Education through Nature Study

Munson

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EDUCATION
THROUGH
NATURE STUDY

FOUNDATIONS AND METHOD

BY

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To my Mother,

Elizabeth Dvergsdal Munson

PREFACE

THIS work is the result of a course of lectures delivered by the author on Methods of Science-teaching. It owes its form and content, first, to impressions concerning the scope and character of current nature-study literature; and second, to impressions regarding the general scientific preparation of teachers who have been under his instruction and supervision in institute, normal school, and normal training-school work.

Current nature-study literature, dealing chiefly with the facts of nature study, fails to aid the teacher in two important difficulties where help seems to be most needed, namely: (1) many teachers fail to grasp the real significance and importance of the subject; (2) they do not know how to handle the subject,—how to begin, how to continue, and how to end the study of an object. This book is an attempt to remove those difficulties.

The facts of natural science are so numerous that they cannot be condensed into a small volume. Besides, even a complete catalogue of all the facts of nature cannot be substituted for a proper study of nature itself. Nature study in book form is a contradiction in terms. The "book of nature" has its own message to give to the inquiring mind; and this message can be communicated only by nature itself. Interpreters have thus far been rather unsuccessfully employed, because we have not been able to become as little children, asking their own mother their own questions in their own language.

The problem of education is, at bottom, the biological problem of growth and development. There is no one law which better expresses the fundamental factors in development than that of "action and reaction." This excludes the notion of isolation; and emphasizes the fact of mutual interdependence; the conception of matter and motion; the kinetic and the static elements in nature, and the organic unity of the world.

With our advances in sciences, especially the biological sciences, we are able now, better than ever before, to appreciate the supreme importance of the physical basis of our intellectual life. Strange to say, it is only recently that the human mind has begun to realize that things grow; and that education is growth, modified and sustained by external influences.

With the marked shifting of psychology, both in matter and method, which biological research has made necessary; with the accumulating results of comparative philology and anthropology, showing the origin and development of language, both in the individual and in the race, to be dependent on physical and biological factors; with the ever-increasing complexity of social conditions accompanying social and industrial evolution, making the environment of children more and more artificial and abnormal, it may be safe to predict that nature study, as a branch of school work, will receive even greater attention than it now does.

It is now fifteen years since I first published an outline for teaching nature study in the grades. The method here presented is the result of a natural selection resulting from my experience in all grades of school work and with all kinds of pupils. I have been convinced by this experience that a good method of teaching nature study must be based on the more fundamental laws of life and development, rather than on the individual tastes of him who applies it. These individual likes and dislikes are transient phases, fluctuating and varying, and apt to lead to those extremes which usually end in a reaction. Such extremes are, therefore, to be avoided. We are to base our method of teaching nature study neither upon the economic value of the subject nor upon the purely emotional or sentimental aspect of it. We are not to make it so practical as to render it impracticable; nor so sentimental as to make it silly. That would be an unfortunate tendency in our schools, if children should be taught to know the busy bee, only to determine how many pounds of honey it can produce, and how much hard cash, reckoned in dollars and cents, it is worth to us. Groveling utilitarianism, like absurd sentimentalism, are passing phases of extremes in education that cannot endure. We need knowledge, united with common sense, to control these two extremes of civilized life. Knowledge wedded to common sense, yielding that intellectual honesty which contact with nature promotes, must find the golden mean between erratic extremes.

Considering that the majority of public-school children do not enter the high school, there is little danger, perhaps, of making the work too scientific. All the science they are able to master will not hurt them any, as some teachers seem to fear. Much is being said now about child study and child interest. May not some attention to the proper method of studying objects enable us better to understand the child? From what we already know of these obscure subjects, it seems reasonable to assume that methods n teaching should be such that the fullest exercise of all the pupil's powers is secured, and the natural results of those activities realized.

It is believed that when the foundations of nature study are understood, and when the aims to be attained have become clearly defined in the teacher's mind, a method will be developed by the thinking teacher. Such a method must be the true method so far as that particular teacher is concerned.

In submitting this rather formal special method of treating nature study in the grades, it is not intended to instruct those who have a satisfactory method of their own; but, rather, to assist those who feel that they have not yet been able to see their way clear amid such an array of objects and phenomena as those with which nature study deals. A sense of fatiguing bewilderment is often felt by the inexperienced teacher. This doubtless must always be the case so long as both the method and the matter of nature study are chaotic. Uniformity and law must be discovered here as elsewhere.

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TABLE OF CONTENTS

CHAPTER III

GENERAL METHODS

TENTATIVE GENERALIZATIONS AND GUIDING PROPOSITIONS

CHAPTER IV

SUGGESTIONS AND COURSE OF STUDY

CHAPTER V

EXAMPLES OF PUPILS' WORK IN NATURE STUDY.

PART II

LIFE: ITS FORMS AND ITS MANIFESTATIONS

CHAPTER I

LIFE OF PLANTS AND ANIMALS

CHAPTER II

THEORIES OF DEVELOPMENT

CHAPTER III

SYSTEMATIC ARRANGEMENT OF PLANT AND ANIMAL FORMS

CHAPTER IV

MATERIAL AND EQUIPMENT

Part I

Foundations and Method of Nature Study

EDUCATION THROUGH NATURE

CHAPTER I

Introduction

I. Historical.

That period in the history of western civilization commonly called the dark ages was peculiar for the absence of those startling events or revolutions of society with which primitive history delights to deal. It was the age of faith, when the human mind, taking things for granted as tradition explained them, felt nothing of that agitation and unrest which is so essential to the discovery of new truths. It was not, however, a barren period. Rather the adolescent period of the race, when, regardless of conventionalism and art, men concerned themselves, not with the greater universal problems, but rather with the little every-day problems which their close contact with nature was sure to occasion.

In that close contact with nature there doubtless was promise of better things. That rugged physical strength, that knowledge of things, and that power of bravely coping with natural forces, of which northern mythology so eloquently speaks, were probably the essential conditions for that richer unfolding of latent powers, that fruitage, which first began to appear at the time of the renaissance. Western civilization has often been traced back to the renaissance, as if all the preceding ages had been a mere blank in the intellectual life of the peoples of western Europe. It is only recently that it is being realized that those obscure centuries were really the maturing age in which western Europe became capable of that remarkable awakening. The fact that the splendid Greek and Roman culture was so eagerly seized upon at this time by the people of western Europe testifies to a maturity which no other people seems to have possessed.

The importance of it all, in this connection, lies in the fact that this Greek and Roman culture, when once discovered, was taken to be the climax of human achievement; and in the mistaken notion that such culture could be transferred from one race to another, directly, without the preliminary process of growth. It was thought that culture must necessarily be transmitted with the language of those civilized peoples. Hence all mental effort was turned away from former subjects relating to nature, and directed towards the acquisition of an artificial culture, supposed to reside, like a hidden virtue, in forms and symbols of thought. The novelty of it so dazzled the mind that it was not perceived that the races in which this culture had developed had succumbed to the very effects of its artificial and enervating influence. The study of symbols and the contemplation of forms devoid of actual living content, so sedulously practiced throughout the fifteenth and sixteenth centuries, was itself an artificial system, which, doubtless, would have ultimately had a similar effect, even if real classic culture could have been acquired and transmitted in the way supposed. The Greeks and Romans, themselves, had lived the life and breathed the very air of that culture which their imitators were trying to resurrect in themselves by means of soulless symbols.

To this should be added the prevailing conception that man is the center of the universe. Self-contemplation and self-absorption thus became inevitable; the testimony of the senses was regarded as vulgar, except in so far as it seemed to point to man's supernatural origin, and to him as the end and aim of all created things. There is food for reflection in the fact, as seen in the history of science, that civilized man has willingly lent implicit confidence to the testimony of the senses so long as this testimony seemed to flatter his self-esteem, as in the case of the sun revolving about him, but has obstinately refused to credit such testimony when less favorable to his dignity.

Introspective methods of observation, together with the study of meaningless and empty symbols, not only developed visionary systems of philosophy, but estranged man more and more from the natural order of things. Developing the highly artificial conception of society that it is all a matter of purely human invention, having no foundation in nature, where no true ethical standards can be found, the most clever of these humanists could easily justify any order of existing conditions, by inventing systems of psychology, ethics, and philosophy, yes, even science, suited to their own particular proclivities and wants. Social distinctions, amounting to feudalism on the one hand and human slavery on the other, arose and were sanctioned by those merely clever ones who thus unjustly had gained an artificial supremacy.

