help to make the gooseberry worm a pest?

After the leaves are well open, have the children look at their gooseberry or currant bushes for flies that keep hovering around the plants. Catch a few of these, put them into a tumbler, and examine carefully. Are they real flies? At first sight they look as if they might be common house flies. How many wings has each one? How many wings has a house fly? True flies never have but one pair of wings. These insects are sawflies. They are relatives of bees and wasps.

What are they doing as they fly in and out among the bushes? Look on the under side of the leaves till you find one that has rows of white eggs on it. These are the eggs of the sawfly. How many on one leaf? On some of the leaves you will find tiny worms that have hatched from the eggs. What are the worms doing? What kind of mouths must they have to nibble the leaves in this fashion? They have strong toothed jaws. Place a few of the worms on some twigs. Keep the twigs fresh in a bottle of water. Fresh leaves should be put in every evening. Watch them feed and grow. These worms, as a rule, do not thrive well for any length of time in confinement, so new ones may be brought in from the bushes from day to day or the various stages may be found at one time, and brought in for study. Encourage the children to observe them on the bushes at home. How many different colors do you find on one worm? Are they all the same color? The ones that are pale green with yellow near the end are the oldest ones. Do the worms keep the hinder part of the body straight or curled? Look at a number of different ones when they are quiet on the leaves before deciding this. How many feet has one? To count them hold the leaf on a level with your eye and look under the worm. The three pointed pairs near the head are called true feet. The six pairs in the middle and the one at the hinder end are called prop feet. Do you remember how many feet the woolly bear caterpillar, or tomato worm had? They had only eight pairs. One way you can tell sawfly larvæ from butterfly or moth larvæ is by the greater number of feet.

If you have some of the light green worms with the yellow spots put them in a jar or box with plenty of fresh leaves. Keep a piece of mosquito netting tied over the top. In a few days the worms disappear. What do you find in the bottom of the box under the leaves? Those black objects are cocoons that were woven by the worms. After three or four days cut one of the cocoons open. What is on the inside? Instead of the worm this sleeping mummy is a pupa. Leave the rest of the cocoons undisturbed. After ten days look in the box every day. Be sure to keep the netting tied over the top. What do you find in the box? These insects are the grown-up sawflies. Look at the cocoons for openings through which they came out. They are now ready to lay their eggs on the gooseberry leaves to produce a new crop of worms.

The worms that were left out of doors dropped down to the ground and made their cocoons under the dead leaves or other rubbish, or just under the surface of the soil. The second brood of sawflies often eat up every leaf left on the bushes by the first brood. When these are grown up as larvæ they spin cocoons just as the others did, but instead of the sawflies coming out in two or three weeks they remain as pupæ in the cocoons all winter and come out in time to lay eggs on the first leaves that appear in the spring.

If these cocoons are close to the surface, or under dead leaves, who will suggest a way to get rid of some of them? Rake up the trash in the fall and burn it. Spraying the bushes with hellebore in the spring as soon as the worms begin to appear is usually effective. It may be necessary to spray several times.

The children will be interested to know that these worms are not natives of America. They were accidentally imported from Europe into the New England states about fifty years ago. Since then they have spread over the greater part of the United States.

BLUEGRASS.—Fifth Grade

Problems.—What are the characteristics of the bluegrass that make it a good lawn plant? What may we do to keep our lawns beautiful?

The work should begin with outdoor observation of the bluegrass during the latter part of winter or very early spring. Note the condition of the grass at this time. What indications have you that it has lived all winter?

Upon looking closely the children will find many green leaves close to the ground. Some of the leaves will be half green and half dead. Have weather conditions had anything to do with the number of leaves that have remained green? Compare the grass that is found growing on a southern slope with that on a northern or western exposure. If the children find a spot where no green leaves are visible, leave with them the problem whether or not the entire plant is dead. Let them watch the spot occasionally until they are convinced that new plants are springing up from the ground. What makes it possible for the plant to do this?

Dig up a small sod of bluegrass, wash all the soil out of the roots, keep it moist, and bring it into the schoolroom for study. Examine the portion of the sod that grew above ground. Can you make out individual plants? How are these related to one another? Are they far apart or close together? Look at the part that grew in the ground. How many distinct structures do you find? Distinguish the mass of small threadlike roots from the underground stem or slender rootstock. Have the children note the difference between this underground stem and the roots. The stem has joints, thin scale leaves, and often a bud at the end which sends up a new grass plant. Have the children look for these new shoots. Note the direction of growth of the rootstock. What are the advantages of this rootstock during a severe winter? The plants above ground may be dead, but the rootstock will still live and have its bud all ready to send up a new shoot when warm weather comes. It enables the plant to spread over a larger area. It helps to tide over a dry season as well as a cold one.

Propagation.—What ways are there of starting bluegrass on our lawns? By sods and by seeds. If good sod can be obtained this is the quickest way to get a lawn, but the most common way is to plant seed. Have the children plant a few seeds in a box in the schoolroom, or better in the schoolyard, and watch the habits of growth of the young plants. See if the children can find out when the sod begins to form. Plant seeds at varying depths. Leave some almost entirely uncovered. Determine which germinate best. Sow a small plat with pure bluegrass seed, another with bluegrass and white clover mixed. Which succeeds better? Procure several pieces of sod, each about three inches square. Place these in soil about six inches apart. Watch results. What has made it possible for these to cover the ground? Allow some bluegrass plants to remain unmown until they have produced flowers and seeds. Few children recognize the plant in this stage. When do the plants begin to send up their flowering stems? Begin to watch for these the last of May and first of June. From what part of the plant does the flower stem grow? How tall do these flower stems grow? Measure several and compare. Are there any leaves on the flower stem? Is this stem solid or hollow? Notice that the stem branches into many slender parts which bear the small scalelike flowers. Note the color of the branch.

Do not try to make out the parts of the flowers. The children may be interested to know that grasses do not have bright petals as so many other flowers do, but that they do have stamens and pistils. The stamens may be readily found in the bluegrass. When the flowers have become dry have the children find the seeds. Rub the seeds out of one panicle or flower head to determine the amount. How many panicles does it take to produce a teaspoonful of seeds?

Care of the Lawn.—Everyone likes to see a smooth, velvety lawn. Encourage the children to suggest things to do to keep their lawns beautiful. Remove sticks, dead leaves, paper, and weeds. If there are bare spots they should be raked and sown with fresh seeds early in the spring. If the lawn is uneven it should be rolled. Mowing should be done often enough to keep the grass close cut. Evening is a better time to mow during hot weather than morning. Why? In dry weather the grass should not be cut too close. Why? There is danger of exposing the roots to the sun.

Suggestion.—A small bunch of flowering and fruiting bluegrass ought to be put away for schoolroom observation.

What are some of the enemies of the lawn? The children will suggest many. Dandelion, plaintain, mole, grubworm, etc.

DANDELION.—Fifth Grade

Problem.—What characteristics has the dandelion that make it a successful lawn weed?

The study should be taken up about the same time as that of the bluegrass. Begin outdoor observation early enough so that the children may see that the plant has lived over winter. In sheltered places they will find that some of the leaves have remained green during the cold months.

Habits of Growth.—What is the relation of the leaves to the ground? Where are the longest leaves; at the outer or inner part of the rosette? Where are the youngest leaves? Is the center of the rosette level with the surface of the ground or below it? Are there any advantages to the plant in growing as it does? The children will readily see that the plants are better protected from wind and cold because of this habit of growth. Dig up a number of plants, wash off the soil and bring into the schoolroom. Examine the root. Note how long and thick it is and its direction of growth. Compare with bluegrass roots. This kind of root is called a fleshy tap root. Has this root any special advantages? Let the children think about this. Do not try to answer it fully now. Come back to it when the beet is studied. Have the children pull the rosettes apart, carefully noting what is stored away in the center of each. They will be interested to find numbers of tiny flower buds, some larger than a pea, some as small as a pin head. Get the average number of buds in the specimens.

Flower and Fruit.—Note the time of the first dandelion flowers, position of flower on the plant, length of flower stem. Note that as the stem lengthens it does not grow straight upward, but first bends outward. Have children watch to see that the flowers close up at night and during rainy, cloudy days. Bring a number of flowers into the schoolroom. Have the children decide whether what we call the flower is a single flower or a cluster of many flowers. Separate the cluster of flowers and look at one small flower. What do you see? A small seedlike body at the lower part, a cluster of soft hairs above this; and the yellow part, the petal, with the two "pollen-catchers" extending above it. Have children estimate by counting the number of flowers in three or four clusters about how many flowers one plant will produce. If each flower makes one seed, how many seeds will one plant produce? How long after the flowers begin to open until the seeds are ripe? How does this compare with other plants you know? What is the position of the stem with the ripe fruit on it? What advantage in its standing so tall and straight? Examine the fruit. What part of the flower has opened up into the parachute? What has become of the seed? What scatters the seeds of this plant?

Experiments.—These should begin with the first lessons in early spring. Cut off the leaves of a dandelion rosette, leaving the center uninjured. Cut another a little below the surface of the ground. Cut a third about three inches below the surface of the ground. Have the children try these experiments at home as well as at school and report results. They will find that unless the plant is cut off far below the surface it will continue to grow. Have them decide whether or not a lawn mower will kill dandelions, or whether ordinary methods of weeding will do it. Plant a few seeds to determine whether or not they grow the first season. Study a path or some spot that has been trampled upon to decide which can stand trampling better, blue-grass or dandelion.

WATER BEETLES.—Sixth Grade

Water beetles are found in abundance in ponds and pools. They may be obtained by scooping up with a dip net, or long-handled dipper, the vegetable matter from the bottom of the pond. They may often be caught while swimming by means of an ordinary insect net. During the early spring months these beetles may be found on the ground in the vicinity of electric lights. Two specimens are common, the water scavenger and the cybister, a predaceous diving beetle. These are easily distinguished from each other. The water scavenger is a large, shiny black beetle; while the cybister is a little smaller, more flat, and has a cream-colored band extending around the body.

General Problems.—What special adaptations have these beetles that make it possible for them to live in the water? Are they harmful or beneficial to man?

The Cybister.—If possible study this beetle first in its natural surroundings by making a visit to a pond in the neighborhood. Capture some of them, bring into the schoolroom, and place in an aquarium. Have the children arrange the aquariums as nearly like the pond as possible. Place in the bottom a few small stones or gravel, some of the decaying vegetable matter, and a stick leaning against the side of the jar. If you have no aquarium use a glass jar or a large glass dish. Two or three ten-cent glass fruit dishes will be found valuable aids in the study of many water animals. Have the children observe the behavior of the beetles. Where do they stay; at the surface of the water or at the bottom? Shade one side of the aquarium and determine whether they prefer light or darkness. Do they move around much if left undisturbed? Try to determine when the beetles are more active; during the day or during the night? For detailed study place the beetles singly in tumblers about two thirds full of water. Two or three pupils may observe the same specimen.

Problem.—How does the beetle move? What is the position of the body while the beetle is swimming? How many legs has it? Which ones does it use most in swimming? Watch carefully to see if the strokes are made with both hind legs at the same time. Do these legs differ from the others in structure? Look carefully and you will find that these legs are broad and thin and have a fringe of long hairs on them. Watch these hairs while the beetle is swimming to see if they change positions. When the stroke is made the hairs are spread to make the leg more oarlike. As the leg is lifted after the stroke the hairs droop downward close to the leg. The children can see this perfectly. Watch the beetle dive to the bottom of the glass. Does it go head first?

Problem.—How does this beetle breathe? When the beetle is resting in the aquarium what position does it take in the water? You will find it hanging head downward and with the tip of the abdomen protruded above the surface. If it is suddenly disturbed it dives quickly to the bottom while one or two small bubbles of air may be seen coming from the tip of the wing covers. This gives a clue to its method of breathing. When it is resting with the tip of the body above the surface it lifts its wing covers slightly, air rushes in, and is held by fine hairs on the back. Arranged in rows on each side of the back are breathing pores through which the air passes into the body. The space under the wings holds air enough to last the beetle for some time under the water.

Problem.—How does the beetle eat, and what does it eat? Place in the aquarium some small bits of lean meat, fresh liver, or some fish food used for goldfish. Watch to see if those disappear. Place in the aquarium some mosquito larvæ ("wrigglers" or "wiggle tails") and watch results. Let the beetle remain a few days without food, then with a pointed stick or pair of forceps hold a small piece of liver in the aquar um near the beetle. It will soon detect it and swim toward it, seizing it with its strong jaws. Note how the front feet are used in helping to hold the bite while the beetle tears it to pieces.

Problem.—How does the beetle get from the pond to the electric lights? The answer to this question means a study of wings. This is best done by means of dry specimens with wings spread. Have the children note first on the live specimen the line down the middle of the back where the outer wings meet. With the dry specimen in hand note the shape of the inner wings, and the numerous veins. Are these wings longer or shorter than the outer ones? Why is it that the beetle can keep them entirely concealed when in the water? One or two specimens should be kept with the outer wings raised to show how the inner wings are folded and tucked away when not in use.

The Life History.—In scooping up the débris from the bottom of the pond in the spring you will probably capture some of the young cybisters. They do not resemble in any way the mature insects. They are long, slender, segmented larvæ with six slender legs and hornlike jaws. Place them in an aquarium by themselves and feed them insects, earthworms, or bits of fresh meat. The children will soon discover that the sharp, hornlike jaws are used to seize and kill the prey and suck the juices from their bodies. These larvæ are so fierce, and kill so many mosquito larvæ and other water insects that they are known as water tigers. The method of breathing may be seen by the children. At the hind end of the body are two little projections with openings or breathing pores in them. Watch the larvæ curl the end of the body upward and stick these projections above the surface. When the larva is ready to change to a pupa it crawls upon the bank and makes a small cell in the ground. It remains here three weeks and then changes to a beetle. Some time should be given to discussion of the value of the cybister as a mosquito destroyer.

The water scavenger beetle may be studied in much the same way as the cybister. A comparative study of the two will make a profitable lesson. The children will discover that the scavenger uses its legs differently while swimming, that it rests with its head out of the water, that it takes a film of air on the under side of the body, and that it feeds upon decaying vegetable matter as well as insects. The eggs of these beetles may be found floating upon the water in large, white, irregular cocoons. The cocoons are easily identified by a curious handlelike stem on one side. There are from fifty to one hundred eggs in each cocoon.

THE CABBAGE BUTTERFLY.—Seventh Grade

General Problem.—Where do the cabbage worms come from, and what may be done to lessen their numbers?

Ask the children to bring in cabbage leaves that have worms on them, or pass to the school garden and examine the cabbage plants there. Where did the worms come from? The children have probably seen the white cabbage butterfly flying around the cabbage patch alighting now and then upon the leaves. What were they doing? Look on the under side of the cabbage leaves for the eggs that the butterflies deposit there. There are small cream or light yellow bodies standing on end on the surface of the leaves in size not as large as the head of a pin. Are these eggs grouped or single? Do you find as many on the upper surface as on the lower? Is there any advantage in having the eggs on the lower surface?

Place the leaves on plates or in a box, to see if the eggs will hatch. It is not necessary to wait, however, for these tiny creatures to grow before continuing the study. Observe some of the worms or larvæ that are already quite large. Bring a number of these into the schoolroom and place in a terrarium or box. Keep supplied with fresh leaves.

How do they eat the leaves? What kind of mouth parts must they have? The children will readily see that they must have biting jaws in order to make holes in the leaves as they do. Place the worms on fresh leaves and let the children notice how they eat.

How do they move about? Make out the number of feet they have. Are all the feet of the same size and shape? The three pairs near the head are the true legs, the four near the middle and the one at the hind part of the body are pro-legs.

Watch the larvæ closely when they leave the leaves and crawl up the side of the cage. They are now getting ready to change into pupæ. How do they fasten themselves to the support? Notice the little bit of silk at the hinder part of the body and the thread of silk around the middle.

The children may not be fortunate enough to see the larva skin split and wrinkle backward till it drops off at the hinder end, but they will see the pupa that is left in place of the larva. How does it differ from the larva? Does it move about or eat? Is it alive? Touch it gently to see if it moves.

If you start this study in early September, some of the pupæ will change into butterflies. This change occurs during the summer in about ten days. Late in the fall those that pupate remain in that stage all winter, to produce the first generation of butterflies in the spring.

Study the butterflies. Have children watch them out of doors to see what they are doing. They will probably find them flitting among flowers as well as over the cabbage patch. What are they doing on the flowers? Leave this as a problem. Put a few butterflies into the terrarium. Place in it also a bottle of water containing some flowers. Clover will serve the purpose very well. Watch to see how the butterflies uncoil their long sucking tubes to sip the nectar from the flowers. They will do the same thing if you place a few drops of sweetened water in the cage. Are all the butterflies the same color? Those that have two black spots on the fore wing are females.

Find out to what extent the cabbage worms are considered a pest in your district? Do they feed on cauliflower and other members of the cabbage family? What may be done to keep them in check? Insect powder diluted with seven times its bulk of flour and dusted on the leaves is sometimes effective. Many people sprinkle the leaves with hot water. Have the water almost boiling when put in the watering can. By the time it reaches the leaves it will be hot enough to kill the worms but not injure the plants.

What natural foes do the cabbage butterflies and their larvæ have? Many birds eat both worms and butterflies. See if you can find any birds feeding among the cabbage. A common foe is a small insect known as a braconid fly.

The children will often find on the cabbage leaves a mass of yellow bodies that look like eggs. Bring some of these into the schoolroom. Put them into a tumbler and tie a piece of cheese cloth or netting over the top. In a few days the glass will be swarming with tiny creatures not much larger than gnats. Where did they come from? Examine the yellow mass. What do you find? A hole in each of the egglike bodies. When you look closely you will see that these are not eggs but cocoons made out of silk. The flies hatched from the cocoons. They are parasites that help to keep the cabbage butterflies in check. They lay the eggs just under the skin of the cabbage worm. These eggs hatch into tiny white grubs which feed upon the tissues of the worm. They are careful not to touch any of the vital organs such as the heart, digestive system, etc. Why? When they are ready to spin cocoons and change to pupæ, they burst through the skin of the worm in a group, killing it instantly.

The braconid flies are relatives of the bees and wasps and are not true flies. There is another parasite, a near relative of the braconids known as chalcis fly, that feeds upon the pupæ. So sometimes you may find a swarm of chalcis flies emerging from the pupa skin instead of a butterfly.

The history of the cabbage butterfly in America is interesting. It was imported in some way, no one knows how, from Europe to Northeastern Canada, in 1860. In about twenty years it had spread over the eastern half of the continent. In five more years it was found as far west as Denver. It is now found wherever cabbage is grown, from the Atlantic to the Pacific coast.

THE GRAPE.—Seventh Grade

General Problems.—What do we need to know about grapes and their culture in order to produce a good crop of fruit?

The work should begin in the fall with the making of cuttings. If the class has not already made a detailed study of soft-wood cuttings, then as a preliminary lesson soft-wood cuttings should be made with a study of the callus, rooting, and transplanting.

Grape cuttings are made late in the fall or early winter when the leaves have fallen off, and the plant has ceased work for the winter. Cuttings made from hard wood at this season are called dormant cuttings. Will you want old wood or new for the cuttings? They should be made from this season's growth. Measure some of the stems to determine the length of growth in one season. Do these stems vary in thickness?

How many buds on one stem? How arranged? Remove from the vine a number of branches. Make a slanting cut through the joint or node where a bud is attached. To do this place the knife on the side of the stem opposite the bud and on a level with the top of it. Now cut slanting downward and the knife will come out just below the bud. Make one clean cut; it must not be jagged. Each cutting should have at least two good buds.

What will you do with your cuttings? Tie a number together and place them in moist sand in a cool place, or they may be buried in the soil of the garden. If this is done care should be taken not to put them where they will stand in water. What do you want the cuttings to do during the winter? Just what your soft-wood cuttings did, form a callus and start roots.

Take up the work again in the spring. The cuttings should be set out in a row in the garden in a well-drained spot. Set them about eight inches apart and deep enough so that only one bud will be left above the surface of the ground. They should not be less than six inches in the ground. These cuttings will be ready to set out in a permanent place in one or two years. They should be set from six to eight feet apart. If they have made a vigorous growth, it is best to cut them back so there will not be more than four good buds on the stem.

In the spring take up the study of grape vines. Compare with other shrubs and trees as to the time of opening leaf buds? How does the plant climb? Where are the tendrils situated? How many divisions in one tendril? What does the tendril do in order to cling to a support? Which do you think helps support the plant more, the twining stem or the tendrils?

Watch for the flowers. Are they early or late in opening? Can you account for the late flowering? Where are the flowers, on last year's wood or this year's? Where situated on the new stem? You can readily see from this that the flowers cannot open early. Are there flowers on all of last year's stems? Are the flowers single or in clusters? Study one flower carefully, making out its parts. The flower is an interesting one. Note how the petals are united to form a sort of cap above the stamens and pistil.

It is only the strongest of the new branches or canes, as nurserymen call them, that bear fruit. What may be done to have large clusters of well-developed fruit? It is easy to see that too many clusters on a vine will result in small grapes. The secret of having large clusters of good, juicy sweet fruit is the pruning. The pruning should be done in the winter not later than the last of February. Since the fruit is borne on wood of the present season every bud on last year's cane may produce a shoot that will bear fruit. But if this should happen it would mean many small, imperfect clusters. What may be done to remedy this? Cut out some of the canes, leaving the most promising ones. Those of medium thickness are usually considered best. All the long, slender ones and the stout ones should be removed. The canes that are left should be cut back to eight or ten buds, thus reducing the possible clusters on each cane.

In the fall make a study of the fruit. Make a cross section through the middle. Where are the seeds, in the upper or lower half? Do the number of seeds vary in the same variety of grape? Obtain as many different varieties as possible and compare as to size of fruit, yield, flavor, etc.

Of the purple grapes the Concord is the most widely grown. It is hardy and free from many of the diseases that are likely to attack other varieties. Moore's early, Campbell's early, and the Worden are considered by many people good varieties.

Of the red grapes the Delaware is best known, and with good cultivation and spraying it is a very satisfactory variety.

White grapes are not so widely grown as either purple or red, but are to many persons the most delicious of all the grapes. One of the best varieties of the white grape is the Niagara.

If there are wild grapes, Virginia creeper or woodbine, or Boston ivy in the vicinity make a comparative study of these in connection with the grapes. Note difference and resemblance. What common characteristics place these and the grape in the same family?

CLOVERS.—Eighth Grade

Problems.—What characteristics make red clover a good forage plant? Why is it a valuable plant in its relation to soil?

If possible the first lesson should be in the field. Note the habit of growth of the plant; a rather loose rosette close to the ground. How many stems do you find in one rosette? Do the stems branch? Where do you find the new shoots appearing? Is there any advantage to the plant in growing thus close to the ground with new shoots at the center? Bring out by discussion the chance this gives for the natural coverings, leaves and snow, to protect the plant during the winter. Note the arrangement of leaves and the number of leaflets. Later compare with other clovers to determine whether this is a common characteristic of the clover family. What special markings has the red clover leaflets? The light green spots. Look at the leaflets after sunset to see if they remain in the same position as during the daylight. Study the flowers. Are they arranged singly or in clusters? Have the pupils decide for themselves whether or not a clover head is a single flower or a number of flowers. Find the parts of one flower; compare with a sweet pea flower. How many flowers do you find in one head? Which flowers open first; those on the outside of the head or those at the center? Examine a number before deciding. Examine some old faded flowers for the seeds; where are they? Does one flower produce more than one seed? When should clover be mown to make good hay? It should be cut just when the flowers are beginning to fade. How does it compare with other kinds of hay? The stems and leaves contain so much nutritious food that it is considered one of the most important hay crops grown. Will the plant produce a second crop? Does this second crop produce flowers and seeds? The second crop is frequently cut for the purpose of obtaining the seeds for market or to sow a new plat next spring. How is the seed obtained? By running the plants through a machine something like a thresher, known as a clover huller.

Dig up a plant and study the root. Note size, length, and branches. What advantage is this thick, long root to the plant? What advantage to the soil? What else do you find on the roots? These small bodies are nodules or tubercles. Where do you find the tubercles most numerous? Count the number on a small root. What are the tubercles? They are growths on the root caused by small living organisms known as bacteria. These bacteria take from the air in the soil the free nitrogen and act upon this in the tubercles so that the plant can use it just as it can the more usual supply of soil nitrogen that enters through the root hairs in solution in the soil water. From your study of soils and the elements they contain that are used by the plants in making foods, you know that nitrogen is often lacking in the soil and that to supply it with commercial fertilizers is an expensive thing to do. It is very much cheaper to sow clover and let these bacteria gather the nitrogen from the air and in this way give a fresh supply to the soil.

Instead of harvesting the second crop of clover many farmers plow it under. Why? Because the roots and stems add nitrogen to the soil for other crops, and because the leaves of the clover decay quickly and enrich the soil by a fresh supply of humus. Have the pupils look for other clovers in the neighborhood and bring in specimens for study. Sweet clover and white clover will be found in abundance and in some places alsike clover and alfalfa. Note the characteristics common to these plants. Examine the roots to determine whether or not all have nodules. Study the stem of the white clover. Note how the plant spreads over an area. Why is it a good lawn plant? Have grown in the school garden for a comparative study a few specimen plants of other legumes than clovers. Soy beans and cow peas should be grown as they are often used instead of clover as nitrogen-fixing plants.

BUMBLEBEES.—Eighth Grade

Problems.—What is the relation of bumblebees to red clover? To what extent do these bees show division of labor?

If the pupils study red clover in the field they will be sure to find bumblebees. If they are quiet they will be able to get close enough to see what they are doing. Watch a bee go over a head of clover. Where does it put its tongue to get the nectar? Where is the nectar secreted in the flower? Remove one of the flowers. Put the lower tip of it in your mouth and you can taste the sweet nectar at the base of the corolla tube. How far down must the bumblebee thrust its tongue in order to procure the nectar? On what part of its body is it likely to collect pollen? Watch to see whether one bee visits several heads in succession. Capture several bees for close observation. This may be done with an insect net, or by quickly thrusting a pint Mason jar over a flower on which a bee is feeding. Have the lid ready to put on the jar the instant the bee is inside. Place the bees in a terrarium in the schoolroom. Feed them on honey or sweetened water. Place in a bottle of water several flowering stems of clover or other flowers and set in the terrarium. The bees will help themselves to the nectar. Pupils will be able to see here better than out of doors how the tongue is used. They can see this especially well when the bee is licking up a drop of honey or sweetened water. Have pupils note the covering of the body. Of what advantage is the hairy covering in conveying pollen? Note the legs. Do the last pair differ at all from the others? Are there hairs on the legs? How many different things can you see the bee doing with its legs? Breathe gently on the bee and notice how it uses its legs to clean its body. What is the color of the wings? How many wings? How do they differ from those of the honeybee? You can always tell a bumblebee no matter how small it is by its brown, smoky wings. Of what value is the bumblebee to the red clover? It is the chief agent in carrying pollen from one flower to another. Without the bumblebees probably there would be little pollination of the red clover, which would mean great reduction in seed production.

There are many different species of bumblebees. You can tell the difference chiefly by the size and color of markings, some having much more yellow than others. In habits and characteristics they are all similar. The pupils should learn something of the division of labor among them. They will be able to find the large drones and the workers, possibly the queens. They may find a nest of these bees and know that they live in hollows in the ground or under brush piles. The nest of a field mouse is a common home of this bee. Only the queens live over winter. In the spring each queen starts a colony. Having found a suitable place for her home she gathers from flowers quantities of pollen and some nectar. She mixes these together and makes a pasty ball. On this she deposits eggs, from five to twenty, which hatch into bumblebee larvæ. These feed upon the mass of pollen. When they are grown up as larvæ they spin cocoons and change to pupæ, and after about two weeks they emerge as grown-up bees. All of the first brood are workers. They collect pollen for the home, feed the young, and sometimes store a little honey. The queen now gives most of her time to depositing eggs. Late in the summer drones and queens appear. The drones and workers die in the fall, but the females seek a sheltered nook into which they creep and spend the winter.

Following the lessons on the bumblebee their relatives should be taken up for a comparative study. The characteristics which place these insects in the same group should be noted. Special attention should be given to the method of caring for the young and the advance shown in division of labor by the different families. Mud daubers, polistes, hornets, honeybees, and ants should be taken up in order.

PART THREE

CHAPTER X

OUTLINE IN NATURE STUDY AND ELEMENTARY AGRICULTURE FOR RURAL SCHOOLS

THE first part of this outline consists of topics for the grades below the seventh. So far as possible, these have been arranged in the order in which they may be taken up for study. The second part includes topics for lessons in elementary agriculture for the seventh and eighth grades. This outline is followed by expanded treatment of the topics which compose it.

FIRST PART

September

Propagation by cuttings: this should be done as early as possible, so that the plants will get a good start before cold weather.

Insects: select some that are of special interest from an economic standpoint; others that are interesting in themselves; and help the children to understand the habits and characteristics of all insects. Any of the following are good types: grasshopper, cricket, tomato worm, woolly bear caterpillar, butterflies, mud dauber, paper wasp.

Garden plants: nasturtium, sweet pea, morning-glory.

Birds: incidental observations, to be continued through the year.

Fruits: peach, apple, pear.

October

Spiders: webs, egg cocoons, etc.

Weeds: kinds, characteristics, seed dissemination, etc.

Vines: morning-glory, grape, etc.

Fall wild flowers, especially golden-rod.

Trees: incidental observation to be continued throughout the year; special study of nut trees: planting of nuts.

Bulb gardening.

November

Garden plants that are still living: beet, parsnip, etc.

Forcing of bulbs.

Golden-rod galls: other galls that may be found.

Preparation of insects for winter.

Honeybees.

Effects of cold weather on plants, animals, and people.

December

Evergreen trees.

Winter birds: crow, jay, chickadee, hairy and downy woodpecker; put up suet or bones to attract birds to the schoolhouse.

Cat, dog, squirrel.

January

Field animals: rabbit, fieldmouse, gopher, ground squirrel.

Continue bird and tree study.
Weather: snow, sleet, and ice.

February

Domestic animals with special reference to their use and care: horse, cow, sheep, pig.

March

Poultry: chickens, ducks, etc.
Early flowering trees.
Frog and toad eggs.
First migratory birds.
Condition of roads and fields.

April

Early wild flowers.
Small fruits: special study of strawberry and gooseberry.
Continue study of beets started in fall.
Life in water: water beetles and bugs.

Tree study with special attention to opening of buds, care of trees; observation of Arbor Day.

Discuss making of flower beds and decide what seeds to plant. Plant early varieties in school or house gardens.

Plant vines.

May

Continue planting seeds.
Life in water: dragon fly, mosquito, etc.
Set out geraniums kept over winter.

Study of birds that nest in the vicinity; of birds that pass through here going farther north to nest.

Insect life in spring: ladybugs, moths, butterflies.

SECOND PART

Seventh Grade—Fall Term

Study of flowers with pollination and fertilization: corn plant and flowers.

Plant breeding, with special reference to production of the best types of corn.

Insects injurious to farm, garden, and fruit crops with methods of combating.

Fungi, including fungous diseases of grains and other plants.

Propagation by means of budding; making of a peach tree.

Winter wheat.

Seventh Grade—Winter Term

Simple experiments in physics: evaporation and condensation; effects of heat on different substances; different methods of heating bodies.

Application of physical principles to weather phenomena.

Seventh Grade—Spring Term

Germination of seeds with experiments: testing seed corn. (This may be done the latter part of the winter term if desired.)