Not all, however, were thus to be deceived. Shifting standpoints made themselves felt when Copernicus, Kepler, Tycho Brahe, Newton, and Galileo turned their attention to the motions of the heavenly bodies and the laws of gravitation and force. The changes in men's fundamental conceptions of the universe, thus early initiated, and carried forward by Bruno, Laplace, Descartes, Spinoza, and others, were finally completed by Darwin, in 1859, by his epoch-making work, the "Origin of Species."

In politics and education, too, a few brave souls, more devoted to truth and justice than to artificial distinctions, began the difficult task of reforming society, and making social, political, and educational activities conform more to the laws of nature. Bacon, in his "Novum Organum" and "Advancement of Learning," had pointed out the errors to which the human mind is liable when wholly divorced from nature; and had suggested the proper inductive method of studying nature. Rousseau had given the cry "back to nature" in such a way that it could hardly be ignored. Locke had laid the foundations for the new psychology, and Pestalozzi had attempted a practical realization of a natural method in teaching.

There is, of course, room for difference of opinion as to how far reformers are the product of the spirit of the age, or how far that spirit is due to reformers. But, in any case, the benefits of the movement, thus initiated, in turning men's attention back to nature were realized in the progress of literature, arts, and science of the nineteenth century.

Meaning of the "Back-to-Nature" Movement.

It is important to note, in the movement sketched above, the following stages of development: (1) Europe, during the first centuries, was still in a state of semi-barbarism. So closely were these nations united to nature that their mythology is but a personification of it. Gods and giants, such as Thor, Balder, Freya, and Hoder, personifying the forces of nature, were the imaginary beings residing in Thunder, Spring, and Winter and determining men's fortunes and fates. (2) Then came the age of faith. The acceptance of Christianity, which had been developed in a sunnier clime, among a people who were less profoundly impressed by the forces of nature, and given to a less eventful life and consequently more contemplative habits, can be explained only on the supposition of a gradual emancipation of the western mind, and an increased capacity for abstract generalization. The acceptance of monotheism involves such capacity. (3) The renaissance shows a greater emancipation, and a higher capacity of the mind to deal in abstractions; otherwise Greek and Roman culture could have appealed to the European mind no more strongly than to the minds of other peoples similarly exposed. (4) Finally, the return to nature was not a sudden revolution, though it culminated in the French Revolution, but a growth of years and decades.

These steps may, doubtless, be natural steps in mental evolution. It is only after these phases had been passed through, when the peoples of western Europe had become aware of the knowledge and arts of the human race as a whole, that development of science in the modern sense was possible. This may also be true, to a certain extent, of the individual. It is doubtless true that to pass from childhood into the purely scientific stage would be to abridge the natural course of development. Had Europe remained in the earliest phase of development, we could have had no greater control over nature to-day than have the savages of central Africa or the American Indian. Had Europe remained in the humanistic stage of the seventeenth century, modern science would have been as little developed among us as it is among the Hindoos. Hindooism is a clear case of arrested development; and there are many among Europeans even now who are at the point of that stagnation when the mind seeks its activities in senseless occultism. The caste system of India shows what the human mind is capable of when divorced from nature. It is the desire and aim of the Hindoo

Brahmin so far to emancipate himself from nature as even to torture his own body, in order that he may be released from it, and be merged into an eternal unconsciousness, called Nirvana. Modern science has no attractions for him. The Hindoo is a fair sample of what a failure to return to nature means. Nirvana is a state outside the realm of natural law.

The western mind, notwithstanding the renaissance, did not become so thoroughly artificial. The great variety of natural features, such as climate, relief, coast line, and water communication, which contributed so considerably to the development of Greek and Roman civilization by their interactions, was felt throughout all Europe, and gave rise to that commerce and intercommunication between different races which has always tended to develop the practical side of man's powers.

The return to nature was, therefore, not a return to barbarism, but rather the application of the mind to nature, after that mind had won its freedom and mastered the arts of culture. *It meant an appeal to nature for standards wherewith to guide the liberated mind;* for the mind, being not wholly a law unto itself, but necessarily related to things outside itself, must conform to that which it would understand and master. Men thus learned to know nature in the light of freedom. Democracy became possible when this freedom of the mind enabled it to grasp the ethical idea which nature teaches in its interdependence, and which is, at bottom, in accord with the ethics of Christianity. In such society of freemen, made stable by the recognition of ethical laws, the development of modern science became possible.

Science and Culture.

Science is often spoken of as a social product. In the first place, no single individual is able to master all modern science. In the second place, modern science is to a certain extent the result of cooperative effort. Science, therefore, presupposes organized society, and that implies more or less of human culture. Specialization, which must necessarily exist in any highly organized society, implies a diversity of human activities, and such diversity requires more or less of science. We can hardly, therefore, separate science from culture or culture from science, as is so frequently attempted, by those who look upon science as something inferior if not positively degrading. Weak and silly minds often betray this prejudice against science.

If we define science as knowledge reduced to a system, it is evident that, taking the world as a whole, no single individual is equal to the task, and that such classification is possible only in a comparatively stable society. We may conclude, therefore, that science is the ripest fruit of man's intellectual development. The history of human civilization makes that evident.

It would be a mistake, however, to suppose that science has had nothing to do with the creation of those conditions which made the higher development of science possible. Knowledge of nature and her laws must always have been the basis on which human culture has advanced. Temporary or prolonged disregard of nature, and an absorption in an artificial atmosphere of art, as in the case of Greece and Rome, has always ended in degeneration and decay. The reason for this is, perhaps, that art can have no standard as a guide if nature is ignored. Man can improve on nature only by taking nature as a model. By knowing nature we can lead her where we will, but she will not be coerced. Applied science, such as the locomotive and the telegraph, consists chiefly in putting one natural force against another in such a way as to enable the stronger force to overcome the weaker. Pure science enables us to put things together in such a way as to make natural forces minister to our wants. It is largely by thus ministering to human wants that nature, in the harness of science, has enabled us to rise from one level to another in the scale of culture. Having mastered the little problems, we have been made free to occupy ourselves with larger ones.

If this is true of society as a whole, it may be equally true of the individual, namely, that science and art must be acquired together, in order to enable the individual to appreciate the highest culture, and finally be capable of the pursuit of science for its own sake.

II. Stages in Human Culture.

Economic Stages. Human society, culture and science, are the results of slow growth. Changes are sometimes brought about by revolutions that are the results of great discoveries. Such events, however, as, for instance, the discovery of America, are themselves the result of slow changes and accretions to human knowledge which are often overlooked in the contemplation of the magnitude of the event.

Nevertheless, in a general view of human development, there can be distinguished certain stages that are characterized by some feature not so marked in other stages. Thus from the point of view of economics the following stages are noticeable:

1. *The Hunting Stage.* Men with scarcely any social relations wander about over large areas of the earth's surface in search of what food nature produces spontaneously. There is no permanent abode, and hence no stores laid by for a "rainy day." Each day brings its own joy or care, it may be plenty, it may be want. Tools, of the crudest material and construction, like the bow and flint arrow, were the only property possessed by these savages.

2. *The Fishing Stage.* Men were now capable of slightly more settled conditions; a rude hut served for shelter; and a few families were aggregated into the nucleus of a primitive community. A constant supply of food and the conditions for procuring it developed some idea of laying by stores and of possessing crude property.

3. *The Pastoral Stage.* Animals were domesticated and taken care of, thus affording abundance of food, and an incentive to increase flocks and herds. Men were aggregated into tribes, having patriarchs or chiefs, and the first beginnings of a patriarchal government. Hands are now busy building temporary tents, making matting and basket-work, tanning skins, making yarn, and weaving various fabrics for domestic use. Stranger is synonymous with enemy; and bloody conflicts with encroaching intruders are frequent. A dreamy life, too, this is, when the first beginnings of science, art, and philosophy make their appearance.

4. *The Agricultural Stage.* Permanent relation with the soil is now secured. The cultivation of the soil is really a process of domesticating plants. In that way they can be made to increase more rapidly than in a state of nature, and thus furnish more abundant pasture for the flocks of the preceding stage, more abundance of food for man, and more raw material with which to develop the various domestic arts, such as cooking, spinning, weaving, carpentering, etc.

Dependence upon nature is still very marked Rain and sunshine are necessary to a good crop,no matter how well the soil is plowed and cultivated. Yet increased rewards for diligence are more certain here than in former stages; and the incentive to bodily exertion is considerable. Inventions are now often found to be useful; and man's ingenuity is taxed to increase the area of cultivated land without increasing the amount of necessary labor.

The care of animals, and the cultivation of plants, lead to an intimate knowledge of biological laws, such as can be gained through experience alone. This empirical knowledge never becomes scientific, however, as it is acquired unconsciously and incidentally rather than intentionally. Yet it is doubtless to such empirical knowledge of plants and animals, of the dependence of the seasons upon the movements of the heavenly bodies, of qualities of soil as being determined by its chemical and organic ingredients, etc., that modern science owes its beginning.

5. *The Industrial and Commercial Stage.* This stage is characterized by a high specialization of economic activities. Much of the domestic manufacture of the agricultural stage is now given over to special manufacturing agencies. Country life is restricted to few kinds of work. By the invention of machinery, farm life is reduced to a mere routine of sowing and harvesting. Work, other than this of sowing and reaping and feeding of stock, is transferred to factories, around which spring up great centers of population. These are often entirely cut off from the rural districts, save by a highly artificial system of transportation and exchange.

Within these centers of population all is art in the sense that very few of the original physical conditions, such as soil, water, pure air, and sunshine, remain. Labor is specialized. The individual is narrowed to the mechanical performance of a single kind of work, exercising perhaps only a limited number of faculties. It is in these centers of population, amid the nervous stress of a highly developed commercial life and of a highly complex social life, that the need for a return to nature is most strongly felt. None, however, realize fully the effects of these enervating influences who have never known what country life and real personal contact with nature is.

Probable Causes of the Back-to-Nature Movement in Education.

Schools are comparatively modern inventions. The necessity for education has no doubt been discovered by the race in its struggle for existence. Economic conditions are extremely important factors in human life, causing changes in social conditions by which a multitude of new wants arise, and many new and unexpected requisites for the satisfaction of those wants become necessary. Then, too, varying needs give rise to new ideals in the pursuit of which individual habits and social customs are formed. Fashion can be explained very satisfactorily from an economic standpoint; and educational theories and practice are not wholly free from a taint of utilitarianism in some strata of human society.

The struggle for existence assumed a new phase when the race advanced to the higher social stages. In the savage stage it was necessary in the struggle for existence to possess physical strength, courage, endurance, and skill in handling rude weapons of defense and offense in battle. Hence the youth was trained with these ends in view chiefly by the parent.

In the barbarous stages the struggle for existence demanded some power of associated action in war, and a knowledge of the earth's surface where pasture and water for the flocks could be found; as well as some knowledge of astronomy by which the seasons of the year could be foretold. Hence such education as the Arabs, for instance, have to-day.

The agricultural stage requires a knowledge of the soil, of stock, of machinery, of the vernacular language of the community, besides reading, writing, spelling, and ciphering. In the agricultural stage this is the limit of education absolutely required, and hence often the extent of schooling which even the farmer boy of to-day receives.

The struggle for existence in the commercial stage of social development required this and much more. Physical prowess was not now so essential as intellectual acumen. The highest intellectual training was, therefore, sought as the one essential qualification for success.

With the increased specialization of society and the accumulation of wealth and luxury, the fine arts also developed. Even amid such surroundings a human struggle for existence, of a subtle kind, exists; but the struggle is now transferred from the physical to the intellectual. Men no longer use their fists as weapons, but wound the sensibilities of their adversaries by secret thrusts and subtle sarcasm and win their victories by shrewd diplomacy, clever calculation, and insidious connivances. Hence all those intellectual accomplishments of oratory, dialectics, and foreign languages which enable the possessor to influence and control other men's minds became the ideal of education.

This was finally carried so far that a conventional system of professions, beliefs, and practices having no foundation in nature and often in direct violation of fundamental natural laws, pervaded the school and society alike. Labor and practical affairs were looked upon as vulgar, and the secluded scholar delving in old manuscripts within a monastery or writing Latin sermons in prose or poetry for the edification of the ignorant multitudes became the worshiped idol of the hour. It is hardly an exaggeration to say that in England, for instance, during the reign of Queen Elizabeth, next to the court fool, the subtle masters of dialectics and the most consummate diplomatists, if not liars, were socially the élite of the realm. Humanism had thus reached its climax.

A few strong natures, either suffering the inevitable consequences of this artificial and really unpractical training in their struggle for existence, or else true to their better moral natures, became painfully conscious of this depraved state of affairs, and began to utter vigorous protests against the whole social system. Back to nature became the watchword.

Besides these reformers, there were less obvious though more potent forces turning men's minds to the reality of things. The development of wants accompanying social integration and social differentiation led the strongest minds to employ themselves with the solution of those problems which would tend to satisfy those larger wants of society as opposed to individual wants. Humanistic acumen turned its attention to nature, testing the metaphysical system of human beliefs and the artificial practices of their age by skillful observation and experiment. The remarkable results of this method in discovering means whereby to control the physical forces of nature gave a renewed impetus to the growth of science. In the presence of modern science, the struggle for existence has again been shifted, and other qualifications are now essential in that struggle; hence shifting standpoints and new ideals. The idol now is no longer the secluded scholar, but rather a "rough rider" or the president of a steel trust.

If we consider the remarkable complexity of social structure at the present time, where each individual must have a special fitness for special work, or be an outcast of society, we can readily understand that, while the forces of social evolution have from time to time caused shifting standpoints, and the changing needs in the struggle for existence have caused changing ideals, these latter, in turn, tend to produce varying needs.

The needs arising from the struggle for existence are now chiefly physical and intellectual. To be able successfully to satisfy such wants, physical and intellectual training are of course essential. Applied science thus becomes a prominent factor in education.

But ideals will not be materialized, and they consequently create wants that do not refer so much to the grosser struggle for existence as to the enjoyment of the higher pleasures of the spiritual life. The enjoyment of the good, the beautiful, and the true are needs which every normal human being must feel as soon as released from the relentless grasp of nature by a successful struggle for material existence.

Moral education becomes, therefore, an essential element of the ideal education. Our relation to the whole as parts of the infinite must ultimately be the problem of every sane mind which has seriously struggled for intellectual emancipation.

Montesquieu, in his "Spirit of Laws," treats law not as regards its content, but rather as regards its relation to various grades of human society. Is it true that the relation of one thing to another which is too subtle to be stated in physical terms, too obscure to be but vaguely or not at all comprehended by us, is what we mean by the spiritual? The development of the biological and social sciences, and especially the theory of evolution, enables us better to appreciate the importance of the relationships of things, especially the interdependence of human beings and their vital relation to lower creatures. The social side of education is being emphasized as never before. One excuse for the introduction of nature study is that it promotes this social adjustment by developing a keen interest in living things, and a sympathy with things that are not immediately objects of personal selfishness.

Finally, the breaking up of feudalism, the abolition of human slavery, and the spread of democracy are only so many evidences of a powerful tendency of even the human mind to conform to the laws which nature in its universal interdependence teaches. The works of man crumble and decay, and only that is enduring which embodies the eternal laws of nature.

CHAPTER II

General Aims of Nature Study

III. Introductory.

The most general aim of nature study in schools is to promote normal development. More particularly, it aims to place the pupil amid such influences as the laws of human society, on the one hand, and the laws of nature, on the other, prescribe for the final realization, in the pupil, of the higher ideals. Nature study is not intended to supplant the ideals of culture. It is intended to lay such a foundation in body and in mind as shall render the realization of social ideals possible.

The achievements of the human race during past ages are not to be ignored. Traces of these achievements are to be found in written records, sculpture, painting, music, and in social and political institutions. Nature study aims to lay that foundation in the plastic mind and body that will enable the pupil to appropriate these treasures of the past, and to add, perhaps, something out of his own life to the sum of human happiness, the sum of human knowledge, and the sum of human achievement. Thus nature study is not for dispensing with the art of reading, but rather to make intelligent reading possible; not to dispense with writing or arithmetic, but rather to make these something more than mere imitation of muscular movements and manipulation of symbols with no content. In short, nature study is intended to lay the foundations of all arts and sciences, by affording that experience with nature on which all art and science depend.