Propagation by grafting: making of an apple tree; apple culture in a region where apple raising is one of the chief industries; compare pear culture.

Oats: seed testing, method of culture, varieties, etc.

Legumes: red clover, alfalfa, etc.; other forage plants.

Potato culture with experiments: this should be emphasized where potatoes form one of the staple crops.

Insects in connection with plants studied, such as codling moth, cankerworm, bumblebee, potato beetle.

Eighth Grade—Fall Term

Plant products with experiments: simple experiments in the elements of soil chemistry; elements used by plants in manufacturing food products; compounds found in soil; use of fertilizers.

Origin of soil.

Eighth Grade—Winter Term

Simple experiments in soil physics; porosity and capillarity; power to hold water; forms in which water exists in the soil; air in the soil, etc.

Farm animals with methods of feeding, housing, etc.

Eighth Grade—Spring Term

Relation of plants to soil, air, and water with experiments.

Work of plants in manufacturing, digesting, and storing food.

Method of retaining the fertility of the soil.

Earthworm in relation to soil.

CHAPTER XI

SUGGESTIONS FOR RURAL SCHOOLS WITH CROWDED PROGRAMMES

Many rural teachers find lack of time one of the principal obstacles to nature study work. The daily programme is already full and local requirements may prevent much alteration. But it is possible to do much profitable work with nature subjects even under these conditions. It need not involve encroachment upon time scheduled for other work; instead it may prove a valuable adjunct for other work, forming in some cases a center around which other subjects may be grouped. It may be made to lend new and attractive meaning to geography, to relate arithmetic to actual needs in the lives of the children, and to make possible a true interpretation of much of the reading. It affords the best possible basis for written and oral expression. No other subject lends itself so readily to composition work. The pupils no longer look upon the writing of compositions as drudgery, for they have something of their own to write about, things they have seen and observed and are interested in.

Nearly every school has a short period each day for general exercises, a time when the minds of all the pupils are to be centered upon the same thing. A portion of this period may be used two or three times each week for nature study; also an occasional recitation period in geography and language.

Much of the observation may be done informally by the children outside of school hours. The teacher will be able to guide the observations along definite lines, and to keep up the interest by skillful questions and suggestions.

To illustrate: On Monday morning say to the children that you wonder how many things they can find out about spiders this week. Give them a few definite suggestions, such as, "notice in what different places you find spiders, what they are doing, and where webs are made. How do the webs differ from one another? Touch different parts of a round web and note what happens," etc. On the next day ask who has seen a spider since the day before. Let one or two tell where they saw it. Give an additional hint for observation, such as, "I wonder who noticed how many legs a spider has?" Do not let anyone tell them. Do not take more than two or three minutes for this matter; just enough to stimulate interest, and make the pupils eager to see more. On Friday devote ten or fifteen minutes to the discussion. Encourage each child to tell just what he has found out. You probably will be surprised at the fund of facts brought together and at the questions the children will ask. If the interest warrants, carry the work on this day over into the language period. Have the children tell on paper some of the things they have learned.

Work conducted in this way is preferable, in some respects, even to class work. Its greatest merit lies in the fact that the children are working independently. Each is seeing for himself, thinking for himself, and finding out his own problems. Some will see more than others, of course, because of natural ability and innate interest, but the slowest will see something and will be all the better equipped to see more next time.

In some weeks, instead of having the entire school working along the same lines, let one grade alone or two grades together work up a special subject. Follow the same general plan as that suggested above, except that two or three minutes of a recitation period should be taken to arouse interest and to keep it going. Toward the last of the week use the geography or language period for reports on observations.

The making of cuttings, bulb gardening, planting of seeds, etc., may be done the last hour on Friday afternoon. The work should be planned so that by division of labor much may be accomplished in a short time. One group may prepare the soil, another start to make the cuttings, another get the water, and another take charge of placing the cuttings in the propagation box. When the plants are actually started their observation and care may be discussed as a general exercise topic.

Teachers should not feel that every subject treated in this way must be rounded up to a finish. Indeed, no nature study lesson can, in the true sense, ever be completed. The children should be so guided that they will feel this, and have a desire to go on finding out new things, seeing new relations, and solving new problems. Neither should the teacher feel overwhelmed at the number of topics suggested in the outline. She should not attempt too much, but select a few lines of work that seem best adapted to the needs of her children. She should realize that the main purpose of the work is not to accumulate a great number of facts, but to arouse the interest of the children in natural objects, and to train them in accurate and independent observation that they may appreciate and enjoy the world of living objects with which they are surrounded.

Work in certain subjects, such as trees, birds, wild flowers, and weather, may well begin at the first of the fall term and be carried on throughout the school year. Reports may be called for each week or fortnightly.

To illustrate: The teacher may state some morning, when it happens to be true, "I saw a robin (or a meadow lark, or a blackbird) this morning. I wonder if there are many birds here now? Let us see what ones we can find this week, where they are, and what they are doing." Ask questions occasionally to keep the interest alive. When the time for reports arrives let the children have ten or fifteen minutes in which to talk about birds. The interest is almost certain to be enthusiastic. In fact, a check on excitement is sometimes desirable. A chart on which are entered the names of birds seen each week by the children is desirable.

CHAPTER XII

SUGGESTIONS FOR TREE STUDY

The purpose of tree study in the grades, besides the educational value that comes with the study of any living object, is to lead the children to form the acquaintance of the trees in the neighborhood, to learn how to protect and care for them, and to appreciate the value of trees in the industrial world and in their own lives.

For the beginning of the work select any tree that is near the school building. If practicable, for the first lesson take the children out to observe this tree. If not, then ask the children how many know the name of the tree standing at the corner of the yard? If they do not know, tell them. Ask them to look at it closely, and tell you to-morrow whether the trunk is smooth or rough, whether it has many large branches, and whether the trunk and branches are the same color. Do the branches spread out or grow straight upward? Does the tree make a good shade? What is the shape of the tree? Stand off at some distance and look at it. Is it round? Is it wide at the bottom and pointed at the top like a pyramid? Is it in the form of a wide column, or is it shaped like an umbrella?

The next day take a few minutes to discuss the observations of the children. Have a few twigs of the tree in the schoolroom. Note how the leaves are arranged on the twigs. Are they opposite or alternate. What is the shape of a leaf? Lay the twig down on the table spreading the leaves out; do they overlap one another very much? Stand under the tree and look up. Do the leaves completely screen the sky from your view? Are there any leaves entirely shaded by others? Are the stems of all the leaves the same length? Where are the youngest leaves on the twigs? How can you tell? Are all the leaves exactly the same shape? Are they the same color on the upper and under surface? Can you tell how much of the twig has grown this year? It will make an interesting exercise to compare a number of different kinds of trees as to the growth the twigs have made during the season.

Do you find anything else on the twig besides leaves? Where are the tiny buds situated? We say when they are situated between the leaf stem and the twig that they are in the axil of the leaf. Is there a bud in the axil of every leaf? Is there a bud at the end of the twig? What are the buds for? The tree, then, has been getting ready for next year.

Some of the trees will still have their fruit hanging on them. Such are Norway maple, ash, hackberry, box-elder, birch, catalpa, alder, sycamore, locust, and chestnut. If these trees are selected for study, note where the fruit is fastened to the twig and whether or not there is a cluster of seeds. Have the seeds any special adaptation for dissemination? Open up one of the so-called seeds to find the true seed on the inside. If there are no seeds on the tree, look on the ground for some that may have fallen off. The sugar maple drops its fruit in the latter part of summer. Have the children gather seeds of different kinds and plant them.

Have the children look at home for trees of the same kind that are studied at school. If you live in a prairie region, start the children to investigate how the trees came to be where they are. Try to discover the age of some of the largest trees in the district. Who set them out? How many different kinds of trees are there in the district? Are there any trees scattered about here and there that were not set out by anyone? Cottonwoods, willows, box-elders, and elms are frequently found along ditches or fences or in the field. How did they come here? Did the children ever see any of the cotton with the tiny seeds attached that fly from the cottonwoods and willows in the middle of the summer?

If you live near a woods then study the native trees. Select a special tree for the first detailed study, as an oak, a hickory, or a beech. Note shape of the tree, method of branching, appearance and color of bark. Is there more than one kind of oak? The shape of the oak leaves helps to distinguish one kind from another. There are two general shapes of oak leaves. One has the lobes rounded, the other has lobes that are sharp and pointed. The white bur and chestnut oaks have rounded lobes; while black, red, pin, and scarlet oaks have pointed lobes. Note the color of the leaves above and below. Are they all equally smooth and shiny on both sides?

Are there any acorns on the trees? Where are they situated; on this year's twig or last year's? Have the acorns stems or do they grow very close to the twig? Is the saucer shallow or deep? Open an acorn and see what is inside. Are any of the acorns good to eat? Those of the white and chestnut oaks are relished by many people. Plant some acorns.

Compare other nut trees with the oak. How many different kinds can you find? How are the different nuts protected in walnut, hickory, and beech? When do these trees drop their nuts?

Compare trees that are growing close together with others of the same kind that are standing at some distance from other large trees. Why are the former more one-sided than the latter?

When the leaves of the tree begin to change color have the children note the different colors. Does each kind of tree have a special autumn color? Which ones are the brightest? Why do the leaves change color? The children will probably say, as they have heard others say, that this is due to frost. But they should know that the real reason is that the leaves have completed their work, and that the green color fades or is replaced by the brilliant hues because the leaves are growing old and getting ready to drop off.

When do the leaves begin to fall? Do some trees finish their work and drop their leaves sooner than others? Do any of the trees retain their leaves after they are dry and withered? Does any of the fruit hang on over winter?

At least once during the winter have the children note the appearance of the special tree or trees studied in the fall. Note the shape of the branches. Are the twigs drooping or standing upright? Does this tree show any tints of color now that could not be seen when the leaves were on? Can you see the buds on the twigs?

In the spring continue the study. What do the side buds make? The end buds? To answer this, watch the development of the buds outside, or place twigs in glasses of water in the schoolroom. Do any of the buds prove to be flower buds? Any of the maples, elm, beech, or box-elder are good to show the beauty of the tree flowers. Note whether the maple and box-elder flowers all have stamens and pistils. You will find the stamens in one flower and the pistils in another. Watch for the development of the fruit from the flower. The soft or white maple and the elm both mature their seeds very early in the spring. The elm fruit is ripe before the leaves are fully developed. Make a special study of these seeds. Plant some to see if they grow the first season. Why do you find young elms along walks and fences?

The uses of trees should constitute part of the work. This may be coördinated with the geography work in the study of lumbering, paper making, building, carpentry, etc. Also the value of forests in soil making should be considered.

Interesting topics for some of the older pupils to work up are: *What is being done to preserve our native forests? What are the things that are destroying our forests? Tree planting in prairie states. Arbor Day.*

In connection with tree study Arbor Day should be celebrated, and an effort made to set out a few shade trees or shrubs on the school grounds. Let the children help to decide what trees shall be planted. Some of them may have growing about their homes seedling elms, maples, box-elders, etc., that they will be glad to have transplanted to the school yard. Discuss where the trees should be planted to give the best effect, and yet be out of the way. If the grounds are large, a row of trees may be planted across the back of the lot, a few along the sides, and one or two in front. How to plant the trees should be settled before attempting to set them out. Some points to observe are the following: The hole should be large enough to allow the roots to spread out to their full extent. It should be deep enough so that the tree may stand three or four inches lower than it did as a seedling. The roots should be kept moist until ready to set in the ground. Fine soil should be placed around the roots and packed in carefully. As more soil is thrown into the hole, it should be packed down firmly by tramping it with the feet. The last two or three inches of soil should be fine and left loose to help keep in the moisture. The soil should be moist, but not wet. Most horticulturists believe that the trees do better if not watered at the time of planting. The weeds and grass should be kept down a few feet around the young tree. Cultivation of the soil now and then by digging around the tree not only gives a chance for the air and water to enter the soil, but the frequent stirring of the soil on top helps to retain the moisture.

Helpful Books and Bulletins: Our Native Trees, Keeler; Familiar Trees and their Leaves, Mathews; Practical Tree Planting, Bulletin No. 27 of the United States Division of Forestry; Farmers' Bulletins of the Department of Agriculture, Tree Planting on Rural School Grounds, No. 134; Forest Planting and Farm Management, No. 228; Primer of Forestry, No. 173.

CHAPTER XIII

CUTTINGS

Problems.—(*a*) *What is the best way to make successful cuttings?* (*b*) *What are the advantages in propagating plants by cuttings instead of seeds?*

Materials Needed.—A few sharp penknives, a box that may be set on the window sill (one the length of the window and about six inches wide and five or six deep will serve for a window box as well as a propagating box); a common starch box or several chalk boxes will do if the window box cannot be made. A few holes should be bored in the bottom for drainage, and a couple of blocks arranged on the window sill on which to set the box. Place some clean fine sand in the box; soil will do if sand cannot be obtained. Water the sand thoroughly and firm it down with a flat piece of board. Make a groove about an inch deep with an old caseknife. Your box is now ready to receive the cuttings.

No plant is better to make successful cuttings from than the geranium. If there are none growing on the school grounds, some person in the neighborhood who has plants will be glad to let you have a number of large branches or entire plants from which to make cuttings. Select the growing tip of a stem or branch. Cut it off three or four inches in length just below a node or leaf. Make one clean, horizontal cut, break off the lower leaves, and trim the edges off the upper ones. Why is this done? Leave this as a problem.

Now place the cuttings in the groove made in the propagation box. Place them an inch or more apart so the leaves will have room enough to spread out and get the light. When one groove is full, press the sand close to the stem with your fingers. When all the cuttings are in, water very thoroughly so that the sand will be washed up close around the stems. Cover from the light for a day or two with a paper. If the cuttings do not come to the top of the box, a pane of glass laid over the top will keep the moisture in and at the same time allow plenty of light.

In caring for the cuttings keep the sand moist, but not wet. Allow them plenty of light after the first day, but not direct sunlight. If a glass is used over the box, it should be taken off for half an hour each day. Why? Plants need air and this gives a chance for a fresh supply.

When the cuttings are well-rooted then comes the lesson in transplanting. Have the children bring pots in which they may place plants to take home. Baking-powder cans, tomato cans, or small lard pails will serve just as well as earthen flowerpots. With a nail make a hole in the bottom of the can. What for? Have the children bring some garden soil or get some from a field near by. You may use this as it is or you may make an excellent soil for potted plants by mixing thoroughly one part of the garden soil with one-fourth part sand and one-fourth humus, well-rotted leaf mold or well-rotted stable manure. Have the soil just moist enough so that when you press a handful of it together it will readily fall apart when dropped. Cover the hole in the bottom of the can with a piece of broken flowerpot concave side down, or place a few pebbles or bits of broken crockery or brick in the bottom of the can. Why do you do this?

An old caseknife or a small wooden paddle will be found useful in removing the plants from the propagation box. Fill the pot about half full of soil, then place the plant in position in the middle, and hold it while you fill in the soil around it. Press the soil down firmly with the thumbs, water well, and set in a subdued light. After a few days let the plant have plenty of light. Keep it well watered, but do not allow the saucer or vessel that catches the drainage to stand full of water. Why? This will keep the soil standing so full of water that it shuts out the air and the roots need air to keep them alive.

Special Observations.—When making cuttings, place three or four extra ones in the propagation box for examination. When time for transplanting comes, remove the sand or soil from the ends of these to see what has happened. Has the cut healed? Gardeners say the stem has formed a callus. If it does not form a callus, or heal, it will not grow. Where have the roots come out on the stem? Does it take some plants longer than others to produce roots? Put in several different kinds and note the time required. Why is it better to start cuttings in sand or soil than in water? The plants may form a callus and root in the water, but they are not as likely to do well when transplanted. The roots must adjust themselves to entirely new conditions, and this they may not be able to do at once and as a result the plant may die.

After the plants have been transplanted, watch the appearance of new leaves. Where? How does the stem lengthen? Where do new branches grow out? How soon do the flowers begin to make their appearance? Have children report in regard to those they have taken home.

Let one pot remain with the same side toward the window for a number of days. Turn the other pots every day or two. Compare. This shows very well how plants seek the light.

If no one can care for the plants in the schoolroom over Saturday and Sunday fill the saucers with water Friday night. This will provide enough moisture till Monday. During the cold weather, if you have no cellar in which to place the plants to keep them from freezing, make thick covers of paper in the shape of cones and slip over the plants, wrapping extra paper around the pots. In this way you may keep your plants a number of weeks even in very cold weather. Do not attempt to keep too many.

The following is a list of plants that are easily progagated by means of cuttings: geraniums, coleus or foliage plants, wandering Jew, salvia, impatiens or balsam, oxalis, sultana, alternanthera, heliotrope.

The children will readily see the following advantages of propagating by means of cuttings instead of seeds. (*a*) They get quicker results; the plants are ready to flower in half the time. (*b*) They are certain to get the same kind of plant as the parent, while if seeds are used they may get one color or variety when they expected another.

CHAPTER XIV

THE STUDY OF INSECTS

THERE are several good reasons why children of the rural schools should become acquainted with the insect life about their homes. Insects are so intimately connected with the life and success of crops of all kinds that it is much worth while for the children to know something of the habits and life histories of these little creatures, to recognize friends and foes, and to learn some of the ways of combating the pests and increasing the numbers of the beneficial ones. Aside from this practical value the study is worth while from an educational standpoint.

It is best, except in a few cases, to study insects in relation to some plant or plants that the children are interested in.

A few simple pieces of apparatus will aid in the study. Two or three pint, quart, and two-quart Mason jars, a few flowerpots or small tin pails to hold soil, two or three large lamp chimneys or lantern globes, and a wire cage or terrarium, are desirable. The terrarium is easily made. Get an inch board for the bottom; one about six inches wide and two feet long makes a convenient cage to place on a window sill. Saw out the corners, fit into each an upright piece about fifteen inches high, nail these uprights securely to the bottom, and then enclose the lower part of this frame with boards about three inches high. Complete the frame by nailing pieces of board to the top of the uprights. Cover the sides with wire screening, or mosquito netting, and cover the top with a piece of board or panes of glass.

A simple cage for some insects may be made from an ordinary pasteboard shoe box. Cut rectangular pieces out of the top and bottom of the box and replace these with wire screening or mosquito netting. Tie a string around the box to keep the lid on, stand it up on one side, and you may watch the movements of grasshoppers, katydids, etc. The grasshopper serves well as a typical study.

Grasshoppers

The common short-horned grasshoppers of meadow and roadside are good insects to begin with for the purpose of getting the children acquainted with characteristics common to all insects.

Problem.—Where do these grasshoppers live and how do they move about?

Have the children notice the different places in which they see these insects. Watch to see just how the insects move out of the way. This may be left for reports from individual observation, or it may be observed by the class together in a field trip. It will not be difficult for the children to see that the locomotion is a combination of flight and hop. Where do they alight? Do they make any effort to hide? How does their color help to conceal them?

Bring a few into the schoolroom. How do they move about in the terrarium or cage? How many legs have they?

How do the hind legs differ from the fore legs? Can you find anything on the feet to keep the hopper from slipping when he alights? Where are the wings you saw when the insect was flying? Gently lift the outer wings and note the inner ones folded like fans underneath. What do you think is the use of these outer wings? Are they any stronger or firmer than the inner ones?

Problem.—What and how do grasshoppers eat?

Where did the children find the insects? Was there any food there? Place leaves of various kinds in the jars with the hoppers. Do not have too many insects in one jar. If you have them in a wire cage, place sprays of grass, clover, etc., in a small bottle of water and set this in the cage. How do the hoppers eat? Let the children find this out for themselves, even if it takes several days for them to see the insects nibbling and chewing the leaves.

Let the children try an experiment to determine how much one hopper will eat. Place one of the insects in a jar, and with it a half dozen fresh blades of grass. How many blades are left next morning? Try it on other plants; clover leaves, corn, etc. Sprinkle some water on the leaves and see if the hoppers like to drink.

Problem.—How does the grasshopper find out things?

Can it see you when you come near? Can you find the eyes? What else do you see on the head? Try to find out what it does with its horns or feelers. Does it act as if it can hear? If you raise the wings you may see the ear spots on the back, one on each side.

Problem.—(*a*) *When, where, and how do grasshoppers lay their eggs?* (*b*) *How do young grasshoppers differ from the grown-up ones?*

Have the children fill some of the Mason jars about a third full of garden soil. Firm this down, and place one or two female hoppers in each and feed them well. You can identify the females by the four projections, the egg placers or ovipositors, at the end of the body.

In time the hoppers will dig holes in the soil and place their eggs in them. The children may or may not succeed in catching the insects in the act, but they may dig up the pods or packages of eggs. Have them find out how many eggs in one package. Some grasshoppers lay as many as three packages. Where do the grasshoppers out of doors put their eggs? When do they hatch? Why is it that we do not have more crops injured by grasshoppers since there are so many eggs deposited? Think of some of the things that keep them in check; fall plowing, early spring plowing, wet weather, which causes a disease, but, most of all, birds. This is a good time to talk about some of the birds that feed to a great extent upon grasshoppers. Such are the meadow lark, quail, brown thrasher, bobolink, and dick cissel.

While most of the young grasshoppers hatch from the eggs in the spring, there are always a few young hoppers to be found in the fall. Have the children search for these, and compare them with the grown-up ones. What do they lack that the grown-up ones have? Are there any beginnings of wings on their backs? It may be possible to keep some of these till they molt and grow their wings.

How many different kinds of grasshoppers can the children find? The little red-legged, the large dull-green, the dusty-colored road hoppers are all plentiful.

Compare with these the long-horned grasshopper.

One of the most common of these is the meadow grasshopper which sits up on the stems of weeds, grasses, and corn and sings all day long. Place a few of these in the cage and let the children find out how they make their music.

The crickets, also, make an interesting study in this connection. To find out how they like to place their eggs in cracks and crevices, place a lamp chimney on a flowerpot full of soil. Let the chimney rest a very short distance in the soil. Place the crickets inside the chimney, feed them, and in time you will find they have placed their golden eggs in the soil at the edge of the chimney.

Katydids and snowy tree crickets may be added to the list of interesting hoppers. Cockroaches should be studied in this connection if they are troublesome in any of the homes.

Helpful Books and Bulletins: The Study of Insects, Comstock; American Insects, Kellogg; Farmers' Bulletins: United States Department of Agriculture; The Principal Insects Enemies of Growing Wheat, No. 132; *Principal Insects Enemies of the Grape, No.* 70; *Three Insects Enemies of Shade Trees, No.* 99; *The Honeybee; How Insects Affect Health in Rural Districts, No.* 155; *The Principal Household Insects; The Peach Twig Borer, No.* 80; *The Control of the Codling Moth, No.* 171; *Insecticides and Fungicides, No.* 146; *Annual Loss Occasioned by Destructive Insects.*

CHAPTER XV

PLAN FOR WEED STUDY

WEEDS may be studied either in the spring or fall term. The study should be emphasized in the fall, chiefly because many weeds are in flower and fruit at this season.

Ask the children to look in their gardens to see how many different kinds of weeds are growing there, and to bring two to school the next day. Select from those brought in one of the most common, such as pigweed. Ask what characteristics has this weed that make it so successful. Have some of the children count the seeds on one small stem and estimate the number of seeds on the plant. What advantage is the great number of seeds to the plant? Think back to the middle of summer. Were any of these plants prominent in your garden at that time? Then you thought you had all the weeds hoed out. Now you find this tall plant with its seeds ripe. What does all this mean? It means that this weed makes a very rapid growth and matures its seed in a very short time. Other advantages may be pointed out, depending upon the weed under discussion.

Suggest to the pupils that they try to find out all they can about weeds in their neighborhood during the next two weeks. Have them keep a list of all they find, and what they find out about them, noting especially where the plants are growing, and what characteristics they have that make them successful. If possible, have them record whether the weeds are annuals, biennials, or perennials. If these terms are new, there is no better place to explain and illustrate this grouping of plants. Annuals are those plants which grow from seed to seed each year, and die away completely in the winter. Biennials require two years to grow from seed to seed. Many common weeds are both annual and biennial in habit. Those plants which persist from season to season, indefinitely, by rootstock, or otherwise, are called perennials.

Throw out hints occasionally that will keep up the interest. How many seeds are you carrying around and sowing when a burdock bur is fastened to your clothing? Why do you find some burdock plants growing in a green rosette close to the ground, while others have tall stems with small leaves and many burs? What other weeds do you find that show these same characteristics? Thistle, wild parsnip, wild carrot, and mullein are familiar examples of biennials.

Who knows how many seeds in one cocklebur? If some of you find milkweed growing in a cornfield, dig down and see if you can discover the secret as to why this weed is hard to kill out when it gets a start. Try the wild morning-glory in the same way. Why are dandelions and plantain successful lawn weeds?

It will add much to the interest of weed study to have the children make a collection of weed seeds; also of the stems and leaves, where it is not practicable to bring in an entire plant. The latter may be pressed and mounted. The seeds may be placed in envelopes or bottles. Small vials may be purchased at little expense, or brought from home. The value of such a collection lies not so much in the collection itself as what the children gain in its making. When the bottles are all in, have the children group them according to places in which the weeds grow, as garden, field, lawn, vacant lot, and roadside weeds. The seed may also be grouped into annuals, biennials, and perennials.

At the end of the two weeks have reports made by the children as to the weeds they have found, and what they know about them. If the interest has been kept up, the children will ask all sorts of intelligent questions. Follow this with a discussion of why we consider weeds a nuisance, or why they are detrimental to field and garden crops. The discussion will probably bring out the facts that the weeds shade some of the young plants; that they rob the plants of moisture and sometimes of plant foods; that many of them are coarse, homely plants that we do not wish to have around; that weeds with burs are exceedingly annoying to animals, etc. Now ask the children to think of all the various means used to get rid of the weeds. Bring this up for discussion another day, and at the same time give the older children some problems to think out. Which are easier to get rid of, annuals or perennials? Why do you find chiefly annuals in the gardens and perennials in the lawn and pastures? Why can some weeds stand drought better than others?

In the spring many interesting experiments may be worked out with weed seeds. Use some of those collected in the fall. Have the children arrange a number of tin cans with drains and fill with good garden soil. Plant a few seeds in each. Keep a record of number planted and date of appearance above the ground. Note rapidity of growth. Do all the seeds germinate at the same time? After two or three weeks, pull up some of the weeds, such as pigweeds and purslane. Do others now germinate and grow? Plant some cocklebur seeds that have been kept in the house all winter and some that have been left out of doors. Note results.

List of Some Common Weeds

Garden: Pigweed, amaranth, or careless weed [1]; purslane [1]; foxtail grass [1]; crab grass [1]; smart weed [1]; horse weed or colt's tail [1]; lamb's quarter [1]; spotted spurge.[1]

Field: Mustard [1]; cocklebur [1]; Russian thistle [1]; tumble weed [1]; butter print or velvet leaf [1]; shepherd's purse; milkweed [3]; wild morning-glory [3]; bindweed or wild buckwheat [1]; Canada thistle [3]; corn cockle [2]; ragweed [1]; wild lettuce or prickly lettuce [1]; wild oats [1]; pigeon weed or corn gromwell [1]; sorrel or sour weed [3]; fleabane [3]; quack grass.[3]

Meadow: Pasture and lawns; wild carrot [2]; wild parsnip [2]; sow-thistle [2]; foxeye daisy; yellow or bitter dock [3]; iron weed [3]; plantain [3]; dandelion [3]; mullein.[2]

Waste lands and roadsides: Burdock [2]; dog fennel [1]; Spanish needles [1]; giant ragweed [1]; jimson weed [1]; button weed.[2]

Farmers' Bulletins: Weeds and How to Kill Them, No. 28; *Weeds Used in Medicine, No.* 188.

---

[1] Annuals. [2] Biennials. [3] Perennials.

CHAPTER XVI

STUDY OF WEATHER

NOTHING in nature is more closely related to our lives than weather and weather phenomena. For this reason some time should be spent in making weather observations, drawing conclusions, and noting effects of weather on plant and animal life.

To bring about the best results, the study should be continued through several months. The work may well begin in September and be conducted as a general exercise, but the seventh-grade pupils should be responsible for seeing that the observations are recorded.

Start the work by asking the pupils what the term weather means to them. The discussion will no doubt bring out ideas of heat, rain, drought, snow, cold, clouds, winds, storms.

In many localities September is one of the driest months in the year. This being the case, make the first observation in connection with drought. Start with the problem, what is the effect of dry weather on plant life? Ask the children to look at the plants in the garden. What plants are best able to stand dry weather? Which ones are least able to stand it? Observe the plants in the lawn, in pastures, cornfields, oats stubble, meadows, and roadside. Why are some of these plants able to keep green and vigorous while others are dry and withered?

It will, of course, be impossible for the children to find out for themselves all of the characteristics that help plants to withstand drought; but they will be able to discover some of the things. Dig down to find what kind of roots the plants have that look the freshest, such as clover and dandelion. Compare these with the roots of some that are the most withered. Examine the leaves. Do you find any with hairy or woolly structures that might protect them from the heat?

Very early in the term begin keeping a record of daily observations of weather conditions. If there is not enough blackboard to reserve a permanent space for the record, procure a sheet of brown manila paper or bristol board and make a chart by ruling off a table like that indicated below. At the beginning of each week, appoint two of the seventh-grade pupils to see that the record is put in each day. If the work is not conducted as a general exercise for the entire school, then the seventh-grade pupils may keep their own records in notebooks.

WEATHER RECORD

Date.	Hour.	Temperature.	Wind Direction.	Velocity.	Sky.	Precipitation or rainfall.	Remarks.
Sept. 15	9 A.M.	Warm, 65°		Light	Partly cloudy		Heavy thunder shower this P.M.

These observations may be taken without instruments. However, if the school has a thermometer, then the temperature should be recorded in degrees. For temperature the terms warm, hot, very hot, cool, cold, very cold, and chilly may be used. The direction of the wind may be indicated by an arrow. An arrow pointing toward the top of the chart indicates a wind which is traveling north. Is a wind named from the direction it is going, or the direction from which it is coming? What is meant by velocity of the wind? The following terms are in use by the United States Weather Bureau: calm, when there is no perceptible wind; light, just moving branches; brisk, swaying branches; high, swaying whole trees.

Under sky, record whether it is clear, partly cloudy, or overcast.

Precipitation means falling weather of any sort, rain, sleet, snow, etc. Under remarks, record any item of interest that does not appear under the other headings. Thus, for September 15th, a heavy shower this afternoon, or, for September 16th, a slight frost last night.

At the end of each month have the pupils make a short summary derived from their observations. How many fair days? How many cloudy? How many in which there was precipitation? What was the general direction of the wind for the month? What was the direction of the wind when the temperature was warmest? When the temperature was coldest? From what direction did the rain come? From what direction did the snow come? What was the direction of the wind during the cloudy weather?, etc.

Have them note other relations. Is a cloudy night warmer or colder than a clear night? You often hear people say in the early fall: "If it clears it will freeze to-night." Can you see why this is true? After you have studied radiant heat, you will understand better how the clouds act as a screen to keep the heat close to the earth. Which seems colder, a windy day or a calm one? Why?

After the first hard frost ask the children to note the effect it has had upon plant life. If there are some plants near the schoolhouse that show the effects well, make a study of these, or, if that is impracticable, bring into the schoolroom a few that are badly nipped and some that are not hurt and call attention to the difference. Have the children report on the garden plants that can stand the frost best, and those that are easily killed. Continue this observation at intervals during the fall and winter. Are there any plants that remain green over winter? Note clover, blue grass, thistle, dandelion, mullein. The last named makes a most interesting winter study. Observe how wonderfully the leaves are protected.