Emerson could not be accused of materialism, nor of a bias towards realism, nor of dogmatic adherence to a philosophical system. He says: "Words are signs of natural facts. The use of the outer creation is to give us language for the beings and changes of the inward creation. Every word which is used to express a moral or intellectual fact, if traced to its root, is found to be borrowed from some material appearance. Right means straight; wrong means twisted. Spirit, primarily, means wind; transgression, the crossing of a line; supercilious, the raising of the eyebrow. We say the *heart* to express emotion; the *head* to denote thought; and thought and emotion are words borrowed from sensible things, and now appropriated to spiritual nature. Most of the process by which this transformation is made is hidden from us, in the remote time when language was framed; but the same tendency may be daily observed in children. . . . When simplicity of character and the sovereignty of ideas is broken up by the prevalence of secondary desires—the desire of riches, of pleasure, of power, and of praise—and duplicity and falsehood take the place of simplicity and truth, the power over nature, as an interpreter of the will, is in a degree lost; new imagery ceases to be created, and old words are perverted to stand for things which are not; a paper currency is employed when there is no bullion in the vaults. Hundreds of writers may be found in every long-civilized nation who for a short time believe, and make others believe, that they see and utter truths who do not themselves clothe one thought in its natural garment, but who feed unconsciously on the language created by the primary writers of the country—those, namely, who hold primarily on nature. But wise men pierce this rotten diction and fasten words again to visible things."

Nature study aims to prevent that rotten diction of which Emerson speaks, and to guard also against that intellectual bankruptcy which compels the use of a paper currency because there is no bullion in the vaults.

Ideals and Culture in Nature Study.

The reaction theory recognizes the relation existing between all things, the relation of man to man and to the physical universe. This relation is supposed to be one of action and reaction. It, therefore, avoids the extremes of the preformed-evolution theory, the complete isolation of the mind as in the humanistic standpoint, or the extreme, practical view of motor activity of the social theory. (See Part II, Sec. III.)

Interaction is supposed to result in gradual change whereby complete adaptation to environment is secured. Adaptation to human environment means culture. The reaction whereby this harmony between man and man is established is a nervous reaction, and involves the development of acute sensibility to all those influences which human society exerts. Acuteness and delicacy in sense-organs and quick cerebral response to every peripheral stimulation are essential to this social adjustment. Physical defects in these respects, such as general sluggishness of the nervous system, may possibly be the reason why some human beings seem incapable of that social adjustment which we call culture.

Delicate nervous organization is apt to result in nervous tension due to overreaction in nervous response. Hence the too-frequent enervating influence of higher forms of culture.

A constant necessity for reaction leads to striving after relief—a longing for something better than now exists in which the weary soul may rest. Herein is the foundation of the religious sentiment. Then, too, the realization of better conditions, such as partial or total relief from the strain and stress of the struggle for existence, which man, in virtue of social effort, is able to bring about, leads to the hope for still better things in the future. It is doubtless from this sense of fatigue and from the sense of relief being brought about by well-directed effort that the hope of a future life of happiness and our ethical and social ideals arise. Whatever tends to ameliorate our condition in this strenuous life, whether the result of modified external conditions or the result of our augmented strength to meet obligations or to overcome difficulties, tends to elevate our ideals and spurs us on in pursuit of better things. These better things are our ideals. It must be self-evident, therefore, that whatever tends to weaken or degrade us whether mentally or physically tends also to lower our ideals and *vice versa*. Individual and social decay have their concomitant low ideals.

Therefore, whatever promotes the normal development of the individual, body, mind, and soul, in such a way as to enable him to meet successfully that strain and stress which his relation to his fellow beings and to the physical universe brings, tends also to elevate his ideals. Ideals arc not things floating in the air like butterflies to be caught and identified by a name or a symbol, but the promise within us of better things because of our growth towards that which is ideally good. Humanism in its strength had high ideals, but those ideals vanished with the decline and fall.

High ideals can be used, therefore, as a standard by which to measure the quality and character of development; and it is self-evident that educational influences, whatever they may be, which have the effect of lowering our ideals must be guarded against.

Exclusive development of the body has such an effect, because it lowers the individual's power to meet the demands of culture, in which the mind is so largely concerned. Similarly with the exclusive development of the mind, for it lessens the individual's capacity to bear the strain and stress of the highest culture and the struggle involved in the attainment of aims.

The Senses in Nature Study.

All the special senses, hearing, seeing, taste, smell, touch, including the muscular sense, may be used in the study of nature. These senses are evidently developed for that very purpose, or (if we choose to avoid the teleological conception) are developed through those agencies of which they take cognizance. It is difficult to conceive of any mind whatsoever in the absence of these senses. We may well doubt whether one devoid of all of them could really be conscious of his own existence. Imagine all the avenues to the external world closed in a child at birth! Could even innate ideas, so called, manifest themselves?

Our knowledge of the early stages of development does not tend to strengthen our belief in the existence of innate ideas. The existence of such ideas has been affirmed on metaphysical grounds, by those usually who are devoid of scientific training. Transcendentalism of that kind may be left to find its own way in the senseless limbo of metaphysical abstractions. It has little or no use for nature study except as it may minister to physical wants; but it may be doubted whether even transcendentalism could maintain itself without those sense-organs which it professes to depreciate.

The possibility of ideas certainly exists in the normal nervous system developed through physiological processes; but it is hardly probable that this possibility can be realized except through external stimuli. It is through these that the nervous system is made functional. As motion is the function of muscle, so mind and consciousness appear to be the function of the brain. In the latter as in the former the function ceases to manifest itself when the organ is injured or destroyed.

Anatomically the sense-organs are the peripheral portions of the central nervous system. They are the avenues through which the brain is influenced by the external world. Subjective, physical states of internal organs, no doubt, may influence the brain and thus modify, in various ways, the mental activity. But with the senses closed, as the eye in sleep, the mental life becomes essentially a dream-life. Intuitive ideas are sometimes called regulative ideas. Considering the important difference between sleeping and waking, the sense-organs might properly be called regulative organs. For it is by means of them that we are able to distinguish between hallucinations and dreams, on the one hand, and the saner ideas arising through our real experience with the external world on the other.

It is a significant fact that practically all the advance in human knowledge, to which the past century has so largely contributed, has been gained through a more diligent use of the senses than was common among people of earlier ages. Their systematic use, aided by that concomitant power of correct inference, has not only influenced educational theories, but has changed the philosophy and way of thinking of all western peoples. Compare these with the dreamy oriental peoples and the contrast is striking.

Inventions, like the telescope, the microscope, and the spectroscope, have revealed new worlds because of the aid which they give to our senses. It is indeed probable that most of our advance in the future will depend on the success with which we are able to increase our power of sense perception. Invention, which itself is dependent on a knowledge of the laws of nature, may greatly increase our range of vision; but there is also the possibility of a more delicate and complex organic development of the sense-organs themselves.

The conditions under which this organic development of the sense-organs takes place, seem to be suitable activity or proper use. A muscle is strengthened by suitable exercise, and so is a sense-organ. Disuse in the one case as in the other leads to atrophy and degeneration, as can be seen in the blind fishes of caves.

There seems to be no sense-organ that cannot be trained in this way by proper use. Notice in the blind how the sense of touch becomes developed. Certain it is that many persons who have eyes see not, and that many who have ears hear not. Equally certain it is that this defect is a serious one; for it deprives the individual not only of a great source of enjoyment, but of much valuable information which daily observation might give. The acuteness of the senses, resulting from proper use, is not to be sought primarily for its own sake, but rather for the wholesome effect which their best functional activity exerts on the mental and moral life as a whole.

As a rule, children observe well; but a false method of teaching, especially that which reduces all school work to a study of books, often destroys this natural tendency. When we reflect what an important factor in mental growth the habit of close and accurate observation is, we can but deplore that so much of our school work tends to diminish rather than increase this power. Nature study if so taught as to awaken interest, rather than fatigue the pupil, can be made an important aid in the development of this power. When properly developed and trained, observation becomes a habit which cannot fail to be a lifelong aid to intellectual power and growth. By it attention becomes active and concentrated, and the mind's activity is properly maintained. Observation is bringing the mind into contact with the facts of the outer world, thereby increasing the number and intensity of the many forces which contribute to mental evolution.

IV. Training of the Judgment and Imagination.

The Judgment in Nature Study. Mental states affected by repeated sensation seem to be accompanied by changes in the nervous gray matter of the brain, rendering more likely a recurrence of similar states. Phenomena occurring together in this process may, when thus impressed on the mind, recall one another. On seeing a face which is familiar to us, we often recall another face associated with it in our experience; a friend's home may recall the friend who used to reside there; a melody may recall the scenes of our childhood; and an old oaken bucket, many incidents in our early life. Recollections like these often seem instantaneous; no process of reflection or reasoning seems necessary to recall them.