What is the effect of cold weather on insect life? Do the grasshoppers continue to live? Keep eyes open for living insects. Some time you may find in the middle of winter a house fly, a cricket, or even a tiger caterpillar that have crept out of their winter quarters too soon.

Spend a little time discussing what effect the weather has on ourselves; effect of cloudy weather, fair, cold, hot, etc. Have the children think of all the different things we do to protect ourselves from the weather, such as the preparation of shelter, houses, clothing, the making of fires, etc.

The seventh-grade pupils may well learn something of the work of the Weather Bureau, with a study of weather maps. These will be sent to any teacher who will use them. Apply to the Weather Bureau office at your state capital.

Helpful books: Weather, Barber; Practical Exercises in Meteorology, Ward.

CHAPTER XVII

BULB GARDENING

EVERY rural and village school may have a bulb garden, even though a small one. One of the first things to consider is the kind of bulbs to plant. Tulips are perhaps the most satisfactory if we are to have but one kind. Narcissuses, crocuses, and hyacinths are good also and easily grown.

The next question to settle is, where shall the bulbs be planted? If there is a walk leading from the schoolhouse door to the road, then a long bed not more than two feet wide may be made on each side of this walk. If the coal shed stands in a suitable place a bed may be made at the side or end of it. If there are shrubs on the grounds, nothing is prettier than a bed of tulips, crocuses, or hyacinths blossoming with these as a background.

An indoor lesson on bulbs should precede the planting. If you have several kinds, compare them as to size and shape. What is a bulb? Look closely at a tulip. It resembles an onion. If we should cut it open we should find that it is like an onion on the inside, made up of layers. Can you tell which end will produce roots? What will grow from the other end? The bulb is really an underground stem. Do you find any little bulbs (bulblets) fastened to the large ones? This is the way new bulbs are formed. If these bulblets are set out they will not blossom for two years.

The bulbs like rich, mellow soil. If you have a heavy clay soil, have some of the older pupils suggest how it may be made more mellow; by mixing with it some humus (decayed vegetable matter). Nothing is better than well-rotted material from around the barn. Some farmer who is interested will haul you a little of this fertilizer some day when he is going past the schoolhouse. Let the pupils prepare the bed. Throw out the top soil to the depth of six or eight inches. Put the fertilizer in to the depth of two inches and spade this into the soil. Now throw back not quite half of the top soil. Set the bulbs firmly in this, about eight inches apart. Let every child plant at least one bulb. Now throw in the rest of the soil. The bulbs should be covered with four to six inches of soil. Another way to plant the bulbs is to prepare the bed by digging, putting in fertilizers, and raking till it is in good condition. Cut off about nine inches from the upper part of an old spade handle, and sharpen this or sharpen any round stick. You now have an instrument with which you can make holes in the bed. Into these holes drop the bulbs and cover with soil.

What do you expect the bulbs to do this fall? Where is the ground warmer this time of year, six inches below the surface or near the top? Which part of the plant will be likely to grow? What we want the plant to do is to make a good root growth this fall. Why do we not want the upper part of the bulb to grow until spring? We want the roots to get a good start, for only the bulbs with good roots will produce good flowers.

When the top layer of soil is frozen hard, then we must cover up our bulb beds. Straw, leaves, or cornstalks may be used for this. It should be four to six inches deep. What is this done for? It is to keep the temperature even, so the ground will not thaw out and freeze again when the weather changes. In early spring, will the ground under the straw thaw out as soon as uncovered soil? Will this keep the plants from starting to grow early in the spring? This is what we want. If they were left uncovered the first warm weather would start the plants to growing so rapidly that they would be likely to get nipped by the later frosts.

The cover should be taken off gradually early in April. It should all be off before the shoot appears above the ground. When does the first bud appear? Watch the growth and development of the shoot. How many leaves has it? How do they unfold? Where does the flower stem appear? How long after the bud appears above the ground until the plant is in flower?

When the leaves begin to die, the bulbs may be dug up and kept in a dry place for the summer. If you wish to make a permanent bed plant the bulbs an inch or two deeper. When the leaves begin to die, cut them off. Seeds of annuals may now be planted in the bed without injuring the bulb in any way.

If the making of bulb gardens does not seem practicable, the growing of bulbs need not be given up altogether. They may be planted in pots or cans and made to bloom in the house any time during the winter or early spring. Even if bulbs are planted out of doors, every school should try to force a few bulbs for winter blooming.

Tulips, hyacinths, and narcissuses are all good bulbs for forcing. The bulbs should be planted the latter part of October or early in November. Prepare the soil as you would for transplanting cuttings. Place drains in the pots or cans. Fill the pot a little over half full of soil and set in the bulb. Now put in more soil till the top is just below the surface. If you have a large pot or tin pail several bulbs may be planted together. After planting, water till you are certain that all the soil is thoroughly moistened.

What do you want these bulbs to do first? Just what they do in the outdoor beds, grow roots. In order to make them do this we must put them in a cool, dark place. We call this forcing the roots. The pots may be placed in a cool cellar and covered up with a heavy box or other object. They may be placed in a shallow hole in the ground and covered with about three inches of soil. In this case a thick covering of straw or leaves will prevent the freezing of the soil so the pots may be easily removed in the middle of winter. They may be set on the ground along the north side of the coal shed or other buildings and covered up with ashes. They should be left in this cool place at least six weeks. They may be left much longer and brought in one or two at a time as desired.

When you bring them in carefully remove one from the soil so the children may see what has taken place. From what points did the roots start? Are there many roots? What is the length of the longest ones? Has the shoot started to grow? What color is it? Could the roots and shoot grow without food? Where did they get the food to live on? A little discussion will bring out the fact that some of the food stored up in the thick bulb was used for this growth.

At first the pots should be kept in the coolest part of the room and covered from the intense light. If the schoolroom has an entry or hall that is not kept as warm as the main room, this will be a good place to keep the plants for several days. After this bring them into the room where they may have plenty of light and heat, and where the development of the leaves and flowers may be watched.

The Chinese sacred lily or the paper-white narcissus bulb may be grown without forcing the roots, and without soil. These are excellent bulbs for schoolroom study. Fill a dish with small stones and support the bulbs in these. Keep the dish full of water. The bulbs will develop and open up their beautiful blossoms in about six weeks.

Have the children watch the development of the roots and their growth among the stones. Which start first, the roots or the leaves? Watch the unfolding of the leaves. How many from one bulb? How rapidly do they lengthen? Where are the flower buds situated? Watch the stretching up of the flower stems and the unfolding of the flower buds. How many flowers on one stem? Do all open at one time? How long do they stay in flower? Feel the bulb after the plant has been in flower some time. Does it feel as solid as when you planted it? Why? Allow the plant to stand till the leaves begin to die. Now feel the bulb. Has it become solid again? It has been storing up more food for the new plant next year.

Encourage the children to force bulbs at home for winter and early spring blooming.

CHAPTER XVIII

STUDY OF WILD FLOWERS

FLOWERS appeal to children more than some other forms of nature. Sometimes we feel that they do not always appeal in the best way. Often there seems to be a desire on the part of children to pluck every flower in sight, carry it about a short time, and then throw it down to wither with its fellows.

The special purpose of this work should be to lead the children not only to appreciate more fully the beauty of the wild flowers, but to enjoy seeing them as they appear in their natural surroundings. This does not mean that no wild flowers should be gathered by the children. The gathering of flowers and placing them in glasses of water in the schoolroom or house is certainly one of the pleasures that should not be denied. But the feeling that every blossom must be plucked and perhaps torn to pieces before it can be appreciated should be repressed.

Nothing is so likely to bring about this attitude of mind toward the flowers as to make a study of them in their natural haunts, with observations of their development from bud to seed.

If a school building is situated near the woods, the wild-flower study should be emphasized in the spring; if in a prairie region, then the emphasis should be placed on the autumn flowers. This does not mean, however, that children of all schools remote from woodland should have no opportunity of becoming acquainted with the woodland blossoms. If woods are within six or eight miles of the district, somebody may make a Saturday trip and bring into the schoolroom specimens of a few common spring flowers.

The general problem to solve in connection with spring-flower study is, *How do these plants manage to open up their flowers and leaves so early?*

Have the children watch for the earliest spring flower. In most localities this is the hepatica, that blossoms almost before the last snow has melted. It bears a delicate blue, pink, or almost white flower with a fuzzy stem. Have the children note where the hepaticas are to be found. Do they seem to like hillside slopes, or flat, level situations? Are there any leaves on the plant? Are they this year's or last year's leaves? Where are the flower stems attached to the plant, in the middle or around the edges? Look carefully down among the old leaves near the ground. What do you find? What are the buds covered with? Is there any advantage in this thick, fuzzy covering?

When do the first leaves appear? Are there any flowers left at this time? Notice the leaves that come out later. Have they as thick a coat of fuzz as the early ones? What do you find now in place of the flowers? Does one flower produce more than one seed? How many? When are the seeds ripe? How are the seeds scattered?

Does the plant die after it has matured its seeds? Mark several plants in the woods by placing a stake near them, and, if possible, continue the observation in the fall, or, if preferred, the work may begin in the fall. Is the plant still alive? Are any seeds left on it? The plant has sown the seeds chiefly by aid of the wind. Bend down the leaves and look carefully in the center of the plant close to the ground. Can you find any preparation for the early spring blossoming? All summer the plant has been getting ready for the early awakening next year. Its buds are all formed and packed away in the furlike covering. Note how late in the season the leaves remain green. Is this a hardy or tender plant?

Hepaticas and other spring flowers may be easily transferred to the schoolroom for study. Dig up the soil at some distance around and under them so the roots will not be disturbed in the least. Set them in a dish or pan with a little additional soil. Keep them moist and you will be able to preserve them in good condition for several weeks. When you are through with the study, what will you do with them? One thing be sure not to do, and that is to let them wither and die on your hands. Why not start a wild-flower garden in a corner of the school yard? If you have shrubs in the yard, place the plants near these. If it does not seem practicable to start a wild-flower garden on the school grounds, suggest to the children that they take the plants and set them out at home. Many of the children will be delighted to start a wild-flower garden of their own. Try to have them imitate, so far as possible, the natural conditions in which the plants grow, especially as regards shade and moisture.

Watch for the succession of spring flowers. The blood root, with its kidney-shaped leaves and pure white flower, is an excellent specimen to study in order to see how the buds come up and gradually unfold. The spring beauty is as good a type as the hepatica with which to follow the development through the entire term. The same outline may be used for this, varying a little to fit the characteristics of the plant. Place a few of the spring beauties in a glass of water in the sunshine. After a time, remove them to a dark corner or turn a box over them to cut off the light. What do they do? Have the children who have any of these growing near their homes watch them as night approaches. Can they find other flowers that close at night? Dig up a spring beauty. Be sure that you get all that is in the ground. You may have to go down four or five inches. What do you find at the end? This tuber which is like a small potato has in it stored-up food. What is the use of the food? What two things do these plants do every summer to get ready for the next year? Make buds and store food.

The violet is a good plant to study for the thick rootstock which contains food, so is the trillium, the mandrake, or May apple. The dog tooth violet and adder's tongue have interesting bulbs from which they send up their pretty mottled leaves. Other common spring plants worth knowing are shooting star, buttercups, wild geranium, anemone, Jack-in-the-pulpit, bellwort, Solomon's seal, blue bells, Dutchman's breeches, and toothwort.

The autumn flowers are not, as a rule, so attractive to children as the spring flowers. However, they are worth studying, and, like many other things, the better they are known the more attractive they become.

In many prairie localities where the ground is all under cultivation, only a few remnants of the fall flowers are to be found. These are located mostly in corners of fields, along roadside and ditches, and in swampy places. The most common of these are the purple and white asters, the wild sunflower, rosin weeds, blazing star, butterfly weed, black-eyed Susans, and golden-rods.

How do the fall flowers differ from the spring as to height? As to size of leaves, number of leaves? What are the prevailing colors of fall flowers?

A study of the cultivated sunflower of the garden may well precede the study of the autumn flowers. Is the sunflower one flower or a cluster? It is easy to see that it is composed of numerous small flowers grouped to form a flat head. Are all the flowers the same shape? Those on the outside with the yellow strap are called ray flowers. Those smaller ones with little tubular corollas are called disk flowers. Can you find stamens and a pistil in one tiny flower? Compare a wild sunflower with a garden one. Has it the same kind of flowers? The rosin weed? Black-eyed Susan?

The golden-rod may be studied in detail. Where is this plant found growing? How tall is it? How are the leaves arranged on the stem? Are there many or few leaves? Are the leaves soft or rough? Examine leaves of other autumn plants for this quality. Does the stem branch? Where are the flowers? Has this plant a head of small flowers like the sunflower? Are the heads clustered? By looking closely, the children will see that the spray of golden-rod is made up of small, loose heads and that each of these is made up of very tiny florets. Note how very small the single flowers are.

Notice the plant when the flowers have faded. What has taken the place of the flowers? What is the use of this feathery mass? Can you find one seed with the tuft of hairs or plume attached to it? How late do the seeds remain on the plant? Does the entire plant die in the fall? The pupils will not be able to answer this from present observation, but they may from past experience. Have they noticed whether the golden-rod appears in the same spot year after year? While they die down to the ground every winter, the underground part remains alive for many years. Is there more than one species of golden-rod in the district?

Make a comparative study of the asters. Much of the observation for these studies may be made as the children are on their way to and from school.

Helpful Books: How to Know the Wild Flowers, Dana; Field Book of American Wild Flowers, Mathews; Flowers of Field, Hill, and Swamp, Creevey.

CHAPTER XIX

LIFE IN WATER

No phase of nature work affords more real enjoyment as well as profit than a study of the various forms of life found in water. The nearness of the schoolhouse to a pond or stream must determine largely how much time may be spent in leading the children to form the acquaintance of aquatic plants and animals.

If water is near by, then the bulk of the observation should be made out of doors. Note what plants are growing near the pond or stream. Are there any plants growing in the water? Study some special one. Are the stems thick or thin? The leaves large or small? Do the plants stand up straight? Are they stiff enough to stand upright when you take them out of the water? Are the roots anchored in the soil at the bottom of the pond? Do you find any plants floating in the water?

You may find a tiny plant with roundish leaves and a few roots dangling from beneath. This is the duckweed. Sometimes there are so many of these growing that they completely cover large areas of the pond. You will find, also, long green strings of algæ or pond scum. These interesting plants have neither leaves nor roots.

Do you see any animals in the water? You may find the water striders or skaters, slender bugs with very long legs, that skim over the water as easily as boys and girls slide on ice. On the surface you may find, also, the shiny black whirligig beetles. These whirl round and round, sometimes a large number of them together. You wonder how they keep from bumping into one another every minute as they circle around. Have the children keep very quiet as they look down into the water for animals. They may find a few fish or frogs. Among the insects they may see the interesting water boatmen, and the more interesting back swimmers that glide around in the water always with their backs downward. They may catch a glimpse of the giant water bugs and the large black water beetles. They will, without doubt, see the dragon and damsel flies hovering over the water and settling down now and then upon a reed or grass stem.

Have the children watch to see what all these little creatures are doing. Call for occasional reports on what they have seen going on in and about the water.

If water is not near enough to admit of the outdoor observations, then arrange an aquarium or several aquaria in the schoolroom, where the habits and activities of the water animals may be studied. Indeed, an aquarium is a great aid to detailed study even when the out-of-door observation may be made. At the same time nothing affords the children more genuine pleasure.

An aquarium may be made with little expense. Hodge, in *Nature Study and Life*, gives directions for making a cheap, substantial aquarium, somewhat as follows: Decide on the size aquarium you want. It is not best to make a very large one. Better have two small ones than one large one. One ten inches long, eight inches high, and five wide is a fair size for the ordinary schoolroom.

For this you will need two pieces of glass for the sides 10 × 8 inches, two for the ends 8 × 5, and the bottom one 10 × 5. Go to a tinner and have him make you a frame out of angle tin to fit the glass plates.

Make aquarium cement by using eight parts by weight of dry putty, one part red lead, and one part litharge. Mix as wanted for use with pure raw linseed oil to the consistency of stiff putty. To set the glass, first put on the cement evenly all around the bottom of the frame, and then press the glass into place. Put in the sides and ends in the same way. Carefully put a few very limber, green twigs into the aquarium to hold the glass in place until the cement hardens. Cut off all the superfluous cement and smooth neatly along the seams and angles. The aquarium should stand at least a week to become thoroughly dry before putting water into it.

While the aquarium described above will be found very convenient, aquatic animals may be studied in jars of various kinds. Candy, butter, and Mason jars are good substitutes for more elaborate aquaria. Cheap glass dishes that can be purchased for ten or fifteen cents serve very well for certain aquatic animals, such as the water bugs, beetles, and young dragon flies.

In arranging an aquarium that is to be kept permanently, a good rule to follow is to make conditions as nearly like those of the pond as possible. Let the children help to decide what to put into it. A few inches of sand in the bottom, a few stones, and a little of the decaying matter found in the bottom of the pond with some of the water plants makes a good home for any of the animals named above. Let the children decide also what animals they wish to put into the aquarium. Do not overstock. Be careful not to put some of the fierce insects, such as cybister beetles, in the same jar with small ones.

Water bugs, whirligig beetles, and water boatmen may all be kept for some time and studied in detail. Feed these on bits of fresh meat, liver, or fish food.

In the spring the dragon fly is a most interesting specimen for study. Have the children watch the insects flying around. How many wings have they? How do they hold them? What are they doing as they fly through the air so hurriedly? They are feeding upon insects which they catch as they fly. They are sometimes called mosquito hawks, because they catch and eat so many of these annoying insects.

With a long-handled dipper or a garden rake scoop up from the bottom of a pond some of the dead leaves and trash. The latter part of April, or first of May, is a good time to do this. You will find some peculiar-looking dark insects among the trash. Have a jar or pail of water close by and put them into it. These are young dragon flies. They are called nymphs. Put a few of these into your dish or aquarium. Feed them on earth worms or bits of fresh meat. Put a small quantity of the pond trash in the dish. This may contain small insects which will serve as food. Raise some mosquito larvæ as indicated at the close of the chapter. See if the nymphs will eat these. How do the nymphs move about? Do they swim as well as crawl? How many legs have they? Have they any wings? Look for wing pads on their backs. Can you see their eyes? Do not feed them for a few hours, then put a small bit of fresh meat on the end of wire and move this about before them. Watch how they get hold of the meat. Keep a piece of netting, or wire screening, over the aquarium. Place a few upright sticks in the aquarium.

Some morning you will find, instead of a black, crawling bug, a beautiful dragon fly in the aquarium. What did the nymph do when it got ready to change to the grown-up insect? Did it stay in the water? Look at the nymph skin. How did the dragon fly get out? Look on stems of water plants in ponds for the cast-off skins of dragon flies. Look closely at the mature insect. Can you see its eyes? Are they large or small? Why are large eyes an advantage to it as it gets its food in the air? Where are its legs; near its head or far back on the body? The legs are used to help in catching and holding the prey. The dragon fly really makes a basket out of its legs in which it carries its dinner.

When the wings are thoroughly dry, remove the cover from the aquarium and watch while the insect lifts itself on its new wings and flies away. By what other names are dragon flies known? Snake doctor, snake feeder, and devil's darning needle.

Another interesting aquarium study is the development of toads and frogs from the eggs. The eggs may be found in ponds and pools in early spring. Frog's eggs are in masses of white, jellylike material fastened usually to sticks or other objects in the water. Toad's eggs are in long ribbonlike strings of the same jellylike material. As with all other specimens in the aquarium, care should be taken not to have too many of the little tadpoles in the same jar.

Goldfish are easily kept in the schoolroom and may well be studied in detail in connection with the study of fisheries in geography.

The life history of the mosquito may easily be worked out either in the spring or fall. Set a jar or pail of rain water out of doors where it will not be disturbed. The mosquitoes will find this and deposit their eggs in it. By looking every morning you may be able to find the eggs like bits of soot floating on the water. If you do not succeed in finding the eggs before they hatch, you will be able to find the wrigglers that hatch from them. Put a number of these in jars or tumblers and have the children watch from day to day and report on what they see. After a few days keep a cover over the top of the jar to prevent the escape of the full-grown mosquitoes.

CHAPTER XX

RURAL SCHOOL GARDENING

EVERY rural school should carry on some phase of garden work, if nothing more than window gardening for a portion of the year. If there is enough available space for a small garden the work may be grouped into three classes: (*a*) That which includes the propagation and culture of ornamental plants; (*b*) experimental work in growing farm and garden crops; (*c*) the culture of a few industrial plants not commonly raised in the vicinity of the school.

The ornamental plants are perhaps of the greatest importance to the country schoolchildren. The educational and æsthetic value of having a few flowering plants and shrubs on the school grounds cannot be overestimated. The work may well begin in the fall with the making of cuttings and bulb gardening.

The question of where to place the plants so that they may not infringe upon the playground of the children is not always easy to answer. As suggested in the lesson on bulbs and bulb gardening, a narrow bed may be arranged on each side of the walk. If tulips are planted here in the fall they may be replaced by geraniums in the spring or by annual-flowering plants. If there is a fence around the yard, then the back fence will form an admirable background for the main flower bed. Dig the bed about three or four feet wide in front of the fence. Close to the fence plant seeds that produce high plants, such as cosmos or tall nasturtiums that will run up over the fence, golden glow, princess feather, or four-o'clock. In front of the tall plants put in several rows of lower plants, and in front of this a low border plant.

Hardy plants that can stand drought fairly well should be chosen. Nothing makes a prettier border plant than sweet alyssum. It requires little care and continues to bloom until after heavy frosts. Other good border plants are portulaca, California poppy, and candytuft. For the middle portion of the bed, sweet scabious, gaillardia, phlox, cornflower, ageratum, low nasturtium, petunia, marigold, larkspur, and balsam are all good.

Some attention should be given to harmony of color. If the tall plants are yellow, such as golden glow or nasturtiums, then for the lower plants forms should be chosen that harmonize with yellow. Golden glow, low nasturtiums, and California poppy or portulaca, make a good color scheme. Another scheme is, princess feather or gaillardia, sweet scabious, sweet alyssum or candytuft. The children should help to decide what colors will look well together.

Besides the flowering annuals, vines of various kinds will add greatly to the beauty of the school grounds. Plant vines to run up over the coal sheds and other outbuildings. Of the annual vines the wild cucumber is a good one. The seeds of this should be planted in the fall or early in March so they may be frosted. The morning-glory is a beautiful annual vine and a rapid grower. The principal objection to it is the rankness of its growth.

Woodbine is a very satisfactory perennial vine; so is the white clematis, and the matrimony vine. A woodbine may be set out to climb over a building and morning-glories planted at the foot of this. The latter will climb up the woodbine making a very pretty effect.

A few shrubs should be found in every country school ground. These should be arranged in clumps in one or two corners of the yard, or near the corner of the buildings. They should be set out close enough together to form a mass of foliage by the time they are four or five years old. A strip two feet wide at the base of a clump of shrubs may be used for bulbs or for annual-flowering plants.

Some satisfactory shrubs are: flowering quince, snow-ball, common dogwood, syringa, spiraea or bridal wreath, and elder.

All the work should be so planned that the children will feel a sense of ownership and take a keen interest in keeping the grounds beautiful.

If the school grounds are large enough, a plot ten by twenty feet may be set apart for experimental work in agriculture and horticulture. This should be a sort of miniature experimental station where some simple problems relating to the crops of the districts may be worked out. Different varieties of oats may be planted one year, and the yields estimated; or different kinds of wheat, to see which seems best adapted to the soil conditions. Different varieties of corn could be tried from year to year.

A very small plot of ground might well be used for industrial plants in order that the children may become acquainted with plants that give them various useful articles, such as flax, cotton, hemp, sugar cane, broom corn, castor-oil bean, and kaffir corn.

No attempt need be made to raise all of them the same year. Raise two or three one year, and follow those by others the next year, and so on. A few samples of each should be put away from year to year, making in time a valuable collection that may be used in connection with the geography lessons.

Here, as in school gardening, everywhere the real value comes in having the children carry the work over into the home garden. The children should be encouraged in every way possible to start flower gardens of their own. Some time might well be given to the discussion of some good varieties of flowering plants for the home, how and where to plant them.

Books and Bulletins: The Nursery Book, Bailey; The Practical Garden Book, Hunn and Bailey. Farmers' Bulletins: United States Department of Agriculture; Beautifying the Home Grounds, No. 185; *Annual Flowering Garden, No.* 195; *The School Garden, No.* 218; *Tomato Growing, No.* 76; *Potato Culture, No.* 35; *The Vegetable Garden, No.* 94; *Potato Diseases and their Treatment, No.* 91; *The Home Fruit Garden, No.* 154; *Strawberries, No.* 198; *Raspberries, No.* 213; *The Home Vineyard with Special Reference to Northern Conditions, No.* 156.

CHAPTER XXI

SUGGESTIONS FOR CONDUCTING WORK IN THE SEVENTH AND EIGHTH GRADES

THE purpose of the work in the seventh and eighth grades in addition to the training in accurate observation, open-mindedness, and independence of thought, is to aid the pupils in acquiring a knowledge of fundamental principles underlying successful agriculture.

Much may be accomplished by following the same plan as with the lower grades. Some of the general exercise studies may be carried much farther by these pupils. They may be given specific problems to work out, and special reading in connection with the subject under discussion. For example, with the study of grasshoppers, have them find out to what extent these insects injure the grain crops in their district; or what field birds help most in keeping these and other insects in check. Refer them to bulletins that will give them information along these lines.

If the work in these grades accomplishes all that it should, it ought to have at least two recitation periods devoted to it each week. The need of experiments as well as observation makes this almost essential.

So far as possible, the work of each year as indicated in the outline has been made a unit. By this arrangement the work of the two years may alternate, a plan that works in many country schools.

Teachers should look over the lessons carefully in order to plan their work successfully. Many of the experiments, especially in soil physics and in the work of plants, must be started several days, or in some cases weeks before giving the lesson.

A list of bulletins that contain much helpful information is placed at the close of each chapter. No. 195, entitled *Some Exercises Illustrating Some Applications of Chemistry to Agriculture* will be found especially helpful in working out the lessons in soil chemistry, and No. 186, *Exercises in Elementary Agriculture*, will be helpful in the lesson on soil physics and the work of plants. All the bulletins listed may be obtained free by applying to United States Department of Agriculture.

A few pieces of apparatus are indispensable in conducting the lessons in physical experiments in the seventh grade, and in soil studies in the eighth. The following list of necessary articles may be obtained at a very little cost.

Alcohol lamp. This may be made from a vaseline bottle. Get the tinner to make you a small tin tube about an inch and a half long. Push this through the middle of the cork and punch out the cork inside the tube. Twist some soft string into a wick and pull it through the tube. Fill the bottle a little over half full of alcohol. Wood alcohol will serve as well as grain. Turn a small vial or thimble over the wick to prevent evaporation.

A test tube. A small glass flask having a rubber stopper with a hole in it. A measuring cup; a glass one may be purchased for ten cents at any crockery store. A thermometer. A long iron nail, a heavy piece of iron wire, or a long slender bolt. A piece of glass tubing one-fourth inch in diameter. A piece of rubber tubing. Several plates, saucers, and tumblers. Two tin cups. Several pint and quart Mason jars. Half a dozen student's lamp chimneys.

CHAPTER XXII

POLLINATION AND SEED FORMING

Problem.—What is the work of a flower? What is pollination and how is it secured by different flowers?

For this study any flower in which all the parts are well represented should be selected. Petunia, nasturtium, morning-glory, and tomato are all good. It is well to study more than one flower.

Find the parts of the flower: (*a*) corolla, composed of petals, the colored showy part, called polypetalous when the petals are separate as in the nasturtium, sympetalous when the petals are grown together as in the petunia; (*b*) calyx, composed of sepals, sometimes green, as in the petunia, sometimes colored, as in the nasturtium.

Find the stamens. How many? Note the slender filaments and the knoblike anther. Can you find any powder (pollen) in the anther? Compare anthers in old flowers with those newly opened. What has happened in the older ones? Examine the pistil. Make out the ovary at the base, the style, and the stigma at the top. What is the use of the stigma? This is to catch the pollen. When it is ripe, or just ready to catch pollen, it is sticky. Whenever pollen is transferred from an anther to a stigma pollination has taken place. Pollination then is the transfer of pollen from anther to stigma and nothing more. It should not be confused with the subsequent and entirely different act of fertilization. If the pollen is transferred from the anther to the stigma of the same flower, it is called close or self-pollination. If the pollen is transferred from the anther of one flower to the stigma of another, it is called cross pollination. With a sharp knife cut an ovary in two across the middle. What do you find on the inside? Those tiny seedlike bodies are called ovules.

Have children watch the development of a flower from the time it opens until the seed is ripe. What parts of the flower wither and drop off? What parts remain? What part becomes the seed pod? What part becomes the seed or seeds?

Problem.—Is pollination necessary to produce seeds?

If plants are growing near the school select some nasturtium flowers that are just opening and carefully remove the stamens with a pair of sharp-pointed scissors, then cover the flower with a paper bag so that no pollen can be conveyed from other flowers to the stigma. Treat another flower in the same way, but leave the paper bag off.

Leave the bag on for a week or ten days, then remove and note conditions. Cover enough flowers in this way so that there can be no doubt in the minds of the pupils as to results. If there are no plants near the school, have some of the reliable pupils start the experiments at home and bring the plants to school for observation and study.

What are the agents that aid in transferring pollen from one plant to another? Have pupils watch the insects that visit flowers or draw upon their observation and experience. They will probably know also that the wind as well as insects is an agent of pollination.

The children cannot see what takes place after the pollen grain has fallen upon the stigma. But they should know that the pollen grain germinates or sprouts on the stigma and a small tube grows down the style into the ovary. In this tube are certain small cells. One of these cells unites with a cell in one of the ovules, and the new cell formed by this union is the beginning of a new plant. It forms the embryo, which is the essential part of the seed. This act, the uniting of these two cells, is called fertilization. Pollination, then, is the first act, and fertilization the second in forming the seed. The children now see why pollination is necessary for a plant to produce seed.

Problem.—Would it be possible for you to pollinate a flower by hand, choosing the plant from which the pollen is taken?

Remove the stamens of a nasturtium in flowers as in the previous experiment, then with a brush or triangular bit of paper transfer some pollen to the stigma. Place a bag over it so no other pollen can get on it. This is known as hand pollination.

Cornflower. Find, if possible, some belated corn plants that are still young enough to show fresh tassels and silks.

How many kinds of flowers do you find on the corn? The most prominent kind forms the tassel. Examine a tassel. Is it a single flower or a cluster of many? Have these flowers bright petals as the nasturtium? What essential part of the flower is found in the tassel? Since only stamens are found here this is called a staminate flower. Can you find any pollen in the stamens? What is the other essential organ of any flower? When the pistils are borne in separate flowers we call these pistillate flowers.

Where are the pistillate flowers of the corn? Find an ear that is just forming, or at least a young ear. Pull off the husks and notice the very small grains on the cob. Each of these is an ovary. What is attached to each grain? The silk is the style. Where is the stigma? This is at the very tip end of the silk. If pollination takes place, what is necessary? One grain of pollen must fall upon the stigma of each silk. How is corn pollen scattered? Is there much pollen produced? What evidence have we that the wind carries pollen long distances? Discuss at this point what must happen in order that fertilization may take place. The pollen grain must germinate on the stigma and then the pollen tube must grow down through the entire length of the style till it reaches the ovary where the union of the two cells will occur. This, as you know, is the beginning of a seed. Do you think that corn is likely to be self pollinated or cross pollinated? Why?