This association of ideas is important in the training of the judgment. Practical minds seem to be those in whom this quick perception of fundamental relations is especially marked. When we make a statement about an object a judgment is involved. The practical judgment is, therefore, trained in connection with things. Nature study is especially well suited to the training of the judgment, not only because there is an association of ideas, but because of the necessity of forming independent judgments that can be tested as to their correctness.

It is in this department of intellectual training, more than in any other, perhaps, that the usual book work in our school education fails. The helplessness, in practical affairs of life, of those whose scholastic erudition is above the average can be largely attributed to the want of opportunity to develop the power of forming correct, independent judgments. To read other men's thoughts from the printed page, and to passively accept the judgments there expressed, may destroy the power of independent judgment.

It is probable that back of all bad habits, back of all crime, back of most if not all of our social evils, there is a warped and undeveloped judgment. Our schools have been engaged in training youth in committing to memory other people's judgments about things. But as usual, memory often fails when most needed. Besides, some judgment must be exercised as to who shall be our guide, if we are unable to rely on ourselves. The authorities chosen, under such circumstances, are not always the best to say the least; and the inclination to accept the advice of even the best authorities is often wanting.

The ability to form correct judgments about things will assist in forming those correct judgments about our fellow men which is so essential to good citizenship; so essential, also, to a realization of our social ideals. The child is apt to be careless and unreliable. So much the more does he need to be trained to carefulness and deliberation in the judgment of things. The habit of weighing evidence, of investigating facts, before a judgment is pronounced, is not only essential to success in a material sense, but will overcome that servile condition of the ignorant mind, too often the result of book work, which accepts as true the most absurd occultism, with little or no effort to test its intrinsic probability, or the reliability of the witness thereto.

Republican institutions and democracy rest upon the independence and self-control to which a sane and sound judgment is so essential. Modern altruism has obliterated physical human slavery; but there is an intellectual slavery to the critic in that mental attitude of dependence on authority which is hardly less demoralizing. Beggars we will probably always have with us; but the wise philanthropy seems to be to so arrange matters that self-help may be obtained, while independence and self-respect is cultivated.

The Imagination in Nature Study.

From visible and finite things, imagination carries us to the invisible and the infinite. Most if not all works of art are the results of conscious or unconscious experience with nature. From a number of parts we infer the whole; from a number of effects we infer the cause; and passing from the particular to the general and from the general back to the particular, we are aided by imagination not only to solve many difficult problems, but we are able by it to rise, intellectually, far above objects of sense, with which we are immediately concerned. From the varied objects of sense we abstract those essentials which conform to our ethical and æsthetic sense, like fragrance distilled from roses, and recombine the various elements thus abstracted into new ideal forms—composite pictures of many visible, real elements. The product of the imagination is, therefore, a good index to the purity of the human soul. The imagination is not only often responsible for that peculiarity in children which we designate by the terms dull and bright, but is often the secret of the superior mental achievements of one person over those of another.

When the training of the imagination is spoken of, many assume, with the old psychologists, that it is a power or faculty of the mind. We know that it is concerned with ideas, and that these ideas may be derived consciously or unconsciously from experience. In training the imagination, therefore, we shall have to look to the ideas that become prominent in consciousness. With the ethical and æsthetic elements in the child's mind developed, the imagination will doubtless take care of itself. Yet it is true that the teacher has to deal with certain phases of imagination with a view to overcoming them. Much of what is taken to be imagination in the child is mere fancy or fantasy; for it lacks that element of analysis and abstraction, and final integration under the guidance of judgment and of the æsthetic and ethical sense to which reference has been made. To call a broom a horse; to put the head of a man on the body of an ox, or the head of a woman on the body of a fish, as was common among the earliest peoples, and is so frequently seen in children's games, requires no true imagination, but merely an arbitrary manipulation of objects of sense. No natural law sustains such a combination, and no analysis and abstraction necessarily precedes it.

This vulgar representation of incongruous combinations of sense elements may be the natural preliminary steps in the growth of the true imagination. It is, therefore, not to be wholly repressed; but it should be recognized by the teacher as something which the child should outgrow. The pupil should be taught to distinguish between the purely imaginary and the real. Failure in this respect is often responsible for many children's dishonesty in words and deeds.

The imagination is not now considered to be an isolated department of the mind, but rather a mode of activity of the whole mind, in which all powers are involved. Consequently normal development of the whole mind is necessary to a cultivated and refined imagination. Such a cultivated and refined imagination does not make itself vulgar by display, but is guided and controlled by a sane judgment, which must ever be the guiding element in any cultivated taste. Back of all this lies a delicate nervous organization; on which, too, depends intellectual power; both being the result of slow growth amid external forces and influences.

Back of much of the so-called corrupt imagination of school children lies ignorance. To the pure all natural things are pure. Many adults betray their fearful ignorance by what they regard as shocking to the refined imagination and demoralizing to the moral sense. A thorough course in nature study should be a sure cure, on the one hand, for that squeamishness and sickly sentimentalism which pretends to see in the most natural objects and acts a reason for disgust; and on the other, for that sickly and perverted imagination which likes to dwell on vulgar and obscene things. There is nothing that can overcome this so effectively as enlightenment—a knowledge of the pure and simple facts. Ghosts lurk in darkness, and hobgoblins are the creatures of ignorance. The pure light of knowledge will disinfect many a filthy nook in the child's mind. It is the mystery hovering around certain natural facts and events which often make them the chief attraction to a child's morbid imagination. Remove the mystery, and the nightmare disappears.

Considered scientifically, and children can be made to so consider it, there is nothing more beautiful and interesting than the subject of fertilization in flowering plants, and that of cross-fertilization through the medium of insects. A careful presentation of this subject will form a safe bridge on which to lead the pupil to the less flowery fields of fertilization of the animal ovum, and the development of the egg into a chick or a tadpole. A scientific knowledge of these things will dispel the foulness existing in the pupil's mind, rather than in nature, and will make a cleaner person of him.

Nature study is well suited, also, to elevate the child's imagination to that higher plane on which it becomes useful in the acquisition of real knowledge, and in the appreciation of the best works of art. For in its final analysis real knowledge must underlie genuine appreciation, whether in nature or in art.

That lawless cerebration, often mistaken for imagination, which results in a crude juxtaposition of incongruous facts and ideas, or a blending of fact and fiction, and which is so prevalent among children and untrained minds generally, needs to be restrained by the teacher of nature study. The child should be put on his guard against confusing fact and fiction, against using his imagination instead of his senses. Even the higher imagination must be subject to the control of the more sober reason. It is precisely here, in the development of a sound discrimination, between fact and fiction, that the supreme value of scientific training lies. Development, in the individual as in the race, must include a transition from that lawless cerebral activity called fantasy, revery, hallucination, on the threshold of insanity, into that state of well-regulated mental activity which gives reality to life, and value to the products of the mind.

The pupil should be taught to correct the errors which his fickle fancy suggests, by careful application of the safest and surest test at his command, the testimony of his senses. What do I really see? should be a question arising spontaneously in the mind when startling and dubious results are gained.

V. The Æsthetic and Ethical Function of Nature Study.

The Beautiful in Nature Study. Nature teems with beautiful things. Art is nature idealized. It derives its inspiration from nature, and seeks to imitate it in its idealized form. Normal development would require that each human being should be able to perceive the ideal in the real. But the old pedagogy virtually had the effect of making the pupil dependent upon the artist's brush or the sculptor's chisel. How many bewildered mortals there are who worry over the degrading influence of the real in literature and art, simply because they have been made dependent upon the artist; their own creative powers having been reduced to mere perception of paint! How abnormal to be unable to interpret the beauty of a real evening sunset, and yet pretend to admire an imperfect copy of it on canvas!

The idea of beauty is by some philosophers classed as an intuitive idea. But the study of children shows that the æsthetic instinct is a growth which progresses *pari passu* with our experience with beautiful things. What in childhood we consider beautiful we do not necessarily consider so in maturer years. A chromo, with a motley array of brilliant colors, may appeal to the child with greater force than the finest steel engraving; much as a brightly colored scarf is more attractive to the Indian than a tailor-made suit of broadcloth.

As development advances, the beautiful in nature and in art is beautiful in proportion as it is full of meaning and suggestive of law. Our æsthetic appreciation develops, consequently, as we become able to eliminate the non-essential and recognize the essential. Knowledge of the essence of things, so far as that is possible, enhances, therefore, our conception of their beauty. An irregular face may be ugly to the ignorant, but truly beautiful to those who are able to appreciate the essential element of a beautiful and true soul within. The ungainly form and features of a friend vanish, in our estimation of him, in proportion as we learn to know the intrinsic excellence of his character. Thus, by intimate association with things, and the knowledge gained through experience, we eliminate, little by little, those characteristics which betray a violation of law, order, harmony, and symmetry, and obtain, by a process of assimilation and integration, a cultivated taste for what is truly beautiful in itself. Association with beautiful objects helps to accelerate this æsthetic development. Like the bee sipping the fragrant nectar from the flower, we, also, extract, through our senses, the more ethereal essence of harmony, symmetry, law, and beauty.