CHAPTER XXIII

PLANT BREEDING

Because seeds of plants are produced by the union of two cells, one from the pollen grain and the other in the ovary of the pistil, it is possible to produce new varieties or strains of certain plants. Plants, like animals, inherit characteristics of their parents. Now, if the pollen from one plant germinates on the stigma of another, the result of the fertilization which follows is a seed which will probably partake of the qualities of both parents. Florists and horticulturists have taken advantage of this to produce new varieties of flowers and vegetables.

Of late years much has been done to improve the corn crops by a process of breeding.

It has been ascertained by careful experiment that corn which is cross pollinated produces stronger, better plants than that which is self pollinated. How could you insure cross pollination of a number of ears of corn? The hand-pollination method which was tried with the nasturtium may be employed. This, of course, would have to be done just at the time that the corn is in flower, or just as it is beginning to "shoot," as farmers say. Pollen is collected from one plant in a sauce dish or other shallow receptacle and the ends of the silks of another plant gently dipped into this. Then a paper bag is tied over the ear so that no other pollen can reach the stigma. In this way one may select desirable stalks and expect to have seeds that will reproduce the good qualities of both parents.

There is another method that is less tedious and that is coming more and more into practice, and that is by detasseling. Some of the stalks are detasseled before the anthers are ripe. That means, of course, that the ears on those stalks will have to be cross pollinated.

Any boy can start a corn-breeding plot on a simple scale on his father's farm. The first requisite is to have the location of the plot as far from all other corn as possible. In the center of an oat field is a good place. The next thing is to decide what strain or variety of corn to plant. Select an ear for each row. Number the ears and rows alike, and then hang up the ears for future reference. One method of selecting ears is given in the lesson on selecting and judging seed corn. The corn should receive the same attention as the other corn on the farm. The rows of corn may differ from the start because of inherent difference in the ears. If any of the rows show decided marks of weakness, all the stalks in these should be detasseled; also any undesirable stalks in any of the rows. The tassels should be pulled off as soon as they show plainly in the top of the stalks. In order to secure cross-pollinated seed, one half of each row should be detasseled. Begin at one end of the first row, and detassel to the middle; then, beginning in the middle, detassel the other end of the second row, and so on. From which end of each will you choose your ears for seed? Why? From these stalks the desirable ears are chosen for the breeding plot next year. One thing to breed for is productiveness. To find which row produced the greatest yield it will be necessary to gather all the ears from each row separately and weigh, adding to this the weight of the selected seed ears. The most productive ears should be saved for the breeding plot next year, while the best of the others should be saved for general planting on the farm. Since a small breeding plot will not produce enough seed for the entire farm, the seed from this should be planted in a field by itself. From this field and the breeding plot seed should be selected for the next year's planting. In this way the productiveness of the entire crop may be greatly increased in a few years.

Books: Plant Breeding, De Vries.

CHAPTER XXIV

INSECTS

INSECT study in the seventh and eighth grades should be linked as closely as possible with the study of plants. If the pupils have had no previous study of insects, then it is better to begin with some of the large forms for the purpose of getting acquainted with the characteristics common to all insects. A grasshopper is a good type to study for biting mouth parts; a squash or box-elder bug, for piercing and sucking mouth.

The plant life of any locality should determine largely the special insects to be emphasized in these grades. In a region where corn is the chief crop, the insect pests common to this plant should constitute the bulk of the work. In a fruit-growing community the insects found on the fruit trees and shrubs should receive most attention.

Aphids.—Aphids or plant lice may be found on weeds, golden glow, willows, rose bushes, cherry and plum stems, cabbage leaves, wild lettuce, etc. They are small insects which vary much in color. Some are almost black, some red, some green. Have the children bring in some leaves with aphids on them. Do all aphids on the plant look alike? You will probably find on one plant several stages of the insect; some small ones without wings; some larger with small pads; the beginning of wings on the sides; and some that have quite large wings folded above the body.

These last look like small flies. What are the aphids doing? Hold the leaf or stem on a level with the eye and look closely at the head of the aphid to find the slender sucking tube which is inserted in the leaf or stem. It is just like the sucking tube of the squash bug. What kind of food does the aphid eat, solid or liquid? Do you think putting some poison on the surface of the leaf will kill the aphid? Why? In order to kill these, something must be used that will kill by coming in contact with the body. Kerosene emulsion is a good remedy. How many legs has an aphid? How do they hold their horns or antennæ?

Did you find any other insects on the plants with the aphids? You will often find ants. What are the ants doing? The children may or may not be able to make out that the ants are here to get something to eat. The aphids throw out from their bodies a sweet liquid known as honey dew. The ants are very fond of this sweet substance, so that wherever you find plant lice you are almost certain to find some ants. You will often find flies, also, sipping the honey dew.

Look at the roots of small stunted stalks of corn. You may find some green aphids, the corn-root lice, on the youngest, most tender roots. You are more likely to find them in the summer, when the corn is growing vigorously, than in the fall. You may also find a small brown ant near the corn root, or perhaps nests of them in the cornfield. Even if it is too late to find the corn louse this fall, encourage the boys to look for it next year when the corn is growing. Encourage them also to destroy any ants' nests they may find in the cornfield or vicinity.

Why should they do this? The female aphids lay their shiny black, oval eggs in the ground during the fall months. The little brown ants find these, carry them to their underground homes, and keep them safely through the winter. They often carry the eggs out into the sunshine during the warm part of the day and back into the burrows at night. These eggs hatch in the early spring into young aphids. The ants at once place these on the roots of smart weeds. When the corn is beginning to grow, the ants place the aphids on the corn roots from which they suck the juices with their sharp sucking tubes. The ants get their pay for all this work in the form of honey dew which the aphids throw out.

Each aphid that hatches from an egg is called a stem mother. In less than a month this stem mother begins to reproduce young. All these are females which in a month's time begin also to produce young. So in less than two months the stem mother may become the ancestor of thousands of young lice. This goes on all summer. Most of these aphids are wingless. Once in a while there is a generation that has wings. These fly away to some other part of the field, or to another field. Some of them drop to the ground, and are found by ants who carry them at once to the corn roots. In the fall a brood of true males and females is produced. These females are the ones that deposit eggs for the next year's crop of aphids. You can readily see why the destruction of the ants' homes is to be encouraged.

One of the methods employed to destroy these pests is to break up the ground as early as possible in the spring, and then before corn planting go over it once or twice with disk or cultivator in order to destroy the smart weeds, and as many of the ants' nests as possible.

The life history of all other aphids is essentially the same as that of the corn-root louse. One reason they are so destructive is because they multiply so rapidly.

One species of aphid is often found on the oats in early summer. It is known in some localities as the "green bug." It sucks the juice from the stems and leaves of the oats and is often very destructive.

Aphids have many natural foes. Among these are the ladybug beetles, the aphis lion, braconid and syrphus flies, as well as a number of birds.

The White Grub.—White grubs may be studied either in autumn or spring. They are found abundantly in the soil of fields and gardens, in potato patches, and often in pastures and lawns where they kill our great areas of grass.

Ask the pupils to save and bring in some white grubs. To keep these insects alive place them in a tin can or pail in which there is plenty of moist soil. Place on top of the soil a piece of fresh grass sod, firm it down with your hand gently, keep it watered but not made wet. Set the pail aside for several days. At the end of this time carefully lift up the sod. You will probably find some of the grubs under it. Note the position of the body. Is there any advantage in keeping it curled up in this fashion? Is the grub lying on its back or under side? Has it a tunnel to lie in? What has it been doing here? Look at the grass roots. Can you see whether any of these have been eaten? Look carefully at the structure of the insect. Has it a distinct head? How does this differ in color from the body? Is the body hard or soft? What kind of a mouth has the grub? Look at the front of the head for the strong hooklike jaws. It is with these that it bites off the roots of plants and underground stems of plants. Do the grubs ever kill plants in this way? How many legs have they? Where are the legs situated? What is the use of these legs? Put the insect on the floor or desk. Can it crawl well? Now put it on the surface of the soil and watch to see how it succeeds in burrowing into the ground. Is there anything on the feet that enables it to dig easily? Have the pupils name all the adaptation this insect has for living in the ground rather than on the surface.

Does it do any harm besides killing out grass? Some of the pupils will probably know how destructive these white grubs are in cornfields, strawberry beds, and gardens.

Life History.—It may not be possible for the pupils to work out any part of the life history of this insect. It all depends upon how old the grubs are that you are studying. If the study is made early in September it is worth while trying to get the pupæ. To do this simply feed the grubs plenty of grass roots by renewing the sod whenever it begins to wither. In a few weeks the grubs will go down into the soil, make little tunnels, and in these change to a pupa. A pupa looks like a light, brown mummy with undeveloped wings and legs folded close to the sides and under part of the body.

In a few weeks the grown-up insect emerges from the pupa but remains in the ground all winter.

The spring is by far the best time to study the grown-up insects or beetles. These come out of their winter quarters in great numbers during May. They are commonly known as June bugs.

When do you find the beetles flying around; during the daylight or after night? They often fly into our houses attracted by the light. Set a lantern or lamp out on the porch and catch a number of these for study next day. These can easily be preserved for fall study by putting them in a wide-mouth bottle and covering them with alcohol. Pour a little melted paraffin or sealing wax over the top and around the stopper to keep the alcohol from evaporating.

How does the beetle compare with the grub as to length and color? Which has the harder body? Which has longer legs? Which is stouter and thicker? Are the beetle's jaws as large as those of the grub? What does the beetle eat? It is hard for the children to determine this since the beetles eat during the night. They feed upon the leaves of various trees, such as cottonwood, cherry, birch, and no doubt many others. Notice their wings. How are the outer wings related to each other? Do they overlap or just meet? Lift up the outer wings. How are the inner wings folded? Are they longer or shorter than outer wings? Which pair is used in flight? What is the use of the hard, outer pair? Watch a beetle when it alights to see how it succeeds in tucking the inner wings under the outer ones.

These beetles lay their eggs in the ground very often in the cornfields. After the eggs are laid the beetles die, so that by the last of June most of the June bugs have disappeared. The egg hatches into a small white grub that begins at once to feed upon decaying matter in the soil and later upon plant roots. When cold weather approaches it burrows down into the ground below the frost line and remains dormant during the winter. In the spring it comes up and begins feeding again. Toward fall it probably pupates, although it is not definitely known whether all species of white grubs pupate the second fall or not. Some may possibly live as grubs for three summers.

Since these insects are such pests the question of how to get rid of them is of interest to all farmers. As yet no good remedy has been found. One of the best known is to turn pigs into the field whenever that is possible. The pigs are so fond of the grubs that they will dig down into the soil a number of inches in order to get them. Many birds help to lessen the number of these pests. Robins are especially fond of grubs.

CHAPTER XXV

FUNGI AND BACTERIA

THE purpose of the lessons on fungi is to help the boys and girls gain a more intelligent idea of fungous diseases of plants and how to combat them, as well as of the fungi that attack fruits, vegetables, bread, etc. We should begin the study with some of the larger forms, so that the pupils may get a proper notion of the habits and method of reproduction of fungi in general.

Mushrooms and Toadstools.—Have the children bring in a number of mushrooms. They will probably call them toadstools. The common meadow mushroom is usually abundant in the fall, so are a number of cluster mushrooms that grow at the base of old stumps. Where are mushrooms found growing? By discussion it will be brought out that they are found in the woods, around stumps, on trees, in meadows, around barns, etc.

How many parts do you find in your mushroom? The stem is called the stipe, the umbrellalike part, the pileus. You may find small whitish threads attached to the end of the stipe. These make up the mycelium which penetrates the ground or stump or whatever the mushroom may be growing upon. What do you find on the under side of the pileus? Those leaflike flaps are called gills. What are they for? To answer this question break the stem out of the pileus and then lay the pileus on a piece of white paper with the gills downward. Leave it for twenty-four hours. What do you find on the paper? Rub your finger over it. This fine powder is composed of tiny bodies like pollen grains, each of which is called a spore. These spores are for the production of new plants. Name some of the things in which a mushroom differs from the other plants you have been studying. They lack leaves, green color, flowers, and seeds.

Mold.—About a week before time for this lesson place moist pieces of stale bread on a piece of pasteboard and turn tumblers over them. Have pupils examine the bread. What is on it? On what part of the bread is the mold most abundant? Look closely at the mold. How many distinct parts can you see? The mass of threads is the mycelium. Do any of the threads penetrate the bread? Those standing out from the mycelium with tiny white or black dots on the ends are spore-bearers and the dots are spore cases. Touch gently with a pin a group of these black spore cases. What happens? The cases burst open and a shower of minute spores come out. What are the spores for? Let us plant some of these spores to see if they will grow.

Moisten a fresh piece of bread and with a small stick or end of a match transfer some of the spores to this. Plant them in rows. Turn a tumbler over the bread and examine after forty-eight hours. Have the spores germinated? Let the bread stand to find out how long before this new crop of mold has ripe spores on it.

Another set of experiments to show that mold and other fungi grow from spores is as follows: Procure a moldy orange or lemon, and a perfectly sound orange. Roll the point of a pin on the moldy orange, now insert it about one third its length in the good orange and leave it there. Watch developments. What is the first indication that mold is growing on the inside? The orange will become soft around the pin. How long before the mold spores begin to show on the outside? In order to show that this is not due to the puncture of the pin, sterilize a pin by putting it in hot water and place it in the opposite side of the orange. Do this when you set in the first pin. Tie a label to each pin so that you will know which had the mold spore on it. You will get quicker results by setting the orange in a jar and covering the jar. Try planting the spores of a rotten apple in a sound one. Rub some of the spores on the unbroken skin of the apple or orange. Do the spores grow?

Where did the mold come from on the first piece of bread? The spores must have been on it when it was moistened and put under the tumbler. They must have been in the air. Why does stale bread mold more quickly than fresh? Why does canned fruit mold? Can mold spores be killed?

Pour boiling water over a small piece of stale bread and turn over it a tumbler in which you have just dashed boiling water. At the side of this place a piece of the same kind of bread that is soaked in cold water and has a cold tumbler turned over it. Watch for developments. Why do you pour boiling water in fruit jars before canning the fruit? Why should lids of the jars be sterilized in the same way?

Soak a piece of fresh bread in a half glass of water in which you have placed a few drops of formalin. Plant spores on this as you did on the other piece of bread. Do these spores grow? Why? Formalin or formaldehyde kills the spores as effectively as the hot water. However, it cannot be used about the house for it is poison to human beings. It can be used, however, to great advantage in killing spores that produce fungous diseases of plants.

What conditions are best suited to the growth of some fungi?

Experiments.—Place some dry bread on a piece of pasteboard and cover with a tumbler. Beside this place some moistened bread and watch for results. Moisten two pieces of bread and cover with tumblers. Place one where it is warm; the other where it is cool. What conclusion do you come to in regard to the effect of heat and moisture on the growth of mold?

What does the mold feed upon? The mushrooms? The apple rot? All of these obtain food from the substances on which they grow. What part of the plant do you think gets the food? By discussion it may be brought out that the threadlike mycelium which penetrates the substances obtains the food. All fungi such as mold and mushrooms that live upon dead organic matter are called saprophytes.

Do all fungi live upon dead organic matter, as bread, stumps, etc.?

Find some lilac leaves that are covered with a white flourlike growth. This is very abundant on most lilac bushes in the fall. You may find it also on rose leaves. Examine the leaves closely. You will find the white covering consists of a mass of very fine threads, the mycelium. Here and there one of the threads pierces the skin of the leaf. What for? It gets food from the juices on the inside of the leaf. Notice the clusters of small black bodies. What do you think these are? In these spore cases are small spores for the reproduction of the plant. This fungus is known as lilac mildew. Since it lives upon a living plant it is called a parasite. The plant upon which it lives is called its host. Can you think of any other parasitic fungi? If possible have in class some ears of corn covered with smut. Examine this. What is it composed of? The mass of black sooty material is chiefly made of spores. What is the effect of this fungus on the ear of corn? The smut plants have really penetrated the young grains of corn, and have lived upon these grains. Has this fungus many or few spores? Much corn is destroyed by this disease. What other grains are attacked by smut? Both wheat and oats.

Save at harvest time a few heads of oats or wheat with smut on them. Can you find any spores in these? What will every spore produce? A new plant, which, like all the other fungi studied, forms a mycelium. It usually begins its growth when the oat plants are about an inch high. The threads (hyphæ) of the fungus feed upon the growing oats, sometimes so weakening the plant that it dies. Do you think any of the oat seeds are likely to have spores on them if they have grown in a field where some of the heads had been affected with smut? Can you think of anything that might be done to kill these smut spores?

Formaldehyde will kill these spores just as readily as it did the mold spores. The following recipe is used by many farmers: Put one pint of forty per cent. formaldehyde in thirty-six gallons of water, soak the seeds in this for ten or fifteen minutes, and then spread out to dry. This is sufficient for about forty bushels of seed. The seeds are more easily handled by putting them into a gunny sack, and putting this into the solution. Wheat smut may be treated in the same manner.

Examine spots of rust on wheat or oats. Can you find any spores here? Are these fungous diseases? This is another fungus that feeds on the inside of the leaf or stem till it is ready to produce spores, when it sends the hyphæ to the surface and the spores are produced on the outside. The ripe reddish-brown spores on the wheat look very much like iron rust, hence the name.

Can you think of any other plants besides cereals that are affected with fungous diseases? Sometimes plums, cherries, and peaches are attacked with a brown rot or mold while the fruit is hanging on the tree. The fruit shrivels up and continues to cling to the tree sometimes after the leaves have fallen off. This disease is most common on peach trees and often destroys more than half the crop. Have children look on their own trees at home for the dry peach "mummies." These contain spores for the next year's crop of rot. What should be done with the mummy peaches that are on the ground in the fall or winter? This disease as well as other fungous diseases that attack fruit and leaves of trees may be prevented by spraying the trees with mixtures that will kill the fungi.

Have the children look on their pear and apple trees for twigs that are black, and that have on them withered blackened leaves. This disease is called blight, and is one of the worst of the fungous diseases to combat. It is caused by a growth of one of the very smallest plants known. These plants are called bacteria. They live in the sticky layer between the wood and bark. This layer is called the cambium. This is the part of the twig in which the growth of new wood takes place, and these bacteria are so numerous that they use up most of the nourishment of the twig. As a result the twig dies and, of course, the leaves must die too. The best way known to prevent the spread of blight is to cut off every twig that is affected and burn it.

There are many other kinds of bacteria besides those that cause pear blight. They are so small that it is not practicable to attempt to study them by observation. Many of them are not more than one twenty-five thousandth of an inch long. It is worth while to know that while these plants are small they are among the most important living organisms. They are one-celled plants and reproduce by cell division instead of by spores. That is, each cell divides into two parts, each of which becomes a mature cell. This division continues, making the multiplication very rapid. Like the spores of mold, these cells float about in the air or in water. Some cause human disease, such as typhoid fever, diphtheria, etc. Others are beneficial to man, such as those that cause decay of vegetable and animal matter in the soil. Without these we could not have any humus in the soil. The bacteria that live on the roots of leguminous plants are beneficial. We shall see in our study of clover just what they do for us.

Farmers' Bulletin: The Grain Smuts, No. 75.

CHAPTER XXVI

SELECTING, JUDGING, AND STORING SEED CORN

THE lesson on selecting seed corn should be given after the corn has become fully mature and before there are any very hard frosts.

What are some of the characteristics that should be considered in choosing good seed corn? One of the most important is to choose corn that matures early enough to escape the first heavy frosts.

A field study should be made with the class if this is possible. Most rural districts have cornfields near the schoolhouse. Almost any farmer will grant permission to take the class into the field for study. If this cannot be done then the pupils may make all the observations at home.

First, spend a few minutes in observing the general character of the corn plant. Note the jointed stem, the arrangement of the leaves, how the leaves are attached, the number of leaves, their venation, and the prop roots. Dig around one plant and note the direction of growth and extent of the roots. Are all the stalks equally well formed? Are they all standing erect?

What are desirable qualities to look for in choosing a stalk you would like to have reproduced next year? It should be a stout, upright stalk growing in a hill with at least two others, if the hills are forty or more inches apart;

one free from suckers; and one whose ear stem is not more than four or five inches in length. The ear or ears should not be too low or too high, but slightly below the middle of the stalk and convenient in harvesting. There should be no smut. The leaves should be well formed.

Having made a study of suitable stalks, have the children choose ears from similar stalks in their own fields. Are all the ears on these stalks worth keeping? What are some of the qualities to look for in the ear? It must be understood that the most important character of any seed corn is the power to reproduce abundantly, and that this quality cannot be ascertained by examining the ear. However, there are a number of qualities that a good ear should possess that may be determined by observation. It should be well shaped, usually cylindrical, and well proportioned, not long and slender, or short and stocky. The kernels should all be of the same color and should not show any mixing of varieties. The ears should be well matured, sound and dry, not soft and flabby. The tip of the ear should be well filled out; the cob round, not flattened at the tip. The butt should be rounded with grains extending well over the cob. There should not be wide spaces between the rows of kernels. The kernels should fit closely together and should be of uniform length and shape. The kernels should be long and the shape of a wedge, having straight sides and edges. They should not be soft and with chaffy tip caps.

Have each pupil bring ten ears from home which have been selected from desirable stalks. Place these on the desk with tips all pointing one way. Examine and judge according to the points given above. Add to these the following. Measure the length of each ear and get the average of ten. Find the average circumference one third the distance from the butt. Find the ratio of the average circumference to the average length. Weigh five ears. Shell and weigh grain. Find percentage of grain; percentage of cob.

It will aid greatly in this work to have a sample ear of each variety which has been raised by some reliable corn breeder. Have the pupils put into the first class all the ears that approach the standard ear. Discard all others.

Encourage the pupils to select in this way a number of ears at home to save for the spring planting.

The judging may be done by following the points indicated on a score card arranged by the Corn Growers' Association. Almost all of the points indicated above, as well as some others, are found on one of these score cards. Each characteristic counts so many points; for example, if an ear is perfect in shape it scores ten, if a tip is perfect it scores five, and so on. An ear perfect in every particular scores one hundred.

The following interesting and profitable exercise in connection with corn study may be conducted as field work by the class, or as individual study at home. Select a plot in the fields ten hills each way. Find the whole number of stalks in the square, the number with one good ear, with two good ears, number of barren stalks, number with suckers, number with smut. Measure the distance between the hills and between the rows. How many stalks should there be in each hill? If the hills are from forty to forty-four inches apart, there should be three good stalks. How much does the square lack of having its full quota of stalks?

Weigh twenty ears and estimate number of ears in one bushel. Find yield of plot, and of an acre.

Weigh twenty ears, hang up in a dry place, and toward spring weigh again. Estimate percentage of shrinkage.

The next step of importance, after selecting the seed corn, is caring for it during the winter. In the first place, the corn should be dried as soon as possible after gathering. It should then be stored in a dry place of even temperature. It should not be piled up in heaps, but scattered on floors or tied together and hung up so that it may be well ventilated.

Farmers' Bulletins: The Production of Good Seed Corn, No. 229; *Corn Growing, No.* 199.

CHAPTER XXVII

PHYSICAL EXPERIMENTS

Evaporation and Condensation

NATURE study does not mean a study of plants and animals exclusively, but also a study of the soil, air, weather, and certain phenomena that touch our lives on every hand. Indeed, we must know something about the underlying principles of physics before we can understand clearly how plants and soil and weather do their work.

Water is the most familiar liquid that we know. Water in the solid form (ice) is so common that we need no experiment to prove it. Is it possible to change water into a gas or vapor?

Fill a measuring cup exactly half full of water. Pour this into an ordinary tin cup or tumbler and set in a warm place. This should be done several hours before the class time, or even the day before. Fill a glass flask or test tube half full of water, place it over the flame of the alcohol lamp till it boils vigorously. What do you see coming out of the mouth of the flask? Look in the flask above the boiling water, can you see anything above the water in the flask? Where does the steam come from that is visible at the mouth of the flask? It is visible here because the vapor has begun to change back into water. Is the true vapor of water then visible or invisible? Watch the spout of a boiling teakettle. Can you see anything close to the spout? What is there, although you cannot see it? Why can you see steam at a short distance from the spout? Here, of course, the invisible vapor is changing back into a liquid state.

Now examine the cup that you set in a warm place. Can you see any steam coming from it? Measure the water carefully. Has any of it disappeared? What has become of it? We say it has evaporated, which means that the water has changed into an invisible gas or vapor. The same thing happened as when you boiled the water, with one difference; the evaporation went on more slowly. When evaporation takes place rapidly we sometimes use the term vaporize instead of evaporate.

What are some of the conditions that influence the evaporation of liquids?

Experiment.—Measure exactly in the measuring cup a half cup of water and put it into a tumbler. Put the same amount into a shallow pan or plate, and the same into a pickle bottle. Set the three side by side and let them stand until the next day. Now measure carefully. From which has the most water evaporated? The least? What caused the difference? From this we learn that extent of surface has a certain effect on the rapidity of evaporation. What is it?

Place equal amounts of water in two tumblers or cups of exactly the same size and shape. Put one in a warm place, the other in a cool place, and leave for twenty-four hours. Measure and note difference. What is your conclusion as to the effect of temperature upon evaporation?

Place equal amounts of water in cups as suggested in the above experiment. Set them side by side in a window where there is a draught of air. If it is not freezing weather, set them outside on the window sill. Cover one cup by setting a sauce dish or saucer over it. Let them stand till next day. From which has more water evaporated? Why? In this the temperature and surface were the same, but above one, air currents could move freely, while above the other they could not. What is the effect of a change of air on the rapidity of evaporation? Why does mud dry up more quickly on a windy day than on a calm one? What is the effect of a rapid change of air currents on the drying of clothes on a line?

Place equal amounts of alcohol and water in cups side by side. Measure after twenty-four hours. Do all liquids evaporate at the same rate? Can you think of other liquids besides alcohol that evaporate more rapidly than water?

Rub a little water with your finger on the back of your hand. Hold your hand up in the air waving it gently. How does the wet spot feel? Touch your hand in the same way with a drop of alcohol. Does it feel any colder than when you touched it with the water? What is the alcohol and the water doing? If you have a thermometer, dip it into alcohol or water and hold it up in the air and move it about till the liquid has all evaporated. Does the mercury rise or fall? From all of these experiments what do you conclude as to the effect of the evaporation of liquids on surrounding bodies? Why do you feel chilly when you get your clothing damp? Why does sprinkling the street cool the air? How is the temperature of our bodies regulated?

What causes the water vapor to change back into water again? Fill a tin cup or glass flask half full of water, set it over the flame of the alcohol lamp till the water boils. Hold a cold plate about half an inch above the flask. What collects on the plate? Heat the plate very hot and then hold it over the flask. Does as much water collect on the hot plate as on the cold one? Which causes the vapor to change back into water, heat or cold? When vapor changes back into water we call the process condensation.

Is there water vapor in the air of the room although we cannot see it? Place some water in a tumbler or a bright tin cup. Now stir slowly into the water some pieces of crushed ice, or better, some snow. If you have a thermometer keep it in the mixture. Watch carefully the outside of the cup. Where do the drops of water come from that collect on it? Why does the moisture gather on this and not on the other objects in the room?

The children may be led to see that the glass with the ice in it is so much colder than the rest of the room that as the air comes in contact with it the water vapor is condensed and changed into water. What causes dew to gather on objects at night? The objects cool after the sun goes down and as the air touches the cold objects what happens? The more moisture there is in the air the more quickly dew will form, other conditions remaining the same. The temperature at which any mass of air is just cold enough to have some of its vapor condense is called the dew point. If you read the thermometer at the moment you saw the vapor begin to condense on the cup you had the dew point of the air in the room.

When a teakettle is boiling what is the steam that you see? These drops of water in the steam are so small and so light that they float in the air, forming a small cloud. How are the clouds formed that we see floating high in the air above us? First we must think where the vapor of water comes from that is in the air. The pupils will know that evaporation is constantly taking place from the surface of all bodies of water as well as from the soil.

Sometimes the air has just as much vapor in it as it can possibly hold. If now it is cooled even a little, what will happen? The vapor will condense and form a cloud. Suppose it is cooled still more, what will happen? The tiny drops of moisture will begin to unite and form larger drops. Presently the drops will become so large that the air can no longer hold them up, so they must fall and we have rain.

Sometimes the condensed vapor falls in the form of snow instead of rain. Why does it do this? We cannot hope to answer this question fully. We only know that when vapor freezes as it condenses it forms into crystals instead of drops.

When a snowstorm occurs a special observation lesson should be given. Note the appearance of the clouds and the direction from which the storm is coming. Are the flakes large or small? Examine several flakes. Are they all the same size and shape? Find some of the small crystals. If you have a lens, examine these to see how many points they have. Is a flake made up of one or more than one crystal? The snow crystals, while they may vary in external appearance, are all built on the same plan—that of a six-pointed star. One of the wonderful things about crystallization is that each substance has a definite geometrical plan upon which its crystals are built. If the wind is blowing strongly, note how the drifts are made. Why are these drifts in some places and not in others? Note the drifts near buildings and trees. Can you account for the spaces left near the trees and buildings? These are due to the wind currents striking the object and rebounding, carrying the snow back with them.

In the same way, observation of sleet, hail, and rain storms should be taken up informally as these phenomena occur.

CHAPTER XXVIII

SOME EFFECTS OF HEAT ON BODIES

From our previous experiments we know that heat aids in the evaporation of liquids.

Have some of the pupils measure a piece of heavy iron wire, a long nail, or bolt in the following way: Lay the nail on a piece of pine board and make a scratch across the width of the board at each end of the nail. Now place the nail on a shovel on top of a glowing bed of coals in the stove. Heat it till it is red hot. Now lay it on the board, trying to get it exactly between the scratches. What effect has the heat had upon it? Put it out of doors till it is cold. Try it again on the scratched board. What is the effect of cooling it? Most solids act as this piece of iron did. They expand when heated and contract when cooled. Think of some practical illustrations of this. Why heat a tire before setting it on the wheel? Why are bolts which are to hold together two walls often heated red before they are put in, and the nuts tightened as the bolts cool?

Do liquids expand when heated? Fill a tin cup level full of water, heat it slowly. What happens? Put a piece of glass tubing through a rubber stopper. Fill a glass flask full of water. Put in the stopper. The water should now show in the tube above the stopper. Slowly heat the flask. What indication have you that water expands with heat? When the tube is almost full of water set the flask in a cool place. Does the water contract? When fruit jars are filled to the top with the hot fruit, why is it that there is a space left at the top of the jar when the fruit has cooled?

Will gases expand with heat? Use the same flask as in the preceding experiment. Pour out the water and dry the flask thoroughly. What is in the flask now that the water is out? Insert the stopper as before, but place over the end of the glass tube a rubber tube at least a foot long. Hold the end of the rubber tube under water. Now slowly heat the flask. What happens? As you heat the air in the flask it expands and flows out through the rubber tube as indicated by the bubbles. Heat a bottle (a round listerine bottle is a good kind), by rolling it over and over on a hot stove. When hot turn it upside down in a tumbler one fourth full of water. Why does the water rise up in the bottle? Heating the air expanded it so that some of the air flowed out of the bottle. As it cooled, the air in the bottle contracted and the pressure of air on the surface of the water pushed the water up into the bottle.