Doubtless this is largely an unconscious process. But the æsthetic judgment may be cultivated by supplying the proper material for observation and directing this observation wisely. We are often led to admire things which at first did not appeal to us, by seeing others, in whom we have confidence, admire them. Children can often be made to appreciate a poem by observing the teacher's appreciation of it, as expressed or implied in her voice and gestures. So, too, a bird, or a blade of grass, or a flower can be given a new meaning, æsthetically, by the teacher's attitude towards it. In the case of the bird, she may point out its uses, the melody of its cheering song, its parental instincts, its adaptations in form, color, covering, etc., to its environment; and, lastly, the inexpressible sadness or the frolicking mischief in its eyes and countenance. By thus combining the various elements, intricately mingled in every natural thing, even an earthworm may become attractive, rather than repulsive, in the eyes of the pupil.

This appreciation of the essence of things, so far as that is possible, by a careful study of them as regards symmetry, harmony, order, law, and use, cannot fail to be a most potent factor in developing a genuine æsthetic taste. Precluding the false, the lawless, the disorderly, and the incongruous, such a taste is evidence of law, harmony, and beauty of soul, which must manifest itself in the daily conduct of the pupil. The teacher who succeeds well in developing such original appreciation of the beautiful in nature may find further assurance of her worth in the following words of Thomas Carlyle: "He who shows us more clearly than we knew before that a lily of the field is beautiful, has sung for us, made us sing with him, a little verse of a sacred psalm."

Ethical Function of Nature Study.

The study of science is the surest means to the development of scientific culture. This culture is essentially ethical, and, for that reason, must be the safest foundation of social culture. It is true that it is not favorable to the development of useless sentimentalism; but, by the strengthening of the judgment, the development of sane ideas, and the training of the scientific imagination, it must tend to enforce the golden rule and the dictates of a clear and discerning conscience. What is right and what is duty will be revealed, as it has been revealed, by practical experience, if a sound judgment interprets that experience. The child's practical experiences with human beings and with the animate and inanimate things about him are his first and most enduring lessons in right conduct.

The motive to successful scientific endeavor is a natural or acquired thirst for truth, to be satisfied only by the exercise of the will under the guidance of a clear perception and a sound judgment. A wise discrimination between the false and the true is not only essential to any permanent social structure, but is the basic element in the sanity of the human mind.

Nature study cannot be made a science, nor should it be; for science is the ripest fruit of development. Its methods, however, when gradually introduced into school work, must have a wholesome effect, inasmush as it places the pupil's mind and activities into proper relation to reality and truth. The indifference of most children in regard to this matter, and the positive untruthfulness of others, comes from inexperience, on the one hand, and, on the other hand, from a training in which individual responsibility is eliminated by a constant reliance on authority.

The pupil should be made to test the truth or falsity of his conduct, no less than the truth or falsity of his statements. The love of truth for its own sake, and aside from any utilitarian considerations, should be so thoroughly ingrained in the nervous organization of the pupil as to assume the character of an instinct. This accomplished, he can hardly be cruel to any sensitive thing or false to any man.

Nature study, more than any other study of the school, affords educational opportunities in this direction. Here lapses of memory, which are often responsible for false statements, and, in the case of moral maxims, a plea for insincere and immoral conduct, may be corrected by careful examination of the object about which memory has failed. Here, as in no other study of the school, the pupil can be made to feel his moral responsibility both with regard to his work and his utterances. He can be made to feel that truth and nothing but the truth is wanted, and that all carelessness in observation and statement, all slovenliness in his work, is a violation of the moral law, and is detrimental to his reputation and standing in the school.

He can be made to feel, also, that strict adherence to duty and to truth requires constant vigilance on his part; that truth can be attained and adhered to only by systematic effort; that mistakes and error creep in whenever he fails to properly attend to the minor details of his work, and when he shirks his duty in doing the work as the teacher has suggested. At every point he can be made to see that a falsehood or an incorrect statement vitiates his whole work.

In like measure, he can be made to feel that vigilance and circumspection, unyielding adherence to duty and to truth, are the foundation of his success, the measure of the value of his work, and the criterion by which he is personally estimated.

When nature study is properly correlated with other branches of the school there will be no lack of opportunity to develop that quick-wittedness and intellectual versatility which is so desirable in youth, and which is doubtless a desirable phase of mental evolution.

VI. Knowledge and Character Building.

Nature Study and Character Building. Besides a sound judgment, the chief elements which combine to form character are will power and self-reliance. Without these an individual fails to execute what his judgment and ethical sense dictate. A strong character is one in whom these characteristics predominate.

Nature study is well suited to develop will power and self-reliance. The pupil must accomplish his task independently. He is not to rely on the judgment of others, nor is he to get his incentives to effort wholly through foreign aid. His work is, in fact, original work, and should contribute towards making him an original observer and an original thinker. He must get as much of his information as possible at first hand. Nature study should not be taught primarily from books.

This does not imply that books and secondary sources of information should be excluded from his work. He should be made familiar with library sources of information; but they should be the last to be consulted after he has exhausted his own resources.

The pupil should not be trained to despise authority, as there are many instances where good authorities are our best and only guide. A sound judgment, when properly trained, will lead the pupil to subordinate his own personality where it is inadequate to the task, and will warn him not to attempt what is impossible. Yet nature study deals with the original sources of knowledge, and as such will call, in the majority of cases, for that exercise of the will in repeated attempts to overcome difficulties which tends to strengthen it. The success which often follows from such exercise of the will naturally tends to strengthen self-reliance.

With this end in view, the work can be so arranged by the teacher that a proper amount of success in the work will be attained whenever a due amount of energy is put into it. Poor results with work thus arranged should not be accepted, and a due recognition should be given when the work is well done. Such consciousness of success strengthens the self-reliance of the pupil, and stimulates him to further exercise of his will.

Opportunity for this exercise of the will is necessary to the formation of character. Without will power, knowledge, no matter how extensive, produces no results. The theory that all school work should be made as agreeable as possible does not mean that it should be reduced to mere listless and idle play. The aim should be to eliminate the notion of play as the pupil advances, and to lead him to apply himself, voluntarily and systematically, to his work. The great variety of the pupil's powers, both physical and mental, brought into exercise, when nature study is properly pursued, renders it pleasurable, and makes it less fatiguing than are many other branches of the school.

Character is not developed by avoiding contact with the realities of life—contact with things. On the contrary, it is by entering into this real life, by acting and reacting on the physical environment, properly regulated, that the pupil learns to estimate his powers correctly, to realize his weaknesses, and to gain that self-control, amid all vicissitudes, which constitutes the practical demonstration of character.

The physiological explanation of this is, perhaps, to be found in the fact that the laws of nature are uniform. Consequently physiological reactions to similar forces and influences must also be uniform. Hence the nervous system acquires a specific quality of organization which underlies stability of character. Human society, cut loose from nature and guided by fluctuating feelings and motives, does not offer that constancy to nervous reactions. Hence stability of character should hardly be expected as a result of social intercourse alone. The latter tends, rather, to develop that nervous state from which nothing can be safely predicted.

The pupil's physical health has much to do with the development of will and self-reliance, and hence, also, with the development of character. A stunted and diseased body is often the cause of moral depravity. Not by physical torture is the mind and soul purified, any more than the choicest apples are to be gathered from a rotten tree. Let the pupil's health, therefore, be attended to. Remember that states of the body react upon the mind. Proper light, proper positions when at work, and proper activity in the field should be insisted upon. Nature study out of doors is the best of tonics.

Knowledge Gained in Nature Study.

Scientific results cannot be expected in nature study. The acquisition of knowledge should not be made its chief or only aim. In the teacher's mind the pupil should take precedence of the facts to be imparted. Natural growth, in physical and intellectual power, should be considered paramount. This attained, knowledge will be sure to follow; while, if not attained, a few facts more or less will be of little consequence.

It is, however, by exploring the original sources of knowledge, and by acquiring as much of that knowledge as present powers permit, that natural growth of the nervous system, and consequently mental power, is promoted. We gain our knowledge through experience, either personal or ancestral, and we are what we are by virtue of that experience. It is probable that every reaction to a sense impression implies a more or less permanent change in the nervous system, and that a pupil is not the same after having learned a fact by observation that he was previous to the acquisition of that knowledge. However worthless some facts may seem in themselves, therefore, they may be important factors in the shaping of the plastic mind. Furthermore, no fact is really worthless in science.

Youth seems to be a period very favorable to the learning of some facts which in later years are acquired less easily. This is especially true of terms, such as names, etc., which are held more or less mechanically in the mind, with no necessary logical connection with other mental products. The acquisition of this technical language in early life, with the simple idea back of the word, is valuable to every one in this age of science, even though the person fails to enter upon the study of pure science.

Nature study is the natural means of acquiring that language which enables us to appropriate the human treasures of the past as contained in books. With an appropriate method of teaching and study, both the facts and the language will be acquired naturally, without much effort on the part of the pupil. Much of this will be acquired by unconscious induction, while the pupil is engaged in the healthy exercise of his powers.

Knowledge is valuable, intrinsically, in proportion as it is scientific. But nature study should not be made too matter-of-fact, because it is primarily intended to develop those powers which will make scientific work possible. A fact, however, should be a real fact, not an imaginary one; and a clear distinction should be developed in the mind between fact and fiction. There is little occasion for sympathy with that ignorant sentimentalism which insists that interest and appreciation can be divorced from knowledge of facts. The youthful mind and the untrained adult mind are too prone to dwell on the unreal and the absurdly untrue, in fairy tales and fiction, to need any encouragement in this department of school work. From the character of the pupil as he enters the school, and from the natural course which his development must take, it seems reasonable to say that the nature-study work should be made more and more scientific from the lower grades up. In the upper grades it can hardly be made too scientific. Considering the scientific preparation of teachers even in many high-schools, the danger is that it must either become mere recitation from a text-book or else only a crude imitation of scientific work. Again, it may be said that the little science pupils in the grades are able to master, even when conditions are most favorable, will not hurt them, as some theorists seem to believe.

VII. Expression and Generalization.

Expression in Nature Study. An important principle in pedagogy is this, "the idea before the word." The development of language, both in the race and in the individual, teaches us that language is the result of ideas, not necessarily the cause of them. When the child has gained, through experience with its environment, certain ideas, it feels the need of expressing them. As a social being, on entering school, its mode of expressing ideas is by means of oral language. Later it adopts other means, such as drawing, making, and writing.

Each of these modes of expression has its own advantages and disadvantages. Many ideas can be expressed orally which cannot be expressed by drawing or by making; and, on the other hand, many ideas, such as color and form, can be better expressed by means of the pencil and brush.

It is self-evident, of course, that ideas must exist in the mind before they can be expressed. The expression of ideas, however, involves neural processes and muscular activity which react on the mind, and thus become intimately concerned in that final product, mental power, which is the great aim of our work.

Then, too, by expressing an idea we are better able to criticise it. We often discover the inadequacy of our knowledge by trying to express it, and are led to re-examine facts and phenomena from different points of view. Mental assimilation is thus promoted, and ideas assume their due prominence in relation to one another. It is by the pupil's expression of his ideas that the inner cerebral mechanism is revealed to the teacher, who is thus enabled to correct erroneous impressions, or to guide the pupil to proper self-activity.

It was a fundamental principle in the philosophy of the founder of the kindergarten that development is an unfolding of intrinsic powers, and that expression is evidence of that unfolding. Such expression, however, is mere play, for it is not guided by external reality, nor adapted to it. The selection, in the struggle for existence, which contact with nature involves, does not operate amid such conditions, and the expression, therefore, is but the outward manifestation of lawless cerebrations within. That is not nature study.

Nature study is deriving ideas, through the senses, from the external world. These ideas are not spontaneous growths in the mind, nor are they intuitive. They are the results of experience, and should derive their meaning from that experience. Expression in nature study should be conditioned by outward phenomena. Not mere talk, but talk which means something; not merely ideas, but ideas corresponding to realities, rather than subjective states, should be sought in nature study. If this correspondence of the idea with outward phenomena is lacking, its expression had better be reserved for the playground.

There is an educational value, also, in the power of inhibition, the suppression of irrational and erroneous ideas. In fact, the more critical we become, the more do we hesitate to express an idea the absolute truth of which is doubted. Culture is characterized, often, by scrupulous care in expression, whether it be expression by oral or written language, or that expression which reveals itself as conduct and personal appearance. Mental power may often reveal itself in silence; and education and culture reduces meaningless expression to a minimum.

Used as an educational means, rather than as a means for pastime, nature study should promote that scrupulous care in the choice of words which exactly express the idea. Furthermore, it should tend to that accurate and systematic thinking which forbids expression when there is nothing to express. The ability to discriminate between those ideas which conform and those which do not conform to the external reality is not so common, even among adults, as might be supposed, considering that this power is the basis of common sense.

This does not imply that the emotional nature of the pupil should be suppressed, nor that the play of the imagination, so natural to childhood, should be entirely discouraged. It means, simply, that the pupil should be trained to discriminate between fact and fiction; between the real in nature and that which is the result of his own emotional states.

No rule can be laid down. The teacher will find ample opportunity here to exercise a wise judgment in striking a happy mean. The safest way is, doubtless, to confine the pupil to the facts during the first lessons on any one topic, and finally, after the subject is well understood as to the facts, to express whatever of sentiment and poetry it may suggest to him. We have a right to express our appreciation of a thing only after we know that thing. Let appreciation be based, not on our own selfish, indolent states, but on the merit which deeper insight reveals.

Oral expression, speech, is most convenient in the preliminary development of a subject. It saves time when the object is to correct errors or to suggest ways of avoiding them. Drawing and the final written work are better deferred till the subject is well understood. The study of unfamiliar things involves the discovery of new facts and new relations of facts. New ideas of facts and their relations require new terms to express them. A need for such new terms will be felt by the pupil when he begins to relate his observations. The need being felt, there is evidence that the pupil has the idea, the name or symbol for which should then be supplied by the teacher. This is the natural way of acquiring a vocabulary. When the word is supplied in this way when needed, it means something, and will be properly used later in written work.

Hence nature study is the only sensible means of teaching language in its rudiments. Pupils as a rule find no great difficulty with scientific terms if supplied when needed. They often, in fact, enjoy a difficult scientific term, and seem to master it as easily as a simpler one.

It is a common experience to find that children and unscientific people inquire about the name of an object, but often manifest no desire to know more about it. If the teacher knows the name of the object, it may be well to give it at the proper time, but better still to teach the pupil how to find the name by reference to authorities. One important feature of the unabridged dictionaries is often overlooked—that, namely, which gives the figures and the names of most common objects. But the pupil should be trained to realize that the important characters of an object are of greater value than its name. To study nature by merely learning the names of things would be about as sensible as to study economics or sociology by learning the names of the inhabitants of the community. John Smith the man should be of greater importance than John Smith the name.

There are many names, like many laws, that are common to many or all living things. Such names should be insisted upon in this work. They are the labels by which we identify bundles of facts, conveniences of which the teacher, at least, cannot afford to be ignorant.

Generalization in Nature Study.

Extremely important as observation is, it is not to be cultivated for its own sake. To be constantly attending to every trifle, without assimilating what is observed, is a useless waste of time. Indeed, there is danger in nature-study work of overdoing observation to such an extent as to preclude the possibility of reflection. A dilettanteism may be developed in which the mind passes lightly from one fact to another without perceiving the import of the fact or its relation to other facts. That is not peculiar to nature study. Superficial reading produces the same mental habit.

In one sense it is fortunate that we are able to forget unimportant details. For it is by a process akin to forgetting that we are able to generalize. The object of observation is generalization and abstraction. Many facts with which nature study deals are in themselves worthless. They are valuable, however, in proportion as they furnish data for correct generalization. One generalization is worth a hundred facts. The power of generalization, therefore, should be developed; and observation pure and simple should not be allowed to monopolize all the time and energy of the pupil.