We are now ready to conclude that heat expands solids, liquids, and gases, and that cold contracts them. What is the effect of heat on solids and liquids as they change from one of these states to the other?

Fill a cup level full of melted tallow or paraffin. Set it in a cool place. Examine the next day. Is it still level full? What happened to the paraffin as it cooled and solidified? Which occupies the greater space, liquid or solid paraffin? Melted lard, or solid lard? Which is heavier, a cup level full of solid paraffin or the same size cup level full of melted paraffin? Will a piece of solid paraffin dropped into a cup of liquid paraffin sink or swim? Why?

Do all substances contract as they solidify? If the weather is freezing cold, set a tin cup level full of water in a saucer and set both out of doors overnight. Has the water contracted or expanded as it cooled and solidified? Why will freezing water break a pitcher or glass? Which is heavier, ice or water? Put a piece of ice into a cup of water. Does it sink or float?

Water then differs from the other substances studied in that it expands when it solidifies or freezes. But we found by means of a previous experiment that water expands when heated, and contracts when cooled. There must, therefore, be a certain temperature at which water reaches its greatest weight or density. This temperature is 4° Centigrade or 39.2° Fahrenheit. If then water is heated above 39.2°, what does it do? If it is cooled below this temperature what does it do? If you had a cupful of water whose temperature was 70° F. and you heated the water, would it expand or contract? What if you cooled it? At what temperature would it stop contracting and begin to expand again?

All liquids do not act as water does, but continue to contract until they are solidified. Can you think of any practical use that is made of this fact? The thermometer is constructed upon this principle. It is a small tube filled with mercury or alcohol. When the temperature is warm what does the mercury do? When the temperature is cool what does it do? By the expansion and contraction of the mercury we are able to measure temperature.

CHAPTER XXIX

METHODS OF HEATING BODIES

How are bodies heated? Put the end of an iron poker into a bed of glowing coals, or the end of an iron rod in the flame of an alcohol lamp. Allow it to remain fifteen or twenty minutes. Is it hot at any point except where it was surrounded by the fire? How far from this point can you detect heat by touching it? What then must have taken place in the piece of iron? The heat must have traveled slowly along from the part that was in the fire to the other parts. When heat travels from one particle of a body to another in this way we say that the body is heated by conduction. How is a flatiron heated? The handle of a skillet or stewpan?

Will heat travel by conduction equally well in all kinds of material? Procure a piece of a small branch of a tree about as large around and as long as the poker or iron rod used in the last experiment. Trim oft all the twigs. Place this and the poker side by side in the bed of coals or in the flame of the alcohol lamp. Leave for ten minutes. Is the wood hot enough to burn? Is it as hot two inches from the heated end as the iron was? How far from the end can you detect heat in each? What do you conclude as to the power wood has to conduct heat compared with that of iron? Why are wooden handles placed on iron and steel pokers, and on some cooking utensils?

Place your hand on the windowpane, then on the wood of the window sash. Which conducts heat from your hand more rapidly? Since these are side by side in the room they are at the same temperature. The glass feels colder because it takes the heat out of your hand so rapidly. Which is the better conductor of heat, oilcloth or carpet? Why are woolen clothes warmer than cotton? Have the pupils make a list of good conductors of heat and of poor conductors.

While many solids are good conductors of heat, liquids and gases are very poor conductors. Air is among the poorest conductors known. Can you think of any practical application of this fact? Double windows make a room warmer, not so much because of the extra panes of glass but because of the layer of air between the two sashes.

Since air is such a poor conductor, do you think it would be possible ever to heat a room comfortably from a stove standing in one corner or in the middle of the room if there were no other method of heating? How is a room heated?

Light a piece of punk or a candle. A piece of punk is better but a candle will do. When the punk is smoking well, hold it a few inches from the stove, first on one side and then on another. Does the smoke or candle flame indicate any movement of air? How is the air moving at the sides of the stove? Above the stove? Halfway between the stove and the wall of the room? In the corner of the room? Tie the punk on the end of a pointer or long stick and note the movement of the air near the ceiling in different parts of the room. Is the movement of the colder air toward the stove or away from it? What is the direction of the heated air near the stove? Can you account for these movements of the air? You have already seen that heat expands air. Is heated air heavier or lighter than colder air? What does the cold air really do with the light air?

Fill a tumbler two thirds full of very cold water. Heat some water almost to the boiling point and put a few drops of red or black ink in it. Now make a paper tube by rolling up a sheet of paper. Hold this tube in the middle of the glass of water with the end on the bottom of the glass. Now pour some of the warm colored water into the tube. Watch it as it begins to come out at the bottom of the tube. Slowly lift the tube. Why does the colored water come to the top of the glass? Why did the ice come to the top of the glass of water in a former experiment? In the same way that the ice floats in the water, and the warm water floats on the cold water, so the warm air floats on heavier, colder air. Or we may say the cold air buoys up, or holds up, or even pushes up the lighter air. Can air ever be perfectly quiet in a room in which one portion is a little warmer than another portion? What will be the direction of this movement, from light to heavy air, or from heavy to light? With a little thinking the pupils will see that the movement must always be from the heavy toward the light.

How about air out of doors? What makes it move? When there is a difference of temperature there must be difference in pressure, hence movement of air, or wind. Other things as well as temperature may make the air lighter in some places than in others. But, whatever the cause, difference of pressure results in movement.

The method of heating by which the heated bodies move about from one place to another is called heating by convection currents. When you fill a teakettle with cold water, and set it on the stove, will there be any movement of the water while it is heating? Where will the warmest water always be found, at the top or bottom? Where will the convection current stop? When it all reaches the same temperature. When will the convection current of air in a room stop? When you light a lamp, what is the direction of the convection current which carries fresh air to the flame? Determine this by holding a smoking match or piece of punk below the burner and above the chimney.

There is still another method of heating bodies. Hold the end of the poker in the stove till it is quite hot. Take it out and hold your hand above it. Can you feel any heat coming from it? Hold your hand below and at the sides. Is heat coming from it in all directions? This kind of heat is called radiant heat. It is the heat that streams off in straight lines from any heated body. It does not have to have air to travel then. It is the kind of heat that we get from the sun.

Does a stove radiate any heat? You have only to stand in front of a hot stove to feel the heat striking your face. Set a chair about two feet from a hot stove. After half an hour or more feel the chair. How has it been heated? Chiefly by radiation from the stove. How is the schoolroom heated when it has a stove in it? A little discussion will show that it is heated by convection currents and radiation.

When the rays of heat strike a body, what becomes of them? What did the chair do with the rays from the hot stove? It absorbed them, or at least part of them. No doubt some were reflected or thrown back. Some substances allow some rays of heat to pass through them. This is true of glass. The rays of heat from the sun pass through it. What use do florists make of this?

How is the soil or ground heated? The radiant heat of the sun strikes it, and while some of this is reflected back into the air, some of it is absorbed into the top layer of soil. Just as different substances differ in their power to conduct heat, so some substances absorb heat more rapidly than others.

Lay a piece of black cloth on the surface of the snow on a sunshiny day. Beside it lay a white cloth. Under which does more snow melt? Which absorbs more heat from the sun? Which is warmer, black or white clothing? Which will get warm sooner in the spring, a black soil or a light-colored one?

How does a body that is heated lose its heat? Think again of the hot-poker experiment. Did it get cold after you held it awhile in the air? What do you mean by "getting cold"? It gave out, or radiated heat. How does the earth cool? Just as the poker did. All day long while the sun shines the earth absorbs heat. All night long it radiates heat. What do you think becomes of this heat that the earth gives out? Much of it is absorbed by the air, or rather by the water vapor in the air, and thus it warms the air. In fact, the air is warmed much more by the heat from the earth than it is from the direct rays of the sun that pass through it.

CHAPTER XXX

GERMINATION OF SEEDS

From our study of flowers we know that fertilization results in a seed. We are now ready to find out what a seed is, and what it does.

In preparation for this lesson soak a number of large beans in water overnight. Keep a few of the dry beans for comparison. Remove the covering from a soaked bean. What is inside? These two thickened bodies are called seed leaves. The short rodlike sprout is called the hypocotyl. What do you find at the inner end of the hypocotyl? This little bunch of leaves is the plumule. These three things, the seed leaves, the hypocotyl, and the plumule comprise the little plantlet in the seed. If we wish to be exact we shall call it the embryo. Another name for the seed leaves is cotyledon. A plant whose embryo has two cotyledons is called a dicot. How does the soaked seed differ from the dry one? Can you find the place where the water entered?

What does each part of the embryo produce? To answer this, plant some of the beans in moist sand or soil. These may be planted several weeks before time for the lesson. Do the seed leaves come up above the ground? What becomes of them? Why do they slowly shrivel up? The food stored in them is being used up in feeding the growing plant. What does the hypocotyl make? The pupil will be interested to see that the lower part of it makes root, while the upper part makes stem. What has the plumule become? Plant some pea seeds. Do the seed leaves come above the ground?

Soak some corn seeds at least twenty-four hours. Compare the dry seed with the soaked one. What part of the seed has been changed? This shows where the germ or embryo is located. Remove the covering from the soaked grain. You can now see the germ, which is dirty white in color. With a knife dig this out of the grain. You will find that instead of two seed leaves or cotyledons this has but one. Plants whose seeds have but one cotyledon are called monocots.

Cut the embryo open to find the rodlike hypocotyl and plumule. Which end is plumule? Which hypocotyl? To determine this, place a few soaked grains on some moist blotting paper or sand on a plate. Turn another plate over this. Keep moist. In a week the seeds will be ready to answer the question.

Is there much of the grain of corn left after the embryo is removed? This is called the endosperm. What is it for? Leave this as a problem to be solved later if there is any doubt in the minds of the pupils.

What conditions are necessary for the germination of seeds? For the following experiments beans, peas, or corn are good. Soak five seeds, place them on moist blotting paper in a cup, and set in a warm place. Treat five other seeds in exactly the same way, but place the cup in a very cool place. If some one has a refrigerator, have it placed in this. Be sure to keep both moist but not wet.

What is your conclusion as to the effect of temperature on the germination of seeds?

Arrange two other cups as in the first experiment, but in one put dry blotting paper and dry seeds. Place these side by side in a warm place. What is your conclusion as to the effect moisture has on germination?

Arrange two cups as in the first experiment. Set them side by side in a warm place. Leave one open to the light. Cover the other so that the seeds will be in total darkness. Is light necessary for germination?

Arrange two cups as above. In one place the seeds on moist blotting paper. Fill the other full of water. What do the seeds lack that are covered with water? Can they germinate without air? Test this in another way. Procure two wide-mouthed bottles of the same size. Fill each full of water and drop some dry sand into the water till it stands an inch from the bottom in one and within an inch of the top in the other. Let it stand till the sand has settled, then pour off the surplus water and drop into each five seeds. Put in stoppers and cover with melted paraffin or vaseline to keep out air. Which bottle contains more air? Note carefully to see if the amount of air affects germination.

Does the method of planting seeds have any effect on germination?

Plant some corn in a pot or can in very loose soil. Plant the same number of grain in another can, but in this one firm the soil down on the seeds with your hand. Watch carefully to see which germinates first. Place some moist soil one half inch deep in a two-quart Mason jar or a deep candy jar; close to the glass on one side plant a grain of corn, and on the other side a bean. Fill in an inch and a half or two inches more soil, and plant another seed of each kind. Continue this until the last are planted within an inch of the top. Watch to see whether depth of planting affects germination and subsequent growth of the plant.

Plant some radish or other small seeds three inches deep in tumblers. At the same time plant others at varying depths, the last a little below the surface of the ground. Note effect on growth. A good rule to follow in planting most small seeds is to cover them with soil about four times as deep as the seeds are wide.

Is there anything else worth considering in planting seeds? In putting in a farm crop or garden plant one of the most important things is to be sure that the seeds planted will germinate. Sometimes all of the conditions are right but there is something wrong with the seeds themselves. We can never be perfectly certain that a seed has the power to awaken into a growing plant until we try it. To make then a germination test of grains that are to be planted is very important.

Germination test of corn. From the fall study desirable ears of corn have been selected from desirable stalks. Now we must see whether or not these will grow. Six grains from each ear should be chosen for the test, two of these near the butt, two near the middle, and two toward the tip. A simple method of testing is to put about three inches of moist sand in the bottom of a box. Rule this off into squares, two and one half inches each way. Place six grains on each square with the germ side up. Number the squares and ears to correspond. Place a sheet of muslin or cheese cloth over the grains, cover with sand, keep moist and warm. When the grains have sprouted examine carefully and discard all ears whose six grains do not all show vigorous germination. The test may be made by putting moist sand or soil in a dinner plate, dividing it into sections and planting the grains in these. Turn another plate over the top to keep in the moisture. Encourage the children to make a germination test for the corn which is to be planted at home.

Home and Vacation Experiments

1. Plant two hills six inches deep, two four inches, two two inches. Give all the same sort of cultivation and note results.

2. Dig up a few plants that have been growing one week. Examine the grain to see if any changes are shown. Repeat with other plants at the end of two weeks' growth, and again after three and four weeks. Compare conditions. What has become of all the food material that was in the grain?

3. Cultivate one row of corn deep, and close to the hill; another shallow, early in the season, and deeper later in the season. This makes a good soil mulch which keeps the moisture in the ground. Cultivation also destroys weeds, and loosens the soil so the air may reach the roots.

4. Secure three or four varieties of corn and distribute different kinds to different pupils to plant half a dozen or more hills; cultivate well and compare yields.

5. Plant seeds obtained from stalk bearing two ears and see if you can produce many stalks with two ears.

6. Plant one stalk of corn alone in the middle of the garden in which no other corn is grown.

7. Plant two hills of white corn and two of yellow side by side.

8. Cover half a dozen ears with paper bags just at the time the silk begins to grow. (*a*) Pollinate four ears by hand, using pollen from same stalk; then cover with bags to keep other pollen from falling on silks. To do this collect some pollen in a saucer and gently rub the silk in this. (*b*) Perform the same experiment with four other ears, but use pollen from other stalks, thus cross pollinating them. Detassel these stalks to make sure that there will be no self-pollination. Compare results of (*a*) and (*b*).

9. Plant four hills forty-four inches apart with five grains in each, four hills with four grains, and four with three grains. Compare numbers of good ears produced in each lot. Compare weight of corn raised in each lot.

10. Keep a record of the time of planting, time of blossoming, time of maturing. Note effect of dry weather on corn; of wet weather. Keep a list of insects you may find on your corn plants.

Farmers' Bulletin: The Germination of Seed Corn, No. 253.

CHAPTER XXXI

STUDY OF OATS

General Problems.—What varieties of oats, and what methods of culture seem best adapted to soil and weather conditions in the vicinity of the school?

Begin the work with a study of the grain. Note its shape, size, and color. Compare different varieties in regard to these points. Remove the hull and compare the grain with those of wheat and rye.

Ask each pupil to bring in a handful of seed oats, or oats from the granary. Test these for purity. To do this have the pupils spread their samples on a sheet of paper or on the table. Look closely for foreign bodies of any sort. Are there any weed seeds? Can you identify any of these? Put all the weed seeds and trash in one pile and all the oats in another. About what per cent of your sample is oats? If you wish to be exact, weigh the sample before spreading it out, then weigh the pure oats and compute per cent. of purity.

What other characteristic do you want your seed oats to have? The most important quality of all is their power to germinate. To test this place some moist sand or soil in a dinner plate, or box. Select one hundred seeds from your sample. Scatter these over the sand, not allowing any two to touch each other. With your finger press gently each grain so that it will rest firmly in the sand, but not be covered. Turn another plate over this one, set in a warm place and keep the sand moist.

Watch for the germination of the seeds. How long after planting before the first sprout appears? Allow the grains to remain at least one day after germination begins, then remove the sprouted grains daily till all have sprouted that will. By counting the grains that are left you will be able to determine the per cent that germinated. If you do not wish to take the time to remove the sprouted grain each day, allow the plate to stand three or four days after the grains have begun to sprout, then remove those that have failed to germinate and compute your per cent of germination as before. Did all the grains show equal vigor of germination? Would you expect to get a good stand of oats from seed whose germination test was not higher than sixty or seventy per cent?

When should oats be planted? Let the class discuss this question, drawing upon their experiences for opinions. Perhaps a good rule to follow is, Sow as early in the spring as the soil is dry enough to work well.

What are the different methods of sowing oats? What is the advantage of using the drill over sowing broadcast? If you have a school garden measure off two plots exactly the same size. Measure or weigh enough oats to sow one in drills. Sow exactly the same amount on the other, broadcast. At the harvesting determine which gives the better yield. If this cannot be done in the school garden, encourage some of the boys to try the experiment at home.

How many bushels of oats does it take to sow an acre? You will probably find differences of opinion in regard to this, as some farmers believe in sowing the grain thicker than others. The average, however, is from three to three and a half bushels per acre. Does it take more or less wheat to plant an acre? It takes from one and a half to two bushels of wheat.

How deep should oats be planted? An inch of soil is sufficient, but they may be covered deeper than this and still do well. An experiment may be tried either in the school garden or at home to determine what effect depth of planting has on the development of the plant. Arrange six drills side by side varying from one to six inches in depth. Sow the same amount of seed in each drill; cover and watch results. Is there any apparent difference in the rapidity of growth? Are the heads equally well developed? Is there any difference in the amount of grain produced?

Watch the development of the plant. How long after planting till the plants appear above the ground? How low a temperature can these young plants stand? Does a frost kill them? Note the habits of growth of the plant? Does one root send up more than one stem?

The following questions may be given to the pupils to work out during vacation. When does the plant begin to send up the flowering stem? Where is this stem situated? How tall does it grow? Measure several and get the average. Are the oats throughout the field even as to height? If there are spots where they are much taller or lower than the average, see if you can account for them.

Does the flowering stem branch? This kind of a branching flower cluster is called a panicle. If the branches spread equally on all sides the oats are called spreading or panicled. If the branches are more numerous on one side than on the other they are called side oats.

Decide what kind you have growing in your field. Look at one of the small flowers. Can you find stamens and pistil?

How long does it take the grain to form after the flowers have opened? When are the grains ripe? What change in color takes place as the grain ripens? What part of the plant begins to change color first? When the leaves have turned yellow they can no longer do their work. Which leaves continue their work longest? How many good grains in one head of oats? Do you find any heads with smut on them? How has the smut affected the development of the grain? What is the color of the smut spores? Can you determine in any way what pecentage of the field is affected with smut? Count the number of blasted heads and also the good heads in ten hills in one spot in the field. Do the same in five other spots and compute the per cent. Do you find any spots of rust on the leaves? Does this seem in any way to affect the development of the plant?

How many different kinds of weeds are there in the oats field? Can you determine which are annual and which perennial? Are there any that ripen their seeds about the time the oats are harvested? Do you find any weeds just above the surface of the ground when the oats are cut? Do these develop rapidly after harvest?

Can you find any insects on the oats? Look for the green aphids. Are there any ladybug beetles and their young feeding upon the aphids?

CHAPTER XXXII

PLANT PRODUCTS

THE purpose of this lesson on plant products is to lead the pupils to discover the various substances found in plants and to prepare them for the lessons in soil chemistry which follow.

Have the pupils scrape as fine as possible one or two potatoes. Place the scrapings in a tumbler of water, stir thoroughly two or three times, and set aside to settle. Examine the next day. What do you find in the bottom of the tumbler? Drain off all the water and potato pulp, leaving nothing but the starchy-looking mass in the bottom. Boil some water over the alcohol lamp and pour a little of this into the tumbler, stirring until the starch thickens. This resembles ordinary starch used for clothes. There is a chemical test, however, that will prove beyond any doubt that this is starch. Place a small quantity of the starch on a plate or saucer, and then put two or three drops of iodine on it. Tincture of iodine that may be bought at any drug store will serve the purpose. This may be diluted with water. What is the effect of the iodine on this substance? The blue color indicates the presence of the starch. The darker the blue the more starch is present. Sometimes it is almost black. Place a drop of iodine on a slice of potato. Does it show as much starch as that which was cooked? The reason the latter shows more starch is that the boiling water causes the walls of the starch granules to burst open and the iodine can act more readily upon the starch. Pour a little boiling water over some flour and test it for starch; over cornmeal, oatmeal; cornstarch, etc.

Soak some grains of corn for forty-eight hours, or half an hour in hot water. Each pupil should have at least two grains. At the pointed end of the grain find the tip cap. Remove this. The cap may be lacking on some grains, having been left on the cob. With a knife or a pin remove the hull. You will see that the grain is covered with a thin, smooth material that with care may be scraped off with a knife. This is called horny gluten. Now dig out the germ or embryo. (See lesson on germination of seeds.) Split open the remaining part of the grain. How many kinds of material are left? Place the white, granular material found near the top of the grain in a pile. Add to it the same kind of material found near the tip. Put the hard, solid-looking substance in another pile. You now have six different substances found in your grain of corn. Test each of these with iodine just as you did your potato starch and flour. It is better to crush them as much as possible before putting on the hot water. What part shows the most starch? It is probable that the soft granular part will turn the darkest blue. This part is known as crown starch. The solid, hard part, if thoroughly boiled, will show some starch. This is called horny starch. What parts do not contain any starch? This means of course that there must be some substances other than starch in the grain of corn.

Remove some fresh embryos from soaked grains and crush them on a sheet of white writing paper. Hold the paper between you and the light. What does this show? The grease spot indicates the presence of oil or fat. Test other seeds in this way for oil, such as sunflower, squash or pumpkin, flaxseed, etc. Have some of the pupils put a small pinch of each of the following on a sheet of paper: flour, cornmeal, any cereal breakfast food, buckwheat, and ground coffee. Place the sheet in a hot oven and keep it there several minutes. Now see whether the paper shows that any of these things contain oil. Have the pupils name some plants whose seeds contain so much oil that it is extracted and used for various commercial purposes.

Besides starch and oil, plants contain other substances known as proteids. In your physiology you may have learned of albumen as a kind of proteid. One of the purest types of proteid known is the white of egg. A chemical test may be made for proteid as follows: Dissolve in a two-ounce bottle of warm water about one fifth of an ounce of caustic potash (potassium hydroxide). Care should be taken not to let the potash touch the hands or clothing. Make another solution by dissolving a piece of copper sulphate (bluestone) about as large as a lima bean in a two-ounce bottle of warm water. Place a small quantity of the white of an egg on a plate or saucer and pour a little of the first solution over it. Warm the plate gently. Be careful not to cook the egg. Now add a little of the second solution and stir with a splinter. What change of color do you note? The beautiful violet purple is due to the presence of proteid.

Soak some beans overnight. After removing the skins, crush the beans and place on a warm plate. Test for proteid as you did the egg. You may have to wait several hours before you can be sure of a change of color. A good plan is to start a number of tests on a plate and set away till the next day. Test different parts of the corn grain, squash seed, etc. What part of the corn grain shows the most proteid? What part the least?

There is another substance in plants for which you do not need to make a chemical test. You have been testing it all your life. Why does a sweet potato taste sweeter than the common white potato? Name other plants that have sugar in them. From what plants is the sugar of commerce obtained? All starch found in plants is changed into sugar before it can be absorbed by plants or animals, for starch is insoluble, and all substances absorbed by living bodies must be dissolved.

Is there any part of your corn grain that does not seem to have any of these substances named above? The hulls are made up mostly of a substance called cellulose. Cellulose is found in all plants, and is the material that gives strength and firmness to the different parts. It is found in the cell walls, in fibers of stems, roots, and leaves, as well as in fruits and seeds. It is harder and thicker in some parts of plants than others, as in stems, husks, and roots. The fibers of cotton, hemp, and flax are made chiefly of cellulose. Soak some common newspaper or writing paper in water till all the sizing is washed out. The pulp which remains is almost pure cellulose.

Cellulose may be obtained from plants by the following process: Dry thoroughly some stalks of corn or sunflower. Pulverize as fine as possible. Cover with water in which are a few drops of sulphuric or hydrochloric acid, and boil half an hour or more. Now cover with water in which you have put a little potash, and boil again. Pour off the liquid. The pulp that is left is chiefly cellulose.

One more substance may be found in plants. Here is a green leaf. Just how much starch, sugar, oil, and proteid it may have in it we do not know. But we do know that it has something besides these. Place the leaf in a bottle or tumbler and pour a little clear alcohol over it. Cover the bottle or tumbler to prevent the evaporation of the alcohol. Examine the next day. What has happened? The green coloring matter that the alcohol has dissolved out of the leaf is chlorophyll. We shall find out something about the value of this substance in a later lesson.

Where do the plants get all of these substances? A discussion of this question will bring out the fact that plants manufacture them. They may then be called plant products. It will add interest to the work to have the pupils make a collection of these plant products. These should be put into bottles and carefully labeled. The following are the products most available for this purpose:

Starch—from corn or potatoes.

Sugar—ordinary cane sugar.

Oil—linseed, cottonseed, corn.

Proteid—corn, beans, peas.

Fiber—cotton, flax.

Cellulose—prepare from stems or hulls of corn.

Chlorophyll—obtain by placing green leaves in alcohol.

CHAPTER XXXIII

SIMPLE EXPERIMENTS IN SOIL CHEMISTRY

In the preceding chapter it was brought out that plants manufacture certain plant products. Now, if plants are factories, what equipment must they have? Machinery, power, and raw material out of which to make the starch, sugar, etc. What is the source of this raw material?

By discussion it may be brought out that the environment of the plant is air, soil, and soil water; hence these are the only available sources from which the plant may obtain raw material to make the plant products.

Just how the plants procure the raw material, and how they make the foods, we shall take up for consideration in some later lessons. At present we are concerned chiefly in finding out what the materials are that the plants use in making foods and plant tissues.

We know that we cannot find starch as starch in the environment of the plants. We also know that starch is made up of several substances which are united to form what we call a chemical compound.

What is a chemical compound?

Here is some table salt which is a good illustration of a compound. It is made by the chemical union of two things, sodium and chlorine. Let us look at these. Do either of them resemble salt? Yet chemists can separate salt into these two things; although they cannot separate sodium and chlorine into other substances, and so they are called elements.

What then is an element? There are only between seventy and eighty elements known. Everything else in the world is in the form of a compound. How are compounds formed? By the chemical union of two or more elements. Just to mix the elements together will not necessarily make a compound. They must unite in definite proportions. In order to know what we mean by this you must know that everything in the world is made up of very small particles called molecules. The molecules are so small that they cannot be seen by the most powerful microscope. Each molecule is made up of still smaller particles called atoms. Now when a chemical union takes place a certain number of atoms of one element unite with a certain number of atoms of another element or elements and make a molecule of a new substance which is a compound. We know that water is a chemical compound made by the union of hydrogen and oxygen. Two atoms of hydrogen unite with one atom of oxygen to make water, hence we use the symbol H_2O to stand for water.

Chemical unions are taking place constantly in the world of nature.

Experiment.—Moisten a piece of iron (a nail or iron filings); place the wet iron on a piece of paper exposed to the air. Examine next day. What has happened? A chemical combination has taken place between the iron and the oxygen in the air. In common terms we call this rust. It is iron oxide, or if hydrogen has also combined with the iron and oxygen, which is probable, it is iron hydroxide. What happens to iron of any sort when left exposed to the air?

Another simple experiment to show a chemical combination may be performed. Place a small piece of sulphur on a bright silver coin and set the sulphur on fire. When it has burned look at the coin. What has taken place? The dark substance is silver sulphide. A chemical combination has taken place between the sulphur and the silver. Was all the sulphur used in making the silver sulphide? What did you see taking place above the coin? Was anything uniting with the sulphur to form the blue flame or smoke? This compound is sulphur dioxide. It is a gas, and escaped into the air. How did you know it was in the air?

Now in plants chemical combinations take place which result in the plant products we have found. Starch is a combination of oxygen, hydrogen, and carbon. The symbols for these are O, H, and C respectively. Proteid is a combination of carbon, hydrogen, and oxygen with nitrogen, sulphur, phosphorus, and often other elements.

Plants not only succeed in uniting elements into compounds, but in some cases they separate a compound into its elements and use the elements to make a new compound.

We may succeed in separating some compounds into their elements.

Experiment.—Heat in a test tube a level teaspoonful of potassium chlorate mixed with the same amount of manganese dioxide. After a few minutes hold a lighted splinter in the mouth of the tube. What happens? Is there something in the tube that was not there at the beginning, even though you cannot see it? The heat has caused the potassium chlorate to give out some of the oxygen that was in the combination in it. A good test for oxygen is to hold a glowing splinter in it, and the splinter will burn very brightly.

Where does the plant get the oxygen that it uses in making starch? It probably gets it, as well as the hydrogen, from the water which it gets out of the soil. What must first be done with the water?

If you wish to obtain hydrogen, place in a glass jar or wide-mouthed bottle (an olive or pickle bottle will serve the purpose) a number of small pieces of zinc, and cover with a solution of sulphuric acid and water; about a sixth or seventh as much acid as water. The bubbles that are given off are hydrogen. Be very careful not to allow the sulphuric acid to touch your hands or clothing. Place in the bottle in which the hydrogen is being generated a stopper through which a glass tube passes and extends two or three inches above. After the hydrogen has been coming off for several minutes apply a lighted match to the end of the tube. What happens? The hydrogen gas burns. This is a good test for hydrogen. Care should be taken not to apply the match until all the air is out of the bottle.

Where does the plant get the carbon? This is obtained from the air. How do we know that plants contain carbon? Place a small piece of wood (hard wood is best) on a piece of wire screen, or on a tin pie plate, or in a test tube. Heat by holding the flame of the alcohol lamp under it. When it stops smoking note what is left. This charcoal is mostly carbon. What is its color? Think of other plants which you have seen heated or partially burned, such as leaves, grass, corn stalks, brush. Do you remember seeing any charcoal or carbon?

We said the plant gets its carbon out of the air. Do you think it gets it in the form in which you see the carbon in the charcoal? It gets it in the form of a gas called carbon dioxide, CO_2. Is this gas an element or a compound? How do you know? We may make some carbon dioxide in the following manner. Place a heaping teaspoonful of soda in a glass half full of water and add to this a few teaspoonfuls of vinegar. Stir and see what happens. This gas that bubbles up is carbon dioxide. What does the CO_2 tell you about a molecule of the gas? Test for carbon dioxide with limewater. Limewater may be made by placing a piece of unslaked lime in a bottle, and filling the bottle nearly full of water. Shake well, and set aside for twenty-four hours. The clear water on top is limewater.

Pour a little of the carbon dioxide from the glass, while the bubbles are coming off most rapidly, into a glass which contains a little limewater. Shake well. What change has taken place? The milky limewater is a sure test for carbon dioxide. Test your breath for carbon dioxide by breathing through a straw or tube into a glass containing a little limewater.

We have already discussed three elements that plants use in manufacturing food. What are the other things that are needed? The following is a list of elements that plants need: Oxygen, hydrogen, carbon, nitrogen, sulphur, phosphorus, iron, magnesium, potassium (usually in the form of potash), sodium, chlorine, silicon, calcium. Many plants can get along without sodium, chlorine, and silicon.

How can we show that plants contain potash? Place some unbleached wood ashes in a dish or pan and cover with water. Stir thoroughly several times. Allow the mixture to settle, then pour off the water. Place some of the water in a cup and boil till all the water is evaporated. The yellow ash substance that is left is potash. Test it by moistening and rubbing between your thumb and finger. It feels like lye or soap.

We have seen that the first three elements named above are supplied to the plant from the water and air. Then all the rest must be obtained from the soil.

At this point it will be worth while to take at least one recitation period to discuss what soil is, its origin, and the agents that have aided and are aiding in making it.

How many of the things furnished the plants by the soil may be found as elements in the soil? Can you find sulphur or phosphorus as such in the soil? (Sulphur may be found as an element in volcanic regions.) If not, then in what form must they exist?

Examine some sulphur, and then some calcium sulphate or plaster of Paris. It is in this form that much of the sulphur that is used by plants exists in the soil. Sulphuric acid is also found in many soils.

The compounds that exist in the soil may be acids, alkalies, or salts. We may make some simple tests to determine which one of these three any chemical compound is.

Test for Acid.—Litmus paper is one of the simplest tests. Place a small piece of litmus paper in weak vinegar. What color does the paper take on? Put a few drops of sulphuric acid in half a glass of water and test with the paper. What is your conclusion as to the effect of an acid on litmus paper?

Test for Alkali.—Place a piece of the red litmus paper that you used in an acid in a weak solution of potash and water. What change in color takes place? From this you may draw the conclusion that litmus paper is red in acids and blue in alkalies. Try other substances: sweet milk, sour milk, ammonia, lime water.

Test for Salt.—Fill a glass half full of weak vinegar and slowly add to it limewater. Test at intervals with litmus paper. When the litmus paper does not change color it shows that the solution has become neutral. It is neither acid nor alkali, but a salt.

Make a weak solution of nitric acid, and add to this a solution of caustic potash until the litmus paper shows that the solution is neutral. You now have a salt known as potassium nitrate or saltpeter. You can get the nitrate by evaporating the water.

It is in the form of nitrates that most of the nitrogen that plants use is obtained. There is plenty of nitrogen in the air, but plants cannot use this. They must get all their nitrogen from the soil.

Soils may contain more acids than are good for plants. We may test soils for acidity and alkalinity just as we tested other things.

Boil a sample of soil to be tested in a small quantity of water. Let it settle, and when perfectly clear pour off the liquid into a white dish and test with litmus paper. You may have to leave the paper in for some time. If the paper turns red, what is your conclusion in regard to the soil? If blue? If there is no change of color?

A simple method of testing soil is as follows: Make a paste out of soil and water. Place one end of a small strip of litmus paper in the paste. Allow it to stand for an hour or more, and then note whether or not the color has changed. This should be tried several times before a conclusion is reached. Have the children bring in small quantities of soil from fields and gardens. Test these different kinds for acidity and alkalinity.

If a soil is acid, mix a small quantity of lime with it and test again. If a sufficient quantity of lime is applied the acid is neutralized and the soil is sweetened.

Let us now look over the remaining substances given to plants by the soil and try to get some idea of how they exist in the soil. Iron is found chiefly in the form of iron oxides. What are these combinations of? Silicon is largely in sand. Some plants seem to be able to get along without this. Calcium is in the limestones. Burn a piece of lime rock. It now becomes quicklime. Is it easily broken? Put it in water to see if it will dissolve. Potassium is in the form of potassium carbonate. Chlorine is in combination with sodium, while the sodium is frequently obtained from another compound, sodium bicarbonate. Phosphorus is in the form of phosphates and phosphoric acid.

It is easy to see that sodium cannot exist in the soil as an element. Place a small piece on the surface of water in a pan or dish. What does it do? It unites at once with the water. In the laboratory it must be kept under kerosene or naphtha.

It may be shown also that phosphorus cannot exist as an element in the soil. In the laboratory it is kept under water. It has such an affinity for oxygen that the moment it is exposed to the air it begins to unite with oxygen. Place a small piece, not larger than a sweet-pea seed, on a porcelain dish and watch it. It slowly unites with the oxygen of the air. Care should be taken not to touch phosphorus with the finger, or to leave it where it will touch anything that will burn.

Phosphoric acid may be obtained by burning a bone, pulverizing it, and placing it in a bottle with a weak solution of sulphuric acid. The lime of the bone and the sulphuric acid unite and leave the clear liquid, the phosphoric acid.

Now make a collection of as many of the elements and compounds used by plants as you can get.

Some time should be taken at this point for the discussion of what is meant by fertility of the soil. Of the ten elements that all plants must have, seven are supplied by the soil. Name these seven. Where do the plants get oxygen, hydrogen, and carbon? If any of the elements supplied by the soil are lacking or are not in an available form, we say the soil is poor, or is lacking in fertility. There are many physical conditions as well as plant materials that help to make soil fertile. These will be discussed in a later lesson. But all the proper physical conditions known will not make a fertile soil if it lacks any of the elements that plants must have in order to manufacture their plant products.

Most of the substances used by plants exist in such abundance in the soil that there is little danger of their becoming exhausted. Three elements, however, that all farm crops use are not so abundant. These are phosphorus, potassium, and nitrogen. In some places calcium also is lacking. If fields are cultivated year after year the plants are constantly removing these substances from the soil. If nothing is done to return these substances of course the soil becomes so deficient in these plant materials that plants cannot thrive in it. It is very important that farmers see to it that the lack is supplied in some way.

There are several ways in which the soil may be kept with a sufficient amount of plant materials. Among these are the application of barn manures, the plowing under of green crops, and the use of commercial fertilizers.

Among the commercial fertilizers, the following are in common use:

For nitrogen, dried blood is used. This contains twelve to fourteen per cent of nitrogen. Sodium nitrate is also used, and this contains about fifteen per cent nitrogen.

For phosphorus, steamed bone meal is used, which contains about twelve or fourteen per cent of phosphorus. Rock phosphate is also used.

For potassium, potassium chloride is used, which has forty to forty-two per cent of potassium. Kainit, which contains twelve per cent of potassium, is also used. Potassium carbonate in the form of wood ashes is also used.

Lime is used as a fertilizer either in the form of gypsum, quicklime, or slaked lime. While most soils have enough lime to supply the needs of the plants, lime is, nevertheless, of considerable value to any soil that has become acid, as we have already seen by experiment. It also helps to unlock the unavailable potash, phosphorus, and nitrogen in some soils, and changes them to a form available for plant use. Why do soils become sour?

There are a number of agencies that tend to make soils sour, especially soils that are constantly undergoing cultivation. In our study of fungi we discussed the bacteria that cause organic matter in the soil to decay. Now as this matter decays, acids of various kinds are given off. Another acid in the soil is carbon dioxide, some of which is carried into the soil by the rain. Sulphuric and nitric acids are also found in soils. Some of the nitric acid is formed in the following way: When stable manure is plowed into the soil certain bacteria feed upon it, making it decay, and at the same time making part of it into ammonia. Other bacteria feed upon the ammonia, making part of it into nitric acid. Some of this acid remains in the soil, but some of it unites with potassium or magnesium and forms nitrates. It is in the form of these nitrates that plants obtain the nitrogen from the soil.

From our study of clover and other legumes we know that nitrogen may be also supplied by growing those plants that produce root tubercles.

If possible, add to your collection samples of the commercial fertilizers. In connection with this work a number of experiments in pot culture should be started. The following is a list that has been tried successfully. Others may suggest themselves to you.

Have the children bring in some soil from a field or garden near the schoolhouse. If you have a school garden choose part of the soil from that. Use flower pots seven or eight inches in diameter or small tin buckets or boxes. If the latter are used be sure to provide for drainage. Plant oats, or spring wheat, or some flowering plants like nasturtium or zinnia.

No. 1. Leave the soil as it was when brought in. This we call a check pot.

No. 2. Mix thoroughly with the soil four grams of dried blood or the same amount of potassium nitrate or sodium nitrate.

No. 3. Potassium chloride four grams, or same amount of kainit.

No. 4. Bone meal six grams, or same amount of sodium phosphate.

No. 5. Mix together four grams of dried blood and six grams of bone meal.

No. 6. Mix four grams of potassium chloride and six grams of bone meal.

No. 7. Potassium chloride four grams, and dried blood four grams, or saltpeter.

No. 8. Potassium chloride four grams, dried blood or saltpeter four grams, and bone meal six grams.

No. 9. No fertilizer, hence another check pot.

No. 10. A small handful of slaked lime.

It will be of interest to start the same experiments in different soils. If some of the children will bring in some worn-out soil, a set of experiments in this will probably bring some good results.

Have the children bring in some soil in which red clover has been growing. Place some of it in a hot oven for an hour or more. This will kill the bacteria that are in it. Put this in a pot and plant red clover seeds in it.

Place in another pot some of the soil that has not been sterilized and plant clover in this. Water and treat both exactly alike. When the plants have grown to be quite large, dig up and examine the roots for tubercles. Why do you find them on one and not on the other?

These experiments may be varied by inoculating some clover seed and planting in some of the sterilized soil. This may be done by pouring some water over soil in which bacteria are present and shaking thoroughly. When the water is clear, pour over the clover seeds and plant.

Books and Bulletins: Principles of Agriculture, Bailey; United States Department of Agriculture: Simple Exercises Illustrating Some Applications of Chemistry to Agriculture; Office of Experiment Stations, Bulletin 195. *Farmers' Bulletins: The Liming of Soils, No.* 77; *Soil Fertility, No.* 257; *Renovation of Work-out Soils, No.* 245; *Soil Investigations in the United States, No.* 169.

CHAPTER XXXIV

SOIL AND ITS ORIGIN

SINCE soil is so closely related to plant life and indirectly to all life, we shall be interested to know something about its origin and formation.

In preparation for this lesson, have the pupils bring in different kind of soil: gravel, sand, clay, or silt, obtained from the excavations of a well or for a building; loam, the ordinary soil of field or garden; and humus, thoroughly decayed leaf mold, old logs, or stumps from the woods. If the pupils cannot procure these, the teacher should get together a collection of the different kinds of soil. To the above should be added pieces of rock of various kinds.

What is soil? Lead the pupils to give their opinions. We usually think of soil as the upper layer of earth capable of supporting plant life. How thick is this true soil? It varies from a few inches to several feet. What is under this? If you have ever looked at the side of a freshly dug ditch or well could you see a difference in the appearance of the portion of the soil near the surface and that below? This lower, lighter colored portion is called subsoil. This varies from a few inches to several hundred feet in thickness. It varies also as to material. Sometimes it is sand, sometimes gravel, sometimes very fine clay, sometimes coarser clay or silt. Under this subsoil or mantle rock, as it is sometimes called, is bedrock. Everyone who has ever heard about boring wells knows that often the well digger strikes solid rock and must abandon the excavation at that point. Some of the bed rock juts out of hillsides only a few feet below the surface, and in some places it is found on the surface. The kinds of bedrock differ in different regions.

If we look back far enough into the history of the earth, we find evidences of a time when there was no soil as we know it to-day. The surface was covered with solid rock, wrinkled and ridged into mountains and valleys. All soil has been formed from the breaking up of this solid rock.

How many agents can you think of that have helped to break up this solid rock and make it into soil? Change of temperature from hot to cold has done much to break up rock and make finer the broken rock. How does heat affect most substances? How does cold affect them? If these rocks expand when heated and contract when cooled, what is likely to happen if they are heated and then cooled rapidly? Did you ever spatter a drop of cold water on a hot lamp chimney? Why did it break?

Freezing not only helps to break up solid rock, but helps to pulverize soil. In your study of the effect of freezing on water, what did you find out? If water settles in the cracks and crevices of rocks and then freezes, what will happen?

Experiment.—Make a ball of garden soil by moistening it and working it like dough. Now put it in the oven or on top of the stove and let it get dry and hard. Pour some water over it and set it out of doors where it will freeze. What is the effect?

Rain, wind, and snow all help to disintegrate the rock. Running water plays an important part, not only in helping to grind rocks slowly into soil but also in carrying the soil from one place to another. One of the chief agents in making the soil in much of the United States was the glaciers, of which you have learned in your geography. These great bodies of ice came moving down over the country from the north, grinding up the rocks and soil, carrying vast masses of this ground-up material long distances, and finally depositing them far from the places where they were ground up.

Plants help also in breaking up rock. They do this in two ways; by their roots penetrating rocks and soil, and by an acid that they give out from their roots which acts chemically upon the soil, dissolving it.

Besides all this broken-up rock, which is inorganic matter, the soil, as we know it, has the humus or organic matter in it. This is the part of the soil that gives it its black color. It is, as we shall find out later, a most important part of the soil. Bacteria are constantly at work on the humus in the soil, making new compounds, setting free elements, and making the soil finer. So we can think of the soil not as made, but as being made. It is constantly changing, not only physically but chemically. It is losing some things and gaining some, and where it is under cultivation the gain and loss depend largely upon the methods used in cultivating it.

CHAPTER XXXV

SOME PHYSICAL PROPERTIES AND CONDITIONS OF SOIL

In the preceding lessons we have learned that plants use certain elements in manufacturing their foods and products, and that they get these elements from compounds which they obtain from the air, water, and soil. The question now arises, how do plants get hold of this raw material? In order to answer this question, we must understand something about the physical conditions of the soil as well as its chemical composition. In the first place, plants cannot use the materials of the soil unless they are soluble in water. What do we mean by this?

Experiment.—Put some salt or sugar into a glass full of water. Drop it in a little at a time, stirring gently until it disappears. Since it dissolves it is said to be soluble in water. Drop a little sulphur into the water and stir. Is it soluble or insoluble? Try some chalk dust. Place a few small pieces of limestone or marble in a tumbler. Cover it with water and stir. Do they dissolve? Drop a little acid into the tumbler. What is the effect? Does the acid aid in dissolving the rock?

We have already learned that acids of various kinds are found in the soil. Some of these acids are valuable in helping to change insoluble substances into soluble ones. Of course we know that a soil may become too sour for plants to thrive well in it. Nevertheless, some acids are indispensable.

If the raw material must be dissolved in water before entering the plant, it is evident that there must be sufficient water in the soil for this purpose. What is the source of the soil water? What becomes of the rain that falls upon the earth? Some runs off into streams, some evaporates, but some soaks into the ground. What becomes of this water?

Experiment.—Place a handful of pebbles or gravel in the bottom of a tumbler or, better, a quart jar. Cover the gravel with a piece of wire screening or cheese cloth. Then fill the jar with fine soil from a field or garden. Pour some water on the soil. What does it do? As it soaks into the soil, can you see it between the particles? Pour in more until you can see water standing in the spaces between the pebbles in the bottom of the jar. When rain falls on the ground it does just what this water did. It percolates slowly downward through the soil till it is stopped by an impervious layer, just as the bottom of the jar stopped this. If it keeps on raining, what will happen? Pour more water into the jar until it stands on top of the soil. Does this ever happen in the fields? Set the jar aside in a warm place till the water stands only a few inches in the bottom.

The water that completely fills the spaces in the soil and moves slowly downward by the force of gravity is known as free water. Plants do not use this free water. What part of the soil in the jar now has free water? If the top layer of the soil seems very dry, remove it and lay it aside. Take in your hand a little of the moist soil.

Does this have water standing in it? Where is the moisture? This is called capillary water because it is found in the pores of the soil. It is sometimes called film water, because it forms a film around each particle.

Put a smooth pebble into some water. Take it out and you can see a layer of water around it. This illustrates how each tiny particle of the soil holds a film of moisture. Capillary water is that which is used by the plants.

There is another form in which water is found in the soil. This form is known as hygroscopic water. This is held so firmly around the soil particles that it is very hard to remove. Put a little very fine dry soil into a test tube and heat it to a high temperature over the alcohol lamp. What evidence have you that this dry soil had some moisture in it?

Do different kinds of soil influence the amount of water that soaks into the ground, and the amount retained? Before answering this question let us become better acquainted with the different soils. You have in your collection several different kinds of soil; gravel, sand, silt or clay, loam, and humus. Which is composed of the coarsest particles? Rub a little of each kind between your thumb and finger. How do they differ? If you have a lens, spread a little of each on white paper and examine carefully. How do the particles of sand look? Note the jagged edges of the hardest particles. Can you find any sand particles in the loam? In the clay?

Place some sand in a large iron spoon and heat it red hot over the alcohol lamp? Does it burn? Try clay, humus, loam. Which ones burn? It is the organic matter or humus in the loam that burns. If a spoon and alcohol lamp are wanting, this experiment may be easily performed by placing the soils on a shovel on a bed of coals in the stove.

Which of the soils have the greatest capacity to take in rain?

Experiment.—For this experiment you will need five straight-topped lamp chimneys. Those belonging to the student's lamp are best. Tie firmly over the top of each a piece of cheese cloth or thin muslin. Now fill the chimneys with equal amounts of different kinds of soil. If you have both clay and silt use those and omit the gravel. The soils should not contain lumps or coarse material. Firm the soil by jarring the chimneys on the table. Have some boy make a rack for the chimneys by boring or cutting a hole for each in a board. The holes should be large enough to allow the chimneys to slip through to the large portion near the base. This board may be nailed to two uprights or may be set on two blocks so that cups or tumblers may be placed under the chimneys to catch the drippings. Having measured a definite amount of water, pour it slowly into one of the chimneys, noting the length of time that transpires till the water begins to drop below into the tumbler. Keep a record of the amount of water you pour in. Do the same with each of the other chimneys. Which soil took in the water most rapidly? Which drained most readily? Which was most porous? Which took in the water most slowly? Which is capable of holding the greatest amount of moisture? To determine this, measure the amount of water that dropped from each chimney and compare with amount poured in.

Vary this experiment by filling one chimney with clay, and another with the same kind of clay mixed with an equal amount of humus. Pour the water in as before. What is the effect of humus on the porosity of the soil? It will take several days to complete these experiments. In the meantime, cover the chimneys to prevent evaporation of moisture from the soils.

What kind of water dripped from the soils? This was, of course, the free water that in a field could be removed by under drainage. The most common method of under drainage is by tiles made for this purpose. Later we shall see that drainage benefits the soil in many ways. From your experiments, which do you think stands more in need of under drainage, a field with a sandy subsoil or one with a heavy clay?

Is there any water left in the soil after the free water has all dripped out? What becomes of this capillary water?

Fill a tumbler with moist soil. Over it invert another tumbler the same size. Set it aside. Examine after twenty-four hours. What do you find on the inverted tumbler? Where did the moisture come from? What may be done to prevent the evaporation of water from the soil? Again place moist soil in the tumbler. Put on top a layer of very dry, fine soil, one inch deep. Invert a tumbler over this as before, and note whether or not any evaporation takes place. If the moisture in the top layer of soil evaporates, does this in any way affect the moisture farther down in the soil? There is a movement of capillary water through the soil which we can best understand by some experiments.

Fill the lamp chimneys once more with the different kinds of dry soil. Stand them in a dish or pan of water so that the mouth over which the cheese cloth is tied will rest about half an inch in the water. What happens? What makes the water creep upward in the soils?

Hang a towel over a desk so that about an inch of the corner will rest in a dish of water sitting on the floor. What takes place? The same thing is happening in the towel and in the soil. The water is slowly rising. This is due to what is known as capillarity or capillary attraction. To explain fully why this takes place would take us too far into the subject of physics. It is enough for us to know that liquids rise long distances through small tubes or pores. We have a good illustration of this in the ordinary lamp wick which conveys oil from the bowl of the lamp to the top of the wick.

In which kind of soil does the water rise most rapidly? In which does it reach the greatest height? If a field has an abundance of water in the subsoil this may be lifted by capillarity to the place where it will be of use to the growing plants. What becomes of this water as it reaches the surface of the ground? May much of it be lost to the plants by evaporation? Is there anything that may be done to prevent this waste of moisture during the dry, summer months? We saw that a layer of fine, dry soil on the moist soil in the tumblers retarded evaporation. Now place in two tin pails (lard or syrup pails will serve the purpose) equal amounts of moist soil. Firm the soil slightly by jarring the pails. Set them side by side. Leave one undisturbed, but in the other stir thoroughly the upper two inches of soil every day. Weigh at the end of a week.

Which has retained the most moisture? Why? Which will keep the more moisture, a field in which the soil is frequently stirred on top with a cultivator or one which is left undisturbed? Can you see why this is true?

Place a lump of loaf sugar so that the lower part will rest in some red or black ink. Does the ink rise by capillarity to the top of the sugar? Place another lump beside this one with a layer of granulated sugar scattered over the top. Does the ink rise as rapidly through the loose sugar as through the lump? Why?

In the same way, as long as the soil is left alone, the water is constantly moving by capillarity to the surface and evaporating. A layer of dry soil on top stops the capillary flow of water and the moisture is conserved for the use of the plants.

Vary the soil experiments by mixing humus with clay in one chimney and with sand in another, and by putting lumpy soil in one and fine soil in another.

In your study of germination of seeds you found that warmth was one of the conditions that affected the germination. Does moisture in any way affect the temperature of the soil?

Experiment.—For this experiment you will need two cans; baking powder or tomato cans. In the bottom of one punch a number of holes for drainage. Fill them with the same kind of soil, and water thoroughly so that some water stands on the top. Set them side by side in a warm place, or in bright sunshine. Insert a thermometer an inch under the surface of each and take readings several times during the day. Which shows the higher temperature at first? Later in the day? What is happening in the one that has holes in the bottom? What is your conclusion as to the effect of drainage on temperature of soil? Other conditions being the same, which will give you the warmer soil in the spring, a field that has under drainage or one which has not?

Thus far we have seen that the soil contains water and certain chemical compounds that are used by the plants, also that different kinds of soil differ in regard to their physical properties. We are now ready to find out something about the relations of plants to the soil and water.

Farmers' Bulletins: Exercise in Elementary Agriculture: Office of Experiment Station, Bulletin 186; *Management of Soils to Conserve Moisture, No.* 266; *Soil Moisture, etc.; No.* 87; *Some Soil Problems for Practical Farmer, No.* 306; *Farm Drainage, No.* 40.

CHAPTER XXXVI

HOW PLANTS DO THEIR WORK

We are now ready to consider plants in relation to their environment and find out something about how they do their work. One of the first questions that comes to us is, how do roots of plants get the water with the other raw material from the soil?

Experiment.—Put some moist blotting paper or sand in a dinner plate. Scatter over this at some distance apart a number of radish or oat seeds. Turn another plate over this to keep in the moisture and set in a warm place. Water if necessary. At the same time plant a few seeds in a pot or can of soil. After five or six days examine the plants in the plate. What do you find on the roots? Those delicate threadlike structures are root hairs. On what part of the roots do you find them most abundant? Watch a plant for several days to see whether any of the hairs wither and die and whether new ones continue to appear. Are there any at the very tip of the root? Can you see any advantage in not having root hairs here? Note what direction the tips take as they grow. What do you think is the use of the root hairs? If the little plants were growing in the soil instead of on blotting paper the root hairs would penetrate the spaces between the particles of soil. Pull up one or two of the little plants that are growing in the pot. Do any of the soil particles cling to the roots? They are really clinging to the root hairs. Of course in pulling up the plants you pulled off most of these delicate hairs. If, then, these hairs are penetrating the spaces between the soil particles are they in close contact with the film water on the particles? They are so surrounded with this moisture that they absorb it. The next experiment will help you to see how they do this.

Experiment.—Remove the shell from the large end of an egg, leaving a space about as large as a quarter. Be careful not to break the skin. This is easily done by gently striking the egg till the shell is full of small cracks, then picking it off in little pieces. Make a small hole through both shell and skin at the small end of the egg. Over this, place the end of a glass tube four or five inches long. Stick the tube firmly to the egg by means of sealing wax or paraffin. Another way to fasten the tube on is as follows: cut from the lower end of a candle a piece about one-half inch long, bore a hole in this just the size of the tube. This may be done by pushing a nail through it. Heat the end gently, and stick it to the egg, so that the hole in the candle covers up the small hole in the egg. Heat a long nail or piece of wire and rub it over the edges of the candle, fastening it more securely to the egg. Now place the tube in the hole in the candle, and with the hot wire fasten it securely. Fill a wide-mouthed bottle, a pickle or olive bottle, with water and set the egg with the large end in the mouth of the bottle so that the membrane will be surrounded by the water. Set it aside for a few hours or overnight and then examine. What has happened? What pushed the white of egg up into the tube? Lift up the egg and examine the lower part. Does it seem to have anything more in it than when you placed it on the bottle? The fact is that water has passed through the membrane into the egg. So much has gone in that some of the white of egg has been pushed up into the tube. The process by which liquids or gases pass through animal or plant membrane is called osmosis.

This process may be shown in another way. Have a butcher remove a piece of the thin membrane from a leg of lamb or mutton, or when butchering time comes have some of the pupils save the skin or pericardium that surrounds a pig's heart. You can spread this out, dry it, and keep it any length of time. Tie a piece of this membrane over the large end of a student's lamp chimney, moistening it thoroughly, first by soaking in a little warm, soapy water. Fill a tumbler two-thirds full of water colored with red ink. Place in the lamp chimney a little clear water so it will stand about an inch and a half from the bottom. Now hang the chimney so it will rest in the colored water. Set aside for a few hours and then note what has taken place. Has any water passed into the chimney through the membrane? Instead of water in the chimney place some thick syrup and hang it in the water.

How do these experiments show what is taking place in the soil between the water and the root hairs? The walls of the root hairs are very thin and by osmosis the soil water with the plant materials passes readily through them. At the same time it is probable that a little of the thicker substance in the root hairs passes out into the soil.

It will be an easy matter to show that roots seek moisture. Remove a portion of the bottom of a chalk box. Tack a piece of wire screening over the hole. Now put into the box about three inches of moist sand or sawdust. Place directly over the screening three or four beans or grains of corn. Set the box upon blocks. Keep the sand moist. Lift up the box occasionally and examine from beneath. Can you see the roots? Did any of them grow through the wire? Why did they turn backward?

This characteristic of roots to seek moisture may be shown in another way. Trim a little off the side of a chalk box lid so you may push it down into the box, making a partition through the middle. Near the bottom of this partition cut or bore a hole as large as a half dollar, and tack a piece of wire screening over it. Place clean sand or soil in the box, and plant beans or corn on one side. After the seeds have germinated, put a very little water on the side of the partition where the plants are growing; just enough to keep them alive. Keep the other side well moistened. After two weeks, carefully dig down and examine the roots. Have you any evidence that the roots seek moisture?

If in a field the level of the free water lies near the surface in the spring, will the young plants send their roots very far down into the soil?

Experiment.—Take two tin cans. In the bottom of one punch holes for drainage. Fill each with moist soil and plant corn or beans. Set them side by side. Place exactly the same amount of water in each from day to day. Do not water too much. After a few weeks note the effect on the roots. Which have sent their roots farther down?

Does under drainage tend to make a long or short root system? Which plants will fare better during the dry season, those whose roots have grown to a good depth or those whose roots are near the surface?

To prove how dependent plants are upon water, try the following experiment. Have growing side by side in pots or cans plants of the same kind: sunflowers, beans, or any house plant. Give to one all the water needed. From the other withhold water entirely for a number of days. What is the result? Now begin to water the wilting plant and note effects. What is it that helps to hold an herbaceous plant rigid and upright? Is this an important use of water in plants?

It is possible to determine with some accuracy how much water plants contain. Pull up two or three plants. Weeds will serve the purpose well. Wash the soil off the roots and weigh the plants. Spread them out on a sheet of paper in the room and weigh at intervals of three or four days. Do they continue to lose water for any length of time? By what physical process are they losing the water?

Can you think of any way that we may prove whether or not it is the water alone that supplies the needs of the plants? Has rain water any of the chemical compounds in it that soil water contains?

Experiment.—Fill two pots or cans with clean sand, fine gravel, or sawdust. Plant in each three or four beans, peas, or sunflowers. Water one with rain water, the other with well water. If you wish to be certain that the water contains plant food, stir a quantity of rich soil having plenty of humus into some rain water, let it stand several days, then drain off the water and use this instead of well water for the second pot. This solution should be renewed at least once a week.[1]

We have now seen that that soil water with raw material goes into the roots. We have also seen that one function of this water is to hold the plant rigid. We are now ready to ask, Where does this water go, and what finally becomes of it?

Experiment.—Cut off a growing twig from a maple, or box-elder tree; also the stem of a growing bean or sunflower close to the ground. The plant should be at least five inches high. Place these cut stems in a tumbler half full of water to which you have added a tablespoonful of red ink. Allow these to stand twenty-four hours. With a sharp knife slice off small sections of the stems and examine closely. Through what part of the tree stem did the water travel upward? This is called the wood, the soft portion in the middle is the pith, and the portion outside the woody part is the bark. If you look at this closely you will see that it is made up of three layers—the brown epidermis on the outside, the green layer in the middle, and the white bast on the inside. The sticky layer between the bast and the wood is the cambium. Where did the water travel upward in the sunflower? In the bean? Those spots are made of woody fibers and correspond to the wood in the maple twig. You will remember in the study of germination of seeds that we classified plants into dicots and monocots. Is a bean a dicot or a monocot?

---

[1] The above experiment may be tried by using food tablets in the water. These tablets contain the same kind of compounds found in the soil. They may be procured at ten cents a box with directions for using from Edward F. Bigelow, Stamford, Conn.

All the stems you have examined thus far are dicots. Through what part of the stem of a dicot, then, does the water move upward?

Place some monocot stems in the red ink solution to determine where the water travels through them. A corn plant nine or ten inches high, a stem of a tulip flower, a trillium, an asparagus stem, or any lily will do for this experiment. The spots in the sections show the ends of bundles of fiber. So in monocots the water travels through these fiber bundles.

Is all the water taken into the plant used in the plant?

Experiment.—Cover with glazed or writing paper the top of a pot in which a plant is growing vigorously. To do this slit the paper to the center and cut out a space big enough for the stem. Now slip the paper around the stem and tie around the top of the pot. Turn a glass jar over the plant and let it stand in the light a few hours. What do you find on the glass? Where did the drops of water come from? This process is called transpiration. The leaves transpire, or give out moisture constantly. With a microscope we should be able to find in the thin skin or covering of a leaf small openings. These are called stomata. One is a stoma. It is through these that transpiration chiefly takes place. If you have a pair of balances you can find out by a simple experiment which side of a leaf contains the more stomata. Take from a bean, sunflower, geranium, or nasturtium two leaves of the same size. Balance these on the pans of the scales after having covered the upper surface of one leaf and the lower surface of the other with vaseline. Watch for several hours. Which one has lost the least water during this time? What does this show as to where transpiration takes place more rapidly?

We are now ready to find out something about the way in which plants manufacture their products. To understand this we must know something about leaves.

Examine a leaf of any plant. What are its parts—stem or petiole, expanded portion or blade. Hold the leaf between you and the light. What do you see in it? How are the veins arranged in a bean leaf, maple, sunflower? These are net-veined leaves. How are the veins arranged in a corn leaf? In grass? These are parallel veins. What is the use of the veins? By discussion the value of the veins in holding the leaf spread will be brought out. Place a twig with growing leaves in a tumbler of water colored with red ink. After twenty-four hours examine the petiole, the veins. What do you conclude? If you can procure a thick leaf, as live-for-ever, tulip, or hepatica, have the pupils peel off a little of the skin or epidermis. Even a thin leaf may have a little of the covering removed, enough to lead the pupils to see that the entire leaf is covered with a thin, almost transparent skin. What is under the skin? This green, granular mass is chiefly chlorophyll bodies. If the pupil could see a cross section of a leaf highly magnified he would find it built up of cells one layer above another. Each cell has a thin wall and contains a number of green, roundish bodies called chlorophyll bodies, and a mass of colorless protoplasm. The protoplasm is the living part of the leaf, and is the machinery that manufactures the plant products. But just as any machinery must have power to make it run, so must the protoplasm of the leaf. What is the power?

Experiment.—Fill a box or dinner plate with soil and sow some oats or wheat seeds. After the grains are sprouted, cover one-half the plants with a box or tin can. Give all the plants the same amount of water. After a week compare the plants grown under cover with those grown in the light. What do the former lack? What is your conclusion as to the ability of the plants to make chlorophyll without light? Can the plant make starch without chlorophyll?

Experiment.—Cut two thin slices from the end of a cork stopper. Place one slice on the upper surface of a leaf of a vigorously growing geranium, or better, a nasturtium and the other slice directly beneath. Stick a couple of pins through them to hold them on. Leave them till the afternoon of the next day if the sun has been shining. Now remove the leaf from the plant and the piece of cork from the leaf. Boil the leaf in water for a few minutes. Soak the leaf for several days in strong alcohol. Change the alcohol until you are sure all the chlorophyll is dissolved out. Rinse out the alcohol with plenty of water, then place the leaf in iodine for fifteen or twenty minutes. Rinse off with water. Does any part of the leaf show the presence of starch? Is there any starch where the leaf was covered from light with the slice of cork? It is a good thing to try several leaves at once. Some will probably be much more successful than others.

Without light, then, plants cannot make chlorophyll, and without the chlorophyll no starch, protein, or other product can be made by the protoplasm. The light then is the power that runs the machinery, but the chlorophyll is the connecting link between the power and the machine.

In some way it succeeds in hitching them together so that they may do their work.

We have only to think back to our study of soil chemistry to remember that starch is made out of oxygen and hydrogen from the water, and carbon from carbon dioxide of the air, and that proteids contain these three elements with the addition of nitrogen from nitrates, sulphur, phosphorus, etc., from the soil. The leaves take in the carbon dioxide probably through their stomata. What must be done with this compound before the plant can use the carbon? If the protoplasm decomposes the carbon dioxide and uses the carbon, what becomes of the oxygen? It is thrown out of the leaf into the air. Therefore, when a plant is actively engaged in manufacturing starch it is taking carbon dioxide from the air and giving out oxygen. Could this process be carried on during the night? Why?

The question now arises, what do the plants do with the starch proteids and oils that they make? By discussion the facts may be brought out that the starch by a process something like digestion in our bodies is changed into sugar, and that this and the other foods are conveyed in liquid form from the leaves to all parts of the plants when they are used in the growth of these parts. Some of the food is stored for future use. Recall the study of potato, corn seeds, biennial roots, etc.

Dig up some corn plants that have been growing two or three weeks. Examine the grains. What has become of their contents?

But plants need something besides food in order to live and grow. They are like animals in this respect. They must have air to breathe as well as food to eat. They cannot live without the oxygen of the air any more than animals can. In our study of germination we proved that air was necessary for the beginning of growth from the seed. Is it necessary for further growth of the plants?

Experiment.—Place a plant that is growing in a very small pot or can in a quart Mason jar. Put water enough in the jar to stand almost to the top of the pot. Screw the top on tightly, using a rubber as in canning fruit. Allow it to stand several days. What takes place? What have you deprived the plant of? The plant droops because you have cut off the supply of fresh air or oxygen. If you leave it long enough here it will die. Do the roots need oxygen as well as the leaves and stem? In a can or pot in which a corn or other plant is growing, pour water until the soil is completely saturated and the water stands on top around the stem. Now set the plant in a jar of water completely covering the brim of the pot. Keep in this condition several days and note effect. What part of the plant is deprived of air? Is there any air in the soil when all the spaces between the soil particles are filled with water? Fill a tumbler full of dry soil. Pour water in one spot. Watch for bubbles of air that the water is driving out. What happens to corn or oats on which the water stands for several days? They are "drowned out" because air is cut off from their roots. It is well to know that plants in the act of breathing throw out carbon dioxide just as animals do. It is worth while knowing also that breathing or respiration in plants goes on all the time both night and day.

CHAPTER XXXVII

HOW TO KEEP THE SOIL IN CONDITION TO SUPPLY THE NEEDS OF PLANTS

Now that we know something about the needs of plants and the work they do, we are ready to consider what may be done not only to produce good crops, but to insure the production of good crops in the future.

One thing to be considered is tillage. This is of two kinds: the breaking up or the plowing in preparation for the seed, and the cultivation of the soil when the crop is growing. The plowing may be done in the fall or spring. Can you think of any advantages of fall plowing? What is the effect of freezing on the soil? There may be some disadvantages in fall plowing in some localities. Where there is a subsoil of sand, heavy rains may wash out or leach from the soil some of the soluble compounds that with the spring plowing might have been saved for the plants. One of the most important things to think about in tillage is the preparation of the seed bed, so that it may be fine and fit for the seeds.

Experiment.—Plant some corn seeds in a pot containing coarse, lumpy soil. In another plant seeds containing the same kind of soil that has been made fine. Water both. In which do the seeds germinate first? Which plants thrive best after germination?

What are some of the other benefits due to tillage? It increases the depth of the soil. How does it do this? Which is better, shallow plowing or deep? Why? If year after year only the upper three or four inches of soil are turned over, this will become so depleted of its plant foods that it will be "worn out." Besides, the lower layer of soil will become so packed and sour that it will be utterly unfit for the plant roots. How will deeper plowing prevent this? Tillage also aids in the saving of moisture. How? It also loosens the soil so that it will hold more air and be better ventilated. It kills out the weeds, and thus prevents a loss of plant foods and water. By breaking up the soil particles it renders the plant foods more available. It turns under vegetation and thus increases the amount of humus in the soil.

The second thing to consider in helping the soil to supply the needs of plants is drainage. We have already seen some of the advantages of under drainage. It renders the soil more porous. It increases the temperature in the spring. It gives an opportunity for better ventilation. It results in a deeper root system. Proper tillage and drainage then are two very important forces in maintaining good physical conditions of the soil.

The rotation of crops is another important consideration. Agriculturists are coming to believe more and more that to grow the same kind of crop in a field year after year will result in absolute ruin to the soil. There are several reasons for this. One is that certain kinds of crops use more of one kind of plant material than of others. After a number of years the soil is so lacking in this particular compound that it is difficult to grow any kind of a crop in it. Another probable reason is that each plant gives out a certain amount of organic waste matter into the soil. When a plant has been grown for a term of years in one locality, the soil becomes so full of this poisonous waste that the plant can no longer thrive in it. This substance is not so poisonous to other plants, and thus by a wise rotation of crops this waste need not result in disadvantage to the plants. Rotation also gives an opportunity to kill out weeds that are likely to persist if the same crop is grown year after year.

Every region must settle for itself the crops that are to be rotated; but every farmer in any locality should adopt a definite system of plant rotation. In the Middle West, where corn is the staple crop, a three-year rotation is carried on successfully in some places. This consists of oats or wheat, clover, corn.

One important result that comes with crop rotation is the increase of humus. Humus is added in the plowing under of the oats or wheat stubble, as well as the stems and roots of the clover. The value of humus in any soil cannot be overestimated. From our experiments what do you know of the effect of humus on the capacity of soils to hold moisture? Besides this, humus improves the texture of the soil, adds plant foods, and helps to make available other plant materials that are locked up in the soil.

What are the sources of humus? We have already mentioned the plowing under of stubble and clover. What plant food does the clover and other legumes add to the soil? Other crops besides legumes are sometimes raised and plowed under for the purpose of supplying humus. Such crops are called green manures. Rye is frequently used in this way. Stable manure is by far the best source of humus. It not only improves the physical condition of the soil but adds some of the most important plant foods, phosphorus, nitrogen, and potassium. It is the most perfect of all fertilizers.

One thing more is done in many places to keep up the fertility of the soil, and that is the use of commercial fertilizers. This we have already discussed in our study of soil chemistry. Just what plant materials may be lacking in any soil can be told only by testing the soil, not in the laboratory but in the field. Any boy can have a fertilizer plot in which he can determine whether the application of commercial fertilizers will increase the productiveness of the soil. See suggestion for home experiment.

To sum up the whole story then. In order to increase the fertility of the soil we must see to it that the soil is kept in good physical condition by proper tillage, drainage, and the addition of humus; and that the plant materials that are removed by the plants to manufacture their products be returned in good measure in the form of stable manures, leguminous plants, green manures, or commercial fertilizers.

Farmers' Bulletins: Beneficial Bacteria for Leguminous Crops, No. 214; *Soil Inoculation for Legumes; Bureau of Plant Industry, No.* 71; *Cowpeas, No.* 89; *The Soybeans as a Forage Crop, No.* 58; *Alfalfa or Lucerne, No.* 31; *Alfalfa Growing, No.* 215; *Drainage of Farm Lands, No.* 187; *Practices in Crop Rotations, No.* 289; *Relation of Sugar Beets to General Farming, No.* 320.

PART FOUR

CHAPTER XXXVIII

BIRD STUDY

Reasons for Bird Study.—There are several good reasons why bird study should find a place in our public-school programmes.

The boys and girls should be taught to recognize the value of birds from an economic standpoint. Few persons who have not made a careful study of birds and their habits have any adequate notion of what benefactors these little creatures are to farmers, fruit growers, and gardeners.

The forces of nature are so nicely balanced that we are scarcely aware of their existence till something disturbs the equilibrium and we feel the resulting disorder. Because our crops are not destroyed every year by insect pests we give little heed to the matter, and never realize that if it were not for the birds that keep these pests in check many of our cultivated fields, as well as our forests, would become "Deserts without leaf or shade."

According to Hornaday the fact is well established that birds are less numerous in United States now than they were a hundred years ago.

One cause of the decrease is due to the changed conditions brought about by the forward movement of civilization. As the woods have been cleared, the prairies broken up for cultivation, and the swamps drained, nesting and feeding places of many birds have been destroyed. These birds have been compelled to do one of three things: retreat to more inaccessible haunts, adapt themselves to the new conditions, or give up their lives in the struggle.

While several species have become practically exterminated, many have succeeded in adjusting themselves to the changed conditions and thrive just as well, or better, under the new order of things as under the old.

There are other causes, however, which constantly tend toward the destruction of our birds. Among these are cats, English sparrows, and other natural foes, besides the indiscriminate shooting of birds on the part of many hunters.

Another important cause is the wholesale robbing of nests, and often the destruction of entire broods of young birds by boys who are seized with a mania for collecting eggs. Like many other fads the collecting craze is dangerously contagious. Let one boy in a village or school district catch the disease and a score of others are attacked immediately. The result is that almost every nest for miles around is spied out and ruthlessly pillaged.

Occasionally this may result in value to the collector. It may bring about a genuine love for the birds and a knowledge of their lives and habits that is worth while, but in ninety-nine cases out of every hundred the result is a lessening of the number of birds without gain or profit of any kind to the boys.

Another cause of bird destruction is the prevailing fashion of decorating women's hats with bird skins, wings, breasts, etc. The number of birds sacrificed for this purpose every year is appalling. An editorial in the *Forest and*

Stream a few years ago mentions a dealer who during a three-months trip to the coast of South Carolina prepared no less than eleven thousand and eighteen bird skins. This is but one instance. Many others of the same sort might be quoted. It is a well-known fact that in Florida the white heron is becoming practically extinct because so many of the delicate, graceful plumes known as egrets, have been transferred from the backs of the birds to the hats of American women.

It is also true that on many islands along the Atlantic coast gulls, terns, and other sea birds have been almost exterminated for the same reason.

But we must not imagine that it is only Southern and sea birds that are slaughtered for the millinery trade. Many bright plumaged birds of our Middle West suffer the same fate. An Indianapolis taxidermist stated that in 1895 there were shipped from that city five thousand bird skins, all collected in the Ohio valley.

If women could be brought face to face with the facts, if they only knew the terrible cruelty practiced in securing bird skins, if they realized the great loss to the country due to the destruction of so many insect eaters, the sacrifice would be stopped. But they do not know and the destruction goes on.

In view of all these facts, is it not time that we make an effort to awaken in our boys and girls a genuine interest in the protection of our birds?

When the girls of our public schools have been thoroughly aroused to use their influence in the right direction, the problem of how to prevent the killing of birds for millinery purposes will be solved.

Likewise, when the boys clearly see and appreciate the value of birds in orchard, field, and forest, the collecting of eggs and the use of air guns and sling shot will cease.

While the first practical reason is a strong one for urging bird study in the schools it is not the only one. The study is worth while because of its educational value; it quickens ears and eyes, as well as sharpens the intellect and develops patient self-control.

Its æsthetic value is hard to estimate. Few natural objects are so well adapted to touch the finer chords of ones being. The beauty of form and color and song stimulates the imagination and awakens the poetic sense.

Suggestions for Bird Study.—Bird study to be successful must be a study of living birds in their natural haunts. In no other way can we hope to establish a permanent interest in the subject. While out-of-door observations are essential, it may not be practicable for classes to make these observations during school hours, nor is this necessary. A little planning makes it possible to do the work with ease outside of school hours. For the lower grades a short trip at the close of school now and then is sufficient. With the older classes early morning excursions will prove very profitable. This is easily accomplished in towns and villages where the children may come together without going long distances. In rural districts the pupils may start earlier than usual some morning and have an hour's study before nine o'clock, or they may take time after school for a short ramble. Numerous field trips are not necessary. The study is so attractive in itself that usually two or three excursions are sufficient to arouse the enthusiasm to such a pitch that the teacher finds herself almost overwhelmed with descriptions of birds and questions about birds.

The spring is undoubtedly the best season of the year in which to emphasize bird study. For beginners no time is better than the latter part of winter or very early spring. Only the winter birds are to be found at this time and the acquaintance of these may easily be made before the migrants arrive from the south. Also the birds are less shy, more numerous, and more musical at this season than at any other. Then, too, the buds are only beginning to open and the birds cannot hide behind clumps of foliage as they are able to do later in the season.

The following are suggestions for conducting classes in the field: Quietness on the part of every member of the class is essential. Loud talking and laughing must not be allowed. Move slowly and together. One member who is inclined to chase ahead may spoil the study for all the rest. Make the most of one bird when opportunity offers. If two or three birds appear in the same locality at the same time there is a temptation to try to see them all at once. The result is that nothing definite is observed about any one of them. Strive for accuracy of observation. Do not form the habit of making decisions without sufficient data. One feather does not make a bird. Stop now and then and be perfectly still in order to locate birds by their notes. Occasionally divide the class into small companies. Let each group take a different direction for study. A comparison of reports from the different groups will make a profitable exercise. Encourage the children to feel that it is just as important to become better acquainted with the birds they know already as it is to identify new ones. Help them realize that it is not color alone, but the habits and movements that will enable them to identify new birds and recognize old acquaintances. As far as possible keep your back to the sun, otherwise the colors are likely to be misleading. Opera or field glasses in the hands of the teacher and possibly the older pupils aid materially in the study, but they are not indispensable. All the larger birds and many of the smaller ones may be identified with the unaided eye. If you know of a small stream or pool where birds are in the habit of gathering to drink and bathe, you may study many different specimens by sitting quietly near the spot and watching the birds as they come to the watering place.

A simple outline that may easily be kept in mind, similar to the one given below, adds definiteness to the work.

Where is the bird? What is it doing? What is its size? Compare with robin, English sparrow, or house wren. What is the color of head, neck, back, wings, tail, throat, breast, belly? Color and length of bill. Do you notice any special color markings when the bird flies?

While the study should receive its greatest attention during the spring months, much may be done in the fall at the beginning of the school year. If certain birds have been studied in the spring, observation of these should be continued in the fall. Any difference in habits that the birds have taken on should be noted. The young or immature of many species differ greatly from the adults in color markings. The fall is a good time to identify them. Many of the summer residents gather in flocks several weeks before starting on their journey southward. This is true of robins, bluebirds, blackbirds, cowbirds, doves, meadow larks, song sparrows, and others. The number of birds in a flock may be noted, where the different groups may be found, whether or not all the individuals in a flock look alike. A record should be kept of the date when the last flock was seen. Watch to see if any stragglers are left after the flocks have disappeared. During September and October flocks of migrants that spend the summer farther north will be found in abundance.

The winter residents begin to appear about the same time. It is worth while to continue the observation long enough to enable the children to determine for themselves which birds are winter residents and which migrants. When the leaves have fallen from the trees, nests that have been hidden away during the summer are exposed to view. They may be counted and in this way the number of birds that reared young in the neighborhood be estimated. Children who live in the country will be interested in finding out how many nests are stowed away in the osage hedge rows that border the roadside. The location of nests may be noted as to whether they are in a crotch or on a horizontal limb, whether in a tree or bush, and how far from the ground they are built. Determine whether certain species of trees and shrubs are preferred to others. A few nests may be collected and studied, noting how they are made, the material used, the skill with which they are put together.

The outdoor study may well be supplemented with short exercises in the schoolroom. Fifteen or twenty minutes a week will be ample time for this work. Give the children a few definite points to find out about some bird they are studying. Take a few minutes to compare reports of these observations. Keep a list with dates of the birds actually seen by the class in the field. Encourage older pupils to keep individual bird calendars. Help the children to form the habit of caring for weak and wounded birds. Have them try to attract the birds about their homes as described in another paragraph.

Bird study may easily be correlated with language work and drawing. Many interesting compositions may be written on topics that bear upon the bird study: What I saw during an early morning bird trip. What the woodpeckers do for us. What we may do for the birds. What I saw a robin doing. Why should native sparrows be protected? The water-color hour may well be spent now and then in painting a bird that has been seen and admired.

How to Attract the Birds.—The number of birds in any neighborhood depends largely upon the abundance of food supply, the number of suitable nesting and roosting places, and whether or not the birds feel a sense of security against natural foes. Much may be done to make the surroundings of our homes and schools so attractive that the number of birds will steadily increase.

Trees and shrubs are perhaps of first importance; without those we may not hope for an abundance of bird life. While trees of any sort are better than none, some kinds seem to have a greater attraction for birds than others. This fact may well be taken into consideration when trees are being set out in our yards, or along the streets and in the parks of cities. Maples of various kinds are attractive to robins, wood thrushes, gold finches, and other birds that like crotches in which to build their nests. Elms are regarded with special favor by orioles. Evergreens are general favorites, affording nesting, feeding and roosting places for a great variety of birds. Clumps of shrubs in the corner of yards or gardens are not only beautiful in themselves, but serve as nesting places for at least half a dozen different species.

For birds that build in cavities, boxes and other receptacles may be prepared with little trouble. Any boy or girl who knows how to use a saw, a hammer, and nails can make a birdhouse. It is not necessary to have it fancy or elaborate, only comfortable and roomy. Indeed, a wren or chickadee will often choose a plain, inconspicuous cigar or starch box in preference to a modern apartment house painted up in bright colors. There is nothing better for birdhouses than old weathered boards. These should be left unpainted. If new boards are used they should be painted a dull, dark green or a barklike gray. The entrance for wrens and chickadees should not be more than an inch in diameter; the size of a quarter dollar is a good size. This is large enough to admit the wren, but too small to allow an English sparrow to slip in. For blue birds and martins a two-inch hole is sufficient. Other receptacles than boxes are often received with apparent satisfaction. Old coffee and tea pots which are fastened up in some trees of our garden have been occupied a number of years by wrens and bluebirds.

Birds may often be induced to build near our homes by providing them with suitable building material. Twine strings of different colors hung upon the branches of trees or some other accessible place usually prove a real bonanza to orioles, as well as to yellow warblers, indigo buntings, and cardinals. Strips of cloth an inch or so wide and a foot or more long placed in the shrubbery will be seized eagerly by catbirds and thrashers. Even robins will not despise a strip of cloth or paper to work into the foundation of their nests; but they like better than this a spot of wet soil in the garden from which they may obtain mud for the walls of their nests.

The problem of food supply is not a serious one for the birds during the summer months, since at this season they subsist chiefly upon insects. Some birds, however, vary this insect diet with seeds and fruits of various kinds. For this reason they have acquired a bad reputation among fruit growers. There is little doubt that all fruit-eating birds prefer wild to cultivated varieties. They eat the latter because man has destroyed all of their former wild fruit-feasting haunts. Shrubs and trees that bear wild fruit set out in the yard, or in the corner of the orchard, will not only save the cultivated fruit but will attract to our premises birds that otherwise visit us but rarely.

The following trees and shrubs bear fruit that attract the birds: wild cherry, white mulberry, mountain ash, hackberry, dogwood, elder, and sumach. A few sunflowers will attract flocks of merry goldfinches during the latter part of the summer. Wild columbine and trumpet creeper will bring the dainty hummingbirds to our very doors.

Water should be provided as well as food. Dishes and pans kept filled with a fresh supply during the hot days of summer will insure the visits of dozens of our most charming songsters. Common tin milk pans or granite baking dishes serve the purpose. The water should vary from an inch to two or three in depth. It is best to set the pans on blocks or stakes a few feet from the ground, so that they will be out of the reach of cats.

Winter birds may be kept about our homes by fastening up in trees suet or long shank bones sawed in two lengthwise. Chickadees, woodpeckers, and nuthatches will find the feast, especially during stormy weather when the doors to their own larders are locked with snow and sleet.

Government Publications: Some Common Birds in their Relation to Agriculture. Farmers' Bulletin, No. 34; *The Horned Larks and their Relation to Agriculture; The Food of Nestling Birds; Birds as Weed Destroyers; The Bluejay and Its Food; The Meadow Lark and Baltimore Oriole.*

Helpful Books: Birds of Village and Field, Florence Merriam; Birds in their Relation to Man, Weed and Dearborn; Handbook of North American Birds, Chapman.

Colored Bird Plates may be obtained for two cents each from A. W. Mumford, Chicago.

CHAPTER XXXIX

SCHOOL GARDENS

The school garden, perhaps more than any other phase of nature work, seems to supply a natural demand irrespective of locality. It has a definite mission to fulfill in the city, as well as in the village and rural school. While its purposes may differ in different schools, its value as a factor in education is rarely questioned. It is worth while not only because of its practical bearings, but because it is exceptionally valuable on its educative and æsthetic side.

The location of the school, the size of the garden plot, and the number of children must largely determine the method of procedure in the management of any garden. If the size permits, each grade should have a definite plot set apart for its use. This should be divided into beds of suitable size; four by ten feet with paths two feet wide between make a workable arrangement. So far as possible each child should be made responsible for the care of one bed. At the same time he should feel a class interest in the entire plot. The work of preparing the soil and forming the beds should be done by the children so far as possible.

Vegetables as well as flowering plants should be represented in each plot. It is not well to have the children attempt to grow too many different kinds of plants at one time. The work may be easily made progressive, so that new plants are grown each year and not familiar ones repeatedly. This in itself helps intensify the interest of the pupils. For the primary children plants that have large seeds, that are easily grown, and that give quick results are best. The work may be made of more value if the children are trying to solve some definite problems in growing their plants. These problems must necessarily be very simple for the younger children, but should increase in complexity from year to year.

Indoor exercises must accompany the outdoor work if the school garden accomplishes all that it should. Often a preliminary lesson is indispensable. In this the children decide sometimes by experiment, sometimes by discussion, the special method of treatment for the plant under consideration. They also help decide how the various plants are to be arranged in the beds. They should draw a plan of their garden indicating this arrangement.

If space permits, a portion of the ground should be set apart as a fruit garden. In this all the different kinds of fruit that it is possible to grow in the locality should be planted. A few rows of trees with small fruit between will utilize all the ground. A space should be left for a small nursery in which to exemplify different methods of propagation. Another plot may well be reserved for the purpose of growing industrial plants such as cereals, fiber plants, forage crops, legumes, medicinal and kitchen herbs. An experimental plot tended by the older pupils will be found of great value. In this, problems of soil and seed may be worked out and new varieties tested.

Some of the plants selected, both vegetables and flowering plants, should be those that require their seeds to be started in a hot bed or greenhouse. If neither of these is accessible, the seeds may be grown in the schoolroom window garden and transplanted into the school garden. In some places the garden is too small to make it practicable to grow all the different plants suggested above. If the area is so small that it requires several grades to work together, some valuable work may still be done. Vegetables, some flowering plants, and a few of the most important industrial plants may be grown. The work should be made progressive from year to year instead of from grade to grade as in larger gardens. A small corner should always be reserved for the simple plants grown by the little children. In the fall a portion of the ground may be cleared off and set out in tulip and hyacinth bulbs for spring blooming. The same bulbs may be used year after year if they are taken up two or three weeks after the plants are through blooming and stored in a cool, dry place for the summer. Even in a small garden a portion of the ground may be devoted to geraniums and coleus, from which the children may make cuttings to take home for winter blooming.

Proper arrangement and planting must be followed by care and cultivation of the plants. The children must learn when and how to water transplanted plants, how to distinguish weeds from the crop plants; that the best time to pull weeds is when the soil is moist; and that the ground needs hoeing and pulverizing even if there are no weeds to kill. Every school that attempts gardening should own the tools necessary to carry on the work. These are a few shovels, several rakes and hoes, not too heavy, some handweeders and trowels, a line, measuring tape, and watering pot. An excellent lesson that goes with the garden work is the care of the tools. There should be some place arranged for the tools to be kept when not in use. The children after using them should clean them, occasionally oil them, and hang them up. A few small wooden paddles made by the older boys will be found helpful in removing soil from the tools.

If the school garden accomplishes all that it is capable of accomplishing, its influence will not end with the school, but be carried over into the home. The instruction gained at school will find its practical application in the individual home gardens of the children. The children should be encouraged in every way to start home gardens. Seeds may be procured at very low rates from several reliable seed firms. The Federal Government sends out packages of both flowering plants and vegetables that may be obtained through your congressman. Certain experiments may be carried on at home with better results than in the school garden. Special attention should be given at the beginning of the fall term to reports of observations made during the summer vacation. An exhibit in the fall of plants, flowers, vegetables, fruits, and seeds, from both home and school garden, will prove an excellent incentive for keeping up the work during the vacation.

The following illustrates a plan to make garden work progressive and at the same time adapted to the needs of the children at various stages in their development.

The primary children who are interested chiefly in activities in which they participate, and who gain most of their ideas through these activities, may plant seeds, care for the plants, and gather their flowers and fruit, with little attention to anything except the doing of the work. For them plants should be chosen that yield large seeds, bright colors, and quick results.

In the third grade, while propagation by seeds is continued, the children may work out some of the simple principles upon which germination and plant growth depend. In this grade the selection of seeds from desirable types may be first considered. Thus the children may choose, for example, seeds from the tomatoes having the best flavor and most meat. The children may save these seeds, raise the plants in the greenhouse or schoolroom, and transplant either to the school or home garden.

In the fourth grade propagation by bulbs, tubers, and roots, such as tulips, onions, potatoes, and dahlias may be introduced.

The fifth grade may be set the problem of the working out of the life history of biennials. The beet is a good type. Other biennials should be grown.

Among other things the sixth-grade children may study the culture of plants in a cold frame. They should assist in making and placing the cold frame and in caring for the ventilation, watering, etc. Good vegetables to grow in a cold frame are members of the cabbage family, including several species and flowering plants such as cosmos, pansy, sweet scabious.

The seventh and eighth grade children may grow some of the more difficult plants, such as sweet potato, melons, okra, celery, eggplant, spinach, and asparagus. They may work out by experiment simple problems connected with the relationship of the plants to their environment. More quantitative work may be done in these grades, such as the careful measurement of the corn plots to estimate the fraction of an acre which they represent, the weighing of ears to find the number required to make a bushel, the number required to plant an acre, percentage of grain to the ear, percentage of cob, etc.

Propagation by means of cuttings may be begun in a simple way by third-grade children, but in the seventh grade a detailed study should be made of soft and hard-wood cuttings, with the forming of callus, rooting, storing of hard-wood cuttings, etc.

In the eighth grade part of the work of the boys and girls may be differentiated. The boys may work out special problems in the culture of farm crops and vegetables, while the girls may plan and work out groups of color schemes in the flower garden.

This indicates briefly what work may be done in the garden proper, but it does not indicate the various lines of work which may radiate from it as a center. Instead of studying insects, certain birds, weeds, and soils as isolated topics, they may be studied in the garden in connection with the plants to which they are biologically and economically related. This organization of material unifies and increases its value from an educational standpoint. Indeed, if the full purpose of the garden work is carried out, it means more than the training of the hand in doing its part of the work successfully and skillfully. It means a training of the eye to see things as they are, a training of the mind to think logically and independently, to draw truthful conclusions, and to recognize the dignity of this work.

CHAPTER XL

SOME FUNDAMENTAL MISCONCEPTIONS

Any teacher using plants or animals as materials must be much hampered unless she feels herself on pretty sure ground with reference to what may be called the fundamental conceptions in biology. These are, especially, the things which pertain to all living beings; to plants and animals alike. With reference to many of these the best information is, of course, inadequate, and we yet remain in ignorance of the real fundamentals. None the less, the forceful teacher in nature study cannot afford to get along with the antiquated and erroneous conceptions which remain remarkably prevalent. She must be posted as to modern ideas concerning such matters as the relation of light and air and food and water to life, the adaptations of organisms to their environment, and the evolution of new kinds. Otherwise her touch is apt to be decidedly uncertain and wavering when it comes to dealing with many critical matters. However thorough may be her familiarity with details of structure and function in particular forms, unless she has a tolerably firm grasp upon these fundamentals her teachings may give birth to equally fundamental misconceptions. However well the details may be taught or elucidated, the value of such teaching is undermined if there is involved a misapprehension of general biological laws. It is a case of building on very uncertain foundations, and the pupil often comes to look at all living things from a wrong angle.

All living things work in intimate relationship with the forces of the physical world. Life itself can do nothing save as it draws energy from the lifeless. The life stuff of plants and animals establishes relationships with sunlight and the air, with laws of diffusion and evaporation, and life depends upon taking advantage of these forces, upon establishing these relationships. As skilful engineers have harnessed water power, and steam, and electricity to do their bidding, so the life stuff of plants and animals harnesses similar forces, till life itself is primarily a thing of adjustment to external forces. It is these common relationships which we cannot afford to misunderstand if we are to teach intelligently about plants and animals.

It is evaporation which does the work of delivering to the corn leaf the materials which, transformed, will fill the swelling kernels. It is because the laws of diffusion must be satisfied that materials are moved in the plant body, and the plant is served by a system of transportation which requires no expenditure of its own energy, a method which in economy and efficiency excels the method of the throbbing heart. It is sunlight which runs the delicate and mysterious food-making mechanism in the leaves.

To study biology we must study physics and chemistry. Nature study and elementary agriculture must include lessons exemplifying the operation of physical laws and simple chemical reactions. There is a common core which runs through the activities of all living things whatever their special forms and structures, and it is with this common core, in so far as we know it, with the few processes common to all forms, that the teacher needs to be on terms of comfortable familiarity.

The prevalence among grade teachers of misconceptions as to certain of these fundamentals is striking. Inasmuch, however, as grade teachers are being called upon more and more to teach about plants and animals, and few have opportunity to take special courses in preparation therefor, it becomes imperative to provide, if possible, some short cut to an adequate conception of these matters. Otherwise the teaching will be either superficial or wrong.

A few examples may serve to make the point of the preceding paragraph more clear. The writer finds that far more than half of some hundreds of country teachers who have been tested were firmly convinced that plants "breathe carbon dioxide" while animals "breathe oxygen," and that leaves are to be regarded as the lungs of plants. Bees are said to fertilize clover, the processes of fertilization and pollination being in no sense distinguished. The conception that "food burns in the body" appears to be very general, while rare indeed is the teacher who is not quite clear that air, sunlight, and water serve plants as food, just as proteids, fats, and carbohydrates serve animals. The idea that organs or the rudiments of them must have preceded the use of them for some definite purpose is received in teachers' classes as novel and diverting. Firmly intrenched is the idea that everything in nature already has its use or else cannot be. Animate things are conceived of and interpreted like the inanimate creations of man; like machines into which each cunning part has been fitted to fulfil a certain definite function. On the other hand, with naive inconsistency, there is general confidence that Bur-bank can get plants to do just what he likes, with very little if any limitation to variation. The comparison of living things to machines and engines and furnaces, and of simpler forms of life with ourselves, has obscured the facts rather than made them clear. For all this we appear to have some of the elementary "physiologies" largely to thank. To teach things easily they have often taught them wrong. The two chapters which follow are devoted to some of the topics concerning which such misconceptions are prevalent.

CHAPTER XLI

THE GENERAL LIFE PROCESSES

It is important to keep in mind that the fundamental life processes of plants and animals are the same and that whether life manifests itself in a plant or in an animal it works in the same way.

The reason for this becomes plain when it is known that there is only one living substance, which is known as *protoplasm*. Protoplasm is not life itself, but it is the material through which life manifests itself. Huxley called it "the physical basis of life." Of course protoplasm is a substance of supreme interest, and constant effort is being made to discover its composition, but thus far little more has been found out than that it is enormously complex. It breaks up into numerous compounds, but how these are put together in the living substance is not known. It is this protoplasm that makes all the other substances and structures of plant and animal bodies.

In general protoplasm occurs in very small masses known as *protoplasts*, and the ordinary plant or animal body is made up of thousands or millions of these protoplasts. Each protoplast usually builds some kind of wall about itself, and this wall-encased protoplast is called a *cell*. In case the protoplast has no wall it is usually called a naked cell, and these are very common especially in animal bodies. These cells are often spoken of as the units of structure in living things, because the whole body is composed of them, variously fitted together. Through the walls the protoplasts connect with one another by very delicate strands of protoplasm, so that in reality the living substance in a plant or animal body is a continuous substance.

Each protoplast is very definitely and intricately organized, but for our purpose we may disregard all other organization except the *nucleus* and the *cytoplasm*. The nucleus is a more compact mass of protoplasm, usually near the center of the protoplast. The more fluid protoplasm which envelops it and which forms a wall about itself is the cytoplasm. In it usually are found floating particles of various kinds, but these are not living.

In order to do its work the protoplast must be saturated with water, for every substance that passes into it or passes out from it must be in solution, or at least diffusible in water. In fact the whole plant or animal body may be conceived of as a continuous body of water in which solid particles are arranged. Frequently the protoplasm encounters conditions unfavorable for its work, such as cold or drought, and then it loses water and passes into what is known as the quiescent condition. When suitable conditions return, water is taken in and the customary activity of the protoplasm is resumed.

To get some general notion of the ordinary work of protoplasm one may follow the activities of a tree from the germination of the seed to the production of seed. A plant is selected because a very important process (food making) goes on in green plants and does not occur in animals, and none of the fundamental processes which occur in animals are omitted in plants.

In the cells of the very young plant (embryo) within the seed the protoplasts are in the quiescent condition, and food is also stored in them. We will assume that this stored food is in the form of starch, but it must be remembered that starch is only one form of stored food. In this condition the seed awaits the suitable conditions of temperature, moisture, and air which will stimulate its protoplasts to activity again. When the proper combination of these conditions arrives, water passes into the seed in relatively great abundance, and the seed may be observed to swell. This means that the protoplasts are regaining water and with it the structure for work.

Then the starch food is attacked, and this involves the very important process known as *digestion*. Starch is not soluble, and therefore cannot pass through cell walls and into protoplasts. It must be transformed into a soluble substance, and this transformation of insoluble food into soluble or diffusible food is digestion. Digestion puts food into such form that it can be carried through the bodies of plants and animals to the places where it is to be used. In the case of starch the transformation is into a sugar, and the active agent in causing this transformation is a peculiar substance called an *enzyme*. Enzymes are manufactured by protoplasts. There are many different kinds of enzymes in living things, just as there are many different kinds of substances in foods which are to be transformed in this way. The usual enzyme which converts starch into sugar in seeds is called *diastase*, and all the enzymes that have been separated out so as to be studied have also received names.

When the digestion of starch has transformed it into sugar in the seed, this sugar passes in solution to the protoplasts that are working. Then follows the very fundamental process called *assimilation*. The protoplast in manufacturing things is constantly transforming its own substance, and therefore must constantly be renewed. Therefore it receives the sugar and other foods that come to it and makes protoplasm out of them. Of course this is a very complicated process, and we do not know how it is done. We do know, however, that it is done by a series of many steps, the substances becoming more and more complex, until protoplasm is reached. The ordinary food substances nearest to protoplasm are the proteids, and the sugars and starches (carbohydrates) must be built into proteids on their way to protoplasm. Briefly stated, therefore, assimilation is the transformation of food into protoplasm, and thus the working protoplasts are perpetually renewed.

This brings us to the most important and least understood of all the living processes. It is called *respiration*, but the name is in such common misuse that it is more apt to deceive than to explain. The protoplasm works by constructing things from its own body, and in this breaking up of its body to form simpler compounds oxygen takes an important part, and this oxygen is taken in from the air. Among the simpler compounds produced some are wastes, among which the gas, carbon dioxide, which escapes into the air, is most conspicuous. On account of this fact respiration is often described as the taking in of oxygen and the giving out of carbon dioxide, but this exchange of gases is only the external indication that respiration, the breaking up of protoplasm, is going on. Respiration is essential to life, for unless the protoplasm can work none of the phenomena of life appear. The germinating seed shows that respiration is going on by taking in oxygen from the air and giving out carbon dioxide.

The conspicuous work done by the protoplasts in the seed is the formation of new cells, thus causing the little plant to grow. In this work of forming new cells, each protoplast divides, beginning with the nucleus, and a wall is laid down between the two halves. Then each half increases in size until it becomes as large as the original cell. If every protoplast in the embryo should divide in this way, the result would be an embryo twice as large as before. In this way the young plant increases in size, and finally bursts through the seed coat.

Thus the protoplasts, by digesting food, by assimilating it, and by constantly respiring cause the plant to grow from the embryo to the full-grown tree. Long before this growth is completed, in fact soon after the plant escapes from the seed, another process is necessary. The store of food laid up in the seed is soon exhausted, and new food must be provided.

The tree, as all green plants, has the power of manufacturing food, and this process is called *photosynthesis*. This work can be done only by the green parts of plants, and since the leaves constitute the larger part of the green tissue, they are properly spoken of as the organs of photosynthesis or the organs of food manufacture. This process is of supreme importance, for all life is dependent upon it. This means that green plants make more food than they use, and upon this surplus all other plants and all animals live.

The materials out of which food is made are carbon dioxide and water. The former passes directly into the leaves from the air, while the latter passes into the roots from the soil, is carried up through the stem, and so reaches the leaves. For this movement of water a special region of the plant is developed. This region is known as the wood. In herbs it appears as fibers. It is continuous from the root, through the stem, and out into the leaves where it takes the form of veins. This forms a very efficient water transporting system, but a satisfactory explanation of the mechanics of this "ascent of sap" is yet lacking.

The protoplasts of the leaves contain green bodies chiefly composed of protoplasm which are called *chloroplasts*. The substance in them which gives them their green color is called *chlorophyll*, and it is these chloroplasts which do this work of food making. The protoplasts of the leaves receive carbon dioxide and water, and their chloroplasts build these substances into food, such as sugar and starch.

Thus we see that water and carbon dioxide are not really plant foods as is so often stated, but they are the raw materials out of which the food is manufactured.

The chloroplasts can work only in the light, and hence leaves seem to seek the light. Food making stops at night. Also, in this process, since there is more oxygen in the raw materials than is needed in the finished product, some of the oxygen is given off into the air as a waste. This has led to a very general misunderstanding of this process. Since carbon dioxide is taken in and oxygen given off, and since this is exactly the opposite of what occurs in respiration, it was long thought that plant respiration was exactly the opposite of animal respiration. Real respiration in plants was entirely overlooked because the volume of the gases used in food making is so much greater than that used in respiration as to quite obscure the latter process except at night.

We should now see clearly that all living things "breathe in" oxygen and "breathe out" carbon dioxide, for this means respiration which is essential to all life. But green plants, quite in addition to this process, also can do the work of food making, upon which all the rest of the living world depends, and which involves its own characteristic intake and outgo of gases quite independently of respiration.

It is well to contrast sharply this photosynthesis with respiration, for they are very often confused. Photosynthesis requires light, involves an intake of carbon dioxide and an outgo of oxygen, goes on only in cells containing chloroplasts, manufactures food, and can be suspended periodically (as at night). Respiration does not require light, involves an intake of oxygen and an outgo of carbon dioxide, goes on in every living cell, consumes food, and must go on while life goes on.

The processes just described (photosynthesis, digestion, assimilation, respiration) have to do with the ordinary life and growth of the tree, and they are often spoken of together as the work of nutrition. The activities of plants, however, include not only nutrition, but also reproduction. The work of nutrition provides for the maintenance of the *individual;* the work of reproduction provides for the maintenance of the *race.* The tree, which we have selected as a representative plant, provides for reproduction by the formation of flowers. It is impossible to say always just what a flower is, but for our purpose it is easy enough. The flowers of our tree contain stamens and pistils, either both in the same flower or separated in different flowers. It is these stamens and pistils that contain the structures essential to reproduction. The stamen produces pollen grains, and within the pistil there are one or more ovules which will become seeds, if fertilization is secured. Associated in the flower with these stamens and pistils there may be petals and sepals, or only one of them. These are protective structures and perhaps attractive, so that in the work of reproduction they are entirely subordinate and hence not always present.

The pollen is carried from the stamens to the pistil of the same flower, or of some more or less distant flower, the usual agents of transfer being the wind and insects. After lodging upon the receptive surface (stigma) of the carpel, the pollen grain sends out a tube which penetrates the carpel, reaches an ovule, and entering the ovule, finally comes in contact with the egg contained in the ovule. Then the tip of the pollen tube discharges its contents, the egg is fertilized, and this fertilized egg develops the embryo of a new plant.

While the embryo is developing within the ovule, changes are taking place in the outer region of the ovule, by which a hard coat is formed. This hard coat finally hermetically seals the growing embryo within, which then stops growth; the whole structure being now called the seed. The conditions under which the embryo can resume growth and develop into a complete plant were considered at the beginning of this chapter.

There are seed-producing plants whose ovules are not enclosed by pistils; so that in them the pollen grains come directly in contact with the ovules, and there is much less extensive development of pollen tubes. These plants are the pines, spruces, etc., known commonly as "evergreens," and scientifically as gymnosperms, which name means "naked seeds." The other and far larger group of seed plants is called angiosperms, which name means "enclosed seeds."

There are also very many plants that do not produce seeds at all in connection with their reproduction. The visible reproductive bodies are the so-called "spores." These seedless plants, therefore, are sometimes called "spore plants"; but this is unfortunate, because seed plants are also spore-producing plants. The difference in the two cases is not that one group produces seeds and the other produces spores; but that although both groups produce spores, in one of them the work of the spores results in seed formation.

CHAPTER XLII

EXPLANATIONS OF EVOLUTION

THE following chapter indicates the successive appearance of the great groups of plants, beginning with simple algæ and ending with complex seed plants. This is an illustration of what is called organic evolution, which means that the plants and animals of to-day are the modified descendants of earlier forms. This theory of descent, as organic evolution is often called, is now universally accepted by biologists, but they differ widely among themselves as to how the modifications have been brought about. The theory of evolution is as old as our record of human thought, and no man can be cited as its author. The names that have been conspicuously associated with it are the names of men who have tried to explain it. All their explanations may prove to be inadequate, but still the theory of evolution will remain to be explained.

The attempted explanations of evolution have been numerous, but four great epochs in the history of the theory are recognized, each introduced by a new explanation which changed the point of view.

1. The first epoch was introduced in the last decade of the eighteenth century when three men independently proposed the same explanation of evolution. They were Erasmus Darwin of England, St. Hilaire of France, and Goethe in Germany. Their explanation was called the

"theory of environment," for they believed that the effect of environment would explain all the changes necessary in passing from one species to another. They had observed the seasonal changes in the plumage of birds and in the coats of mammals, and inferred that plants and animals are molded by changes in their environment, as clay can be molded by the hand. This explanation was soon found to be entirely inadequate, for the necessary changes are too deep-seated to be brought about by such a superficial agency. But "environment" has ever since played a very real, even if a very subordinate, part in every evolutionary theory.

2. The next epoch was introduced in the first decades of the nineteenth century by the announcement of the same explanation by two men; Lamarck of France, and Treviranus of Germany. It may be called the "theory of the effect of use and disuse," although Lamarck called it the "theory of appetency," which means the theory of desires. It is based upon the fact that use develops an organ and disuse results in its dwindling and possible disappearance. For the sake of illustration it is sometimes called "the law of the blacksmith's arm," because it is well known that such use of the arm develops the muscle, and that disuse will cause a muscle to shrivel and lose its power of functioning. This explanation of evolution was thought to be deep-seated enough, for it could apply to every organ of the body. Lamarck, for example, imagined an animal, adapted to certain conditions, transferred to new conditions that would mean different demands. Certain organs would be called upon persistently that were not so important under the old conditions, and would thus be

developed. Others, important before, would be now less called upon, and would begin to decline. Thus the animal would begin to change, and these changes would be handed down to its progeny and increased by them, and so on until practically a new animal would be the result.

It is evident that this explanation depends upon what is called the inheritance of "acquired characters"; for the progeny must start with all the gains acquired by the parent, and not be compelled to start over again. But, now that it is generally agreed that such acquired characters are not inherited, the "theory of appetency" finds little support. It has recently been revived in a modified form, but this lies outside our purpose.

3. The next epoch was by far the most important one in its results. It was introduced in 1859 by the appearance of a book by Charles Darwin, entitled "The Origin of Species by Means of Natural Selection." In this case also the theory was announced by another observer independently, Alfred Russel Wallace. When Wallace learned that Darwin had had the theory under consideration for twenty years, and was prepared to present it based upon a wonderful collection of observations, he generously withdrew from its further development.

This epoch was the most important one because the new theory revolutionized biology, and in fact revolutionized the point of view in almost every department of thought. The greatness of Darwin really consisted not so much in his theory as in what he set men doing. He called his explanation "the theory of natural selection," but it has been freely spoken of as "Darwinism." It has been the conspicuous explanation of evolution for fifty years, and even if it should now be found inadequate, its place in the progress of knowledge is unparalleled.

The theory of Darwin is so familiar and so accessible that a brief definition of it should suffice. Darwin observed that the "ratio of increase" of plants and animals is so high that many more forms are produced than can possibly exist. This leads to what is often called a "struggle for existence," for out of thousands of plants or animals that are started as spores or seeds or eggs only a single one will survive. This means that death must be the rule and life the exception. It was evident that this wholesale destruction of living forms must result in something of importance. Darwin studied extensively the work of plant breeders and of animal breeders, and showed how by selection, generation after generation, they could greatly modify plants and animals. In fact, certain domesticated animals and cultivated plants had been modified so extensively that the wild forms from which they had come could not be identified. All these changes were made possible by the fact that plants and animals continually vary. No plant or animal is exactly like its parent, for there is individuality as well as similarity. It is this tendency to vary that the plant breeder and the animal breeder took hold of, selecting those variations that they prefer and increasing them by further breeding. This, of course, is "artificial selection," and Darwin conceived that this same process is going on in nature by natural selection. Endless variations are produced, and nature selects by means of the struggle for existence, which is brought about by the high ratio of increase. The forms selected are those that are better adapted to their surroundings than the majority, which perish. Natural selection is thus said to result in the "survival of the fittest," or it may be even more accurately described as the "destruction of the unfit." The individuals thus preserved hand down to their progeny the favorable variation; and, as this selection is repeated generation after generation, the favorable variation is increased, and finally a new species is the result.

This explanation is not now regarded as entirely satisfactory, for the multiplication of facts has introduced serious difficulties. But whether natural selection produces new species or not, it must play an important rôle in the preservation of certain forms and in the destruction of others.

4. The fourth epoch in the history of evolution was introduced during the present decade when DeVries of Amsterdam announced his "mutation theory." He had observed that a certain species of evening primrose occasionally produced forms so different from the parent that he regarded them as distinct species. They were not the small variations that Darwin used in his theory of natural selection, but the large ones that had been called "sports," and had been disregarded as of any significance in the origin of species. DeVries cultivated these plants for many years, and observed them generation after generation. The sports, which he called "mutations" or "mutants," continued to appear, but in very small numbers in proportion to the total number of progeny. In this way he observed this single species of evening primrose produce several new species, all of which bred true and showed no tendency to run back to the parent. He concluded that new species may be thus produced "at a single bound,"

and not necessarily by the slow process of building up small variations generation after generation by natural selection. Of course, natural selection will determine which of the species thus produced will survive.

The mutation theory is so new that it is impossible to say at present whether it has any general application, or is only a very occasional method. Whatever may be its fate the epoch it introduced is the epoch of the experimental study of evolution, which must be the final resort in solving such a problem.

CHAPTER XLIII

EVOLUTION AS SHOWN BY PLANTS

THE first plants lived in water, and their whole structure was fitted to this environment. The body consisted of a single cell, and since it was a green cell the plant could make its own food, as we have seen. Some of these very simple plant bodies bore threadlike extensions of their protoplasm called cilia, and plants possessing these could swim actively. Most of these plants, however, had no such power. Their method of reproduction was very simple, the single cell simply splitting and thus giving rise to two new individuals. This method is called *vegetative multiplication*, because no special reproductive cell is devoted to the work of reproduction, but it is done by an ordinary working (vegetative) cell. Such simple plants as these primitive ones exist in great abundance to-day. They belong to the great group called *Algæ*, and they may be properly regarded as the forms that "started" the plant kingdom.

Later in the evolution of plants, cells which clung together began to work together, and a body of several and finally many cells was developed, the commonest form among algæ being a simple or branching filament. There were also flat, platelike bodies.

In the many-celled plant bodies thus formed, special reproductive cells soon appeared. Under certain conditions the vegetative cells of the body produced small cells within themselves, and these escaped into the water. Such special reproductive cells are called *spores*, and as they swim actively by means of cilia they are called *swimming spores*. These spores swim about for a time, but gradually settle down, and each one produces a new plant.

Still later in the history of plants, another kind of reproduction was developed. Swimming spores much smaller than the ordinary ones were produced, and these were unable to give rise to new plants. However, they came together and fused in pairs, and the resulting cell, produced by the fusion of two cells, did have the power of producing a new plant. These pairing cells are *gametes* and this process of cell fusion is *fertilization*. This method of reproduction is the sexual method, and this transformation of swimming spores into fusing spores or gametes is the *origin of sex*.

There have thus been developed three methods of reproduction, in the following order: vegetative multiplication, reproduction by spores, and sexual reproduction. All three methods are retained by all the higher plants.

A further advance in sex reproduction was secured by what is called the differentiation of sex. When sex first appeared, the pairing gametes were alike, but later they became different. One became much larger than the other and lost its cilia and hence the power of locomotion. The other retained its small size and activity. These two kinds of gametes have received different names, the large passive one being the *egg*, and the small active one the *sperm*. In this way not only sex, but two sexes were developed. The cell produced by the fusion of sperm and egg is called the fertilized egg, and this process is the same in plants and animals.

All this progress in evolution was made by the Algæ and it may be summed up as resulting in plants with many-celled bodies reproducing by vegetative multiplication, by swimming spores, and by fertilized eggs.

The next great advance was the emergence of plants from the water to the land, and this important step seems to have been responsible for all the later development of the plant kingdom. In other words, had plants always remained in the water, there is very good evidence for the belief that they would never have developed into forms much more complex than the ones which have been described. Land plants are more complex and diversified than water plants, just as land conditions are more varied than aquatic conditions. Thus always, to some extent, we find a reflection of the conditions of the environment in the structures of the organisms which inhabit that environment.

This emergence from the water and the formation of the land habit were accomplished by that great group of plants, next above the Algæ, which comprises the liverworts and the mosses. The land habit means exposure to air instead of to water, and the danger to be guarded against is the drying out of the body. We recognize that water is the primary need of the animal as well as the plant body, and that the individual cells of our body require a fluid medium for their life just as truly as a fish requires water. This fact alone is strongly suggestive of the remote aquatic ancestry of all living things. Plant bodies became more compact, but for a long time could live on land only by lying prostrate on muddy flats; such flats as we find on very gently sloping seashores between the tide marks. Swimming spores were necessarily abandoned, and light spores for dispersal by air took their place. The gametes (sperms and eggs) were produced in better protected organs, with jackets of protecting cells. Such an organ containing sperms is the *antheridium*, and the one containing eggs is the *archegonium*.

However, the greatest change introduced at this stage of evolution was what is called the *alternation of generations*, and this change profoundly affected all the future development of the plant kingdom. Unless it is understood, no true interpretation of plant-life histories is possible. In this early alternation of generations the green plant body formed no spores, but did form the sperms and eggs. Then the fertilized eggs, instead of producing a form like their parent, as animal eggs do, produce an entirely different structure. This other structure, or other plant, produces no sperms and eggs, but does produce spores; the plant is thus for the second time, but in a very different way, reduced to the one-cell stage in its life history. Then when one of these one-celled spores germinates (which it does of course without waiting for any act of fertilization), it produces the original sperm-and-egg-bearing plant. In this way two really perfectly distinct plants alternate with each other in making up the life history. The sperm-and-egg producing generation is called the *gametophyte* or gamete plant, and the other the *sporophyte* or spore plant. The gametophyte is sexual, and the sporophyte is sexless, and each in turn produces the other, and this habit continues throughout all the higher groups of plants.

In liverworts and mosses the sporophyte is small and not green. Since it cannot make its own food it attaches itself to the green gametophyte and lives upon it as a parasite lives upon its host; yet it is no more an organic part of the gametophyte generation than the mildew which grows upon lilac leaves is a part of the lilac.

In the next higher group of plants—which is the fern group—the next great advance is to be observed. The sporophyte has become green, can make its own food, and is therefore independent of the gametophyte. Not only that, but its green tissue has developed into leaves; it has developed roots which connect it with the soil; and running from the roots up into the leaves there appears that elaborate water-conducting system of tissue known as the *vascular system*. This system is chiefly composed of the woody strands so familiar as wood in the higher plants. The ferns and their allies differ, therefore, from the liverworts and mosses in having independent leafy sporophytes, with roots and a vascular system.

With the large development of the sporophyte, and its assumption of the task of food making with its large leaves, and its continuation from season to season by means of its fleshy underground stem, it seems natural to find the gametophyte correspondingly reduced. In fact, although leading an independent nutritive life, the gametophyte in ferns is relatively inconspicuous. It looks like an exceedingly small liverwort; like a little green, heart-shaped bit of leaf which often escapes attention entirely. It is called the *prothallium*. Thus we see that the fern plant of ordinary observation is a sporophyte or sexless plant, while the moss of ordinary observation is a gametophyte or sexual plant. It is no wonder that the early students of ferns could find no sex organs, for the plants they examined were sporophytes.

Certain plants known as "club mosses" and "ground pines" belong to the fern group and are better than the common ferns to illustrate the other points of advancing differentiation which appear in this group. They are often used for Christmas greens and are found in abundance in the pine woods of the North. Their long prostrate stems are thickly covered with narrow, pointed, green leaves, giving them quite a tufted or bushy appearance, and explaining the name "ground pine." Now the sporophyte in all members of the fern group bears on its leaves special spore-producing organs called "sporangia." Clusters of these sporangia forming brown dots or patches are matters of common observation on the under sides of fern leaves. At first, in the evolution of ferns, all the leaves bore sporangia, but presently there appeared leaves of two kinds, one being an ordinary foliage leaf doing exclusively the work of food making and bearing no sporangia at all, the other doing no ordinary foliage work and being devoted exclusively to the bearing of sporangia. The latter kind of leaves are called *sporophylls* or spore leaves. Sometimes they do some ordinary leaf work as well as the work of sporangia producing. Now in the club mosses we find these sporophylls grouped together in a club-shaped tuft at the end of the branches, and this definite, conelike cluster of sporophylls is called a *strobilus*. The strobilus is a very important organ to understand, because it is the forerunner of that very familiar organ the flower. It is fair to say that the flower cannot be really understood unless we understand the strobilus. The pine cone furnishes perhaps the most familiar example of a strobilus or "aggregation of sporophylls."

The other important step which is introduced by a few members of the fern and club-moss group has to do with the spores. Up to this point spores are all alike. They all produce just one kind of gametophyte, that gametophyte bearing both kinds of sex organs—the antheridia which contain sperms and the archegonia which contain eggs. But now, in the few members of the fern group referred to (selaginella, a common foliage plant in greenhouses is one of them), two distinct kinds of spores are produced. One of these is relatively very large and is called the *megaspore*. The other is relatively very small and is called the *microspore*. The megaspore produces a gametophyte which bears only archegonia, and is therefore called a female gametophyte. The microspore produces a gametophyte which bears only antheridia, and is therefore called a male gametophyte. This condition, in which two kinds of spores are produced, is called *heterospory*. Heterospory is just as important to understand as the strobilus, for this habit is the forerunner of seed formation, and the seed cannot be understood without understanding heterospory.

When heterospory appears the gametophytes become small and parasitic, just as the sporophytes were small and parasitic when they first appeared. In fact the gametophytes of heterosporous plants are parasitic *within the spores that produce them*. We see herein some explanation of the size of the megaspores. Not only do they have to have food stored up to provide for their own germination, they must also provide food for the whole development of the female gametophyte and the formation of the eggs; for the female gametophyte, instead of developing outward and into an independent plant, as its forerunners did, will develop inward and live as a parasite upon its mother, the megaspore. The sporophyte began by being dependent upon the gametophyte, and now the gametophyte in turn has become dependent upon the sporophyte.

The group of plants next higher than the fern plants is the highest of all and is commonly known as the "flowering plants," but it is better called the "seed plants." (There are some seed plants which could hardly be said to be flower bearers.) To understand this group one must carry forward the ideas of strobilus and heterospory and see how they result in flower and seed.

Among seed plants the strobilus continues for a long time, notably so in the group to which the pines belong. Finally a third type of leaflike structure appears and this new member is close to the sporophylls. Presently we see this new organ itself differentiated into two kinds, and these are called *sepals* and *petals*, which are the most familiar parts of a flower. Thus we may say that when a strobilus has sepals and petals associated with its sporophylls it is a flower. We must note that the sporophylls of a flower were called stamens and carpels or pistils long before their real nature was understood, and these names still persist. It used to be thought that stamens were male organs and the pistil the female organ, and plants which have stamens on one individual and pistils in the flowers of another gave rise to the idea of distinct male and female plants. But, if the argument has been followed up to this point, the inaccuracy of this view is perfectly obvious. The stamens and pistils are members of a sexless generation, or sporophyte. They themselves are sporophylls or spore-producing leaves. The stamens produce that very obvious and well-known product of flowers the pollen; and the grains of pollen are microspores or sexless spores, which upon germination will produce the male generation of the plant; but they themselves are not to be confused with the male element. They have been thus confused largely on account of the process of transfer of pollen from stamen to stigma at the top of the pistil. This process is commonly called fertilization and that is the name of the sex process, and if this were fertilization the pollen certainly would be the male element. But this process is not fertilization. It is pollination, and pollination is no more fertilization than the delivery of a bar of steel at a watch factory is the manufacture of a delicately tempered watch spring. Fertilization occurs after pollination—it may be hours or days or even weeks after—and it is a process which occurs down at the very base of the pistil among those "baby seed" organs known as ovules. It is wholly distinct and separated by an entire generation of life history from the deposit of the pollen grain by insect visit or uncertain breeze upon the sticky stigma. It is also separated in position by the commonly elongated "style" of the pistil down which the pollen tube must grow, and it is this pollen tube which carries the male cells.

In flowers, in addition to having the differentiation of two kinds of spores, which we found also in some of the fern group, we have also the differentiation of two kinds of sporophylls. That is, the stamen is one kind of sporophyll: it bears microspores which are commonly known as pollen. The carpels, usually united to form the organ known as the pistil, are another kind of sporophyll; they bear the megaspores, and the megaspores are commonly known as nothing at all because they are never seen. This is due to the fact that they never are discharged from the sporangium which bears them. This sporangium forms most of the structure commonly known as the ovule.

Having noted that the state of producing two kinds of spores is called heterospory, we can see, for the sake of clearness, that the state of bearing two kinds of sporophylls, each of which bears a kind of sporangium different from that borne by the other, might be called heterosporophylly. As a matter of fact that cumbersome word is not used, but the fact which it names needs to be made clear, and is exemplified by stamens and carpels.

Also, having noted that in heterosporous plants the generations which result from the germination of the spores, that is the gametophytes, are ingrowing within the spores and parasitic, we now need to note that the next step in this direction is the case of the ovule cited above. That is, the megaspores were said to have no common name because they are never seen under ordinary circumstances; they are retained within the ovules which bear them, and there the male generation or pollen tube, bearing the sperms, goes in search for the eggs which have developed in the internal, parasitic female gametophyte inside the megaspore. Thus we have here, added to the retention of the gametophyte within its mother spore, the retention of the spore itself within its mother sporangium, and with the arrival of this step in evolution we have the arrival of that great epoch-marking habit in plants: the seed habit.

These last points, with reference to flowers, are not at all easy to grasp outside of a laboratory course in the subject, despite the familiarity of the material discussed, and a restatement of the points appears desirable. In connection with this study it is desirable to have a few complete flowers, such as any of the lily type, available for use in identifying and making perfectly concrete the points referred to.

Since stamens and carpels or pistils are sporophylls, they, of course, bear the two kinds of sporangia: those that produce microspores (pollen grains) and those that produce megaspores. If stamens and carpels are sporophylls, it follows that they cannot be sex organs, according to the old notion, for they are structures that belong to the sporophyte or sexless generation.

The two gametophytes (male and female) in seed plants are found just where they occur in all heterosporous plants, namely, within the spores that produce them. The male gametophyte, with its sperms, is within the microspore (pollen grain). The female gametophyte, with its egg, is within the megaspore. The sporangium that produces the megaspore in seed plants has long been called the ovule, and its greatest peculiarity is that it does not shed its spore. Therefore, inside of the ovule is the megaspore, and inside of the megaspore is the female gametophyte. It is no wonder that the gametophytes (sexual plants) of seed plants are seen only in the laboratory under the microscope, and then only after special technic has made them visible.

The egg produced by the female gametophyte remains within the ovule and is there fertilized, and there produces a young sporophyte. At the same time the ovule (sporangium) produces a hard coat, and the whole structure is called the seed. In a seed, therefore, we see that three generations are represented: the ovule (sporangium) belongs to the old sporophyte, and is always represented by at least the testa or hard outer coat of the seed. Within the outer part of the old ovule lies imbedded the female gametophyte, which resulted from the germination of the megaspore, grew as an internal parasite, bore the now fertilized egg, and after fertilization constitutes that part of the seed commonly known as *endosperm*. Finally, and innermost, imbedded within the female gametophyte, lies the third generation which is included in this wonderful organ, the seed. This innermost of the three members of the seed is the young sporophyte of the yet undeveloped generation, and it is called the embryo. Thus we should see that it is impossible to know what a seed really is unless we approach it from the lower groups and come to an understanding of its evolution.

INDEX

(2)