The power to generalize differs in different individuals. It is impossible to say whether this difference is due to heredity or to difference in early training. There is, doubtless, a hereditary element in nervous organization as well as an acquired one. This is, however, not synonymous with saying that general ideas are inherited. Generalization means deriving general ideas and concepts from many particulars. This is induction. It is now thought probable that all our general ideas and notions arise in the mind in that way. It seems to be by a process of assimilation, analysis and integration, of the essential aspects of many particulars, and the elimination, forgetting, of the non-essentials, that general concepts arise. Thus, for instance, the general notion of a genus arises from the actual observation of several species. It is true that some of the older psychologists say that the idea of a genus exists before the idea of species; that, for instance, the concept *horse* must exist in the mind before a particular horse, as "*Prince*," can be recognized. This, however, is a mere contention, maintained chiefly for the sake of a philosophical system. We probably get the notion *dog* by repeatedly seeing various dogs, as Rover, Fido, Jack; and, from them, the general concept dog. It is said that Newton, on seeing an apple fall to the ground, was led to the discovery of the general law of gravitation. He had, doubtless, seen many things fall before he undertook to formulate the general law of falling bodies. Others had seen the same thing; yet, unlike Newton, they dwelt on the particular facts without deducing the general law. Newton generalized. Observation should lead to generalization and abstraction. Physiologically, this may possibly mean that a nervous connection should be developed between the various elements of the cerebral cortex, so as to facilitate a regular and well-defined interaction between those elements. Mere observation may involve the activity of isolated centers only, giving no coherence to the elements of knowledge.

Abstraction resembles generalization in this, that, from a number of particulars, we eliminate the non-essentials and obtain an idea of some quality common to many objects, but apart from any one of them. Thus, from the sweet fragrance of many clovers, sweet peas, etc., we may derive the abstract conception of sweetness in general.

These general and abstract ideas, arising thus through our experience with particulars, are of inestimable value in the following stages of mental development. They become controlling influences in the voluntary life of the individual; regulative ideas, as they are sometimes called. They are indications of a formed and stable nervous system. Indeed the one supreme aim of nature study might be said to be to promote this nervous organization, the formation of these general concepts; for it is only after these have been formed that considerable advance in real science is possible. From this point of view, also, nature study is the foundation of all other studies of the school; for it is evident that even reading is impossible without these general ideas.

The proper development of this power of abstraction and generalization is, indeed, the most difficult of all our educational aims. There is danger on both sides—that of overdoing observation, on the one hand, and that of overdoing generalization, on the other. Correct generalization requires a sufficient number of accurate data of particular facts. If generalization is overdone, there is danger of ignoring facts and jumping at conclusions. The confidence we place in the opinions of men depends largely on the deliberation with which they sift their evidence before forming a conclusion. The habit of scrupulously attending to the particulars before a general notion is formed is characteristic of the judicial mind; and it is the same habit which gives weight to the opinions of the man of science. When we notice how prevalent the opposite tendency is—that of jumping at conclusions, with no sufficient evidence,—and when we notice, too, that this is characteristic of youth and the ignorant and untrained, we have reason to believe that there is a physical cause, namely, absence of stable organization of the nervous system.

The habit of generalizing on insufficient data sometimes assumes a morbid form, that of abnormal introspection. In this form it interferes with observation, often making the subject see particulars in a false, subjective light. Prejudices thus arise which render a normal evolution of the mind impossible. Pupils of this type often seem prematurely old.

On the whole, generalization is not normal to the young plastic mind. Generalization should become prominent at that period in life when the nervous organization approaches completion. Juvenile philosophers are abnormal, because they betray an unnatural precocity of nervous organization, which renders them unable to receive those numerous new impressions which would prolong their period of mental evolution if their nervous plasticity could be retained. A wisely planned course in nature study and science, by offering great variety of impressions, may maintain the nervous plasticity, and thus prolong the period of mental evolution of those who by nature are precocious; or, on the other hand, by supplying material duly arranged for generalization, it may hasten the intellectual development of those who are slow in maturing. The teacher can hardly find any field in all his work in which such excellent opportunities offer themselves, not only for the exercise of the best possible judgment, but also for obtaining remarkable results.

While it may be considered undesirable, therefore, to hasten the process of generalization in young children unduly, because it interferes with that plasticity which is desirable in the child, and indeed necessary to the highest intellectual attainments, it is very certain that the opposite course, that of overdoing observation to such an extent as to preclude generalization, is equally undesirable and pernicious. The mere "observer" is a character which is sometimes met with even among naturalists so called. They are the opposite extreme of the morbid introspective dreamer. While the latter's eyes seem to be of no use to him, so far as influencing his mental evolution is concerned the former seems to be all eyes, with no brains back of them to elaborate and assimilate the crude chaff upon which his eyes constantly feast. The one is as abnormal as the other, and it is difficult to say which of the two excites our pity most.

The teacher of nature study must seek to find the golden mean between these two extremes. Remember that not all facts are worth remembering, and that nature did well in enabling us to forget. Mere observation of isolated facts may so load a mechanical memory with rubbish as to interfere with the proper evolution of the mind, which in its normal activity passes from the particular to the general, from the concrete to the abstract, by a process of elimination and forgetting. The possibilities of such an overloaded mind are not great. Dwelling continually on a mass of details, it develops no regulating principles, no rational basis for conduct. For these must be general principles. The achievements of a mind dwelling constantly on isolated facts must ever be a matter of chance. No voluntary rational direction can be given to its mental energies; and science in its true sense, as systematized knowledge gathered in the light of guiding principles and stimulated by a general idea, must ever be foreign to it. "Mere observers" are sometimes called scientists, but erroneously. The ordinary teacher of nature study is doubtless aware that books on nature study are usually made up of a disconnected mass of curious observations, often interesting, but extremely fatiguing to the mind, when attempt is made to get any lasting information from them. Often the sense of equilibrium is restored only after most of the details are forgotten. It is difficult to understand what use such mere observation can be except as it affords a pastime to those who have nothing else to do. A false method may lead to such mere observation of disconnected facts, and develop a dilettanteism which, in the eyes of those unfamiliar with natural science, has all the appearances of a fad.

Such may err in assuming that observed facts that are apparently worthless must necessarily be so intrinsically. It may be doubted if any fact, however insignificant, when impressed upon the mind, does not in some way affect it; that the brain after a stimulation becomes absolutely the same as it was before that stimulation.

Sense stimulation gives rise to unconscious induction. Much of the nature-study work in the lower grades must be of this nature. Observation must here predominate. Indeed it is doubtful if any considerable effort should here be made by the teacher to lead the pupil to generalize. The history of the human race, so far as we have any record of that history, suggests that a period of unconscious induction preceded the age of generalization—the philosophical and theological age—and that the latter ages preceded, in the history of western peoples at least, the period of conscious systematic study of nature—our present scientific age. The same stages properly belong to the individual; (1) the period of unconscious induction by a varied experience with natural things; (2) the period of generalization and speculation; (3) the scientific period, in which the individual, doubtful of his previous generalizations, yet impressed by their importance, proceeds voluntarily and systematically to test, by accurate observation and experiment, the truth or absurdity of those previously formed general notions. This latter, alone, can be called science.

For various reasons, among which may be included not only want of school training, but also unnatural school training, many persons never arrive at this third stage; or do so at such an advanced age that but very little of real scientific work can be done. Nature study, properly graded, can so condense the first two periods as to make of the graduates of our schools, if not scientists, then men and women with that broad-minded conservatism which is so highly to be prized.

Finally, the teacher of nature study should be, not only a good observer, but also a sane thinker. Nature study deals with the finite; yet there is much in it to suggest the infinite. All generalizations are necessarily partial that do not proceed from a central conception of the whole. But that does not detract from their value, since, to the finite mind, the infinite is incomprehensible. The race has developed certain conceptions of the infinite, which to many are sacred legacies of the past. These legacies, having survived the storm and stress of conflicting opinion since man began to think, must possess some fitness to supply a natural need of man. Educational theories, too, are subject to the same law of selection. Progress results, not by destroying the old, but by the new additions that issue from it.

> Build thee more stately mansions, O my soul,
> As the swift seasons roll!
> Leave thy low-vaulted past!
> Let each new temple, nobler than the last,
> Shut thee from heaven with a dome more vast,
> Till thou at length art free,
> Leaving thine outgrown shell by life's unresting sea!

CHAPTER III

General Methods

VIII. Methods of Reasoning.

Logic has been defined as the art of directing the reason aright in acquiring the knowledge of things, for the instruction both of ourselves and others. In this is involved (*a*) objects, (*b*) thought, (*c*) language. In the presence of an object we may (*a*) simply apprehend it, (*b*) then form a judgment about it, and (*c*) reason about it and talk about it. To apprehend is simply to be aware; to form a judgment is to compare with other things, and to reason or converse about it is to express the activity of the mind in symbols or terms combined into sentences or propositions. The terms may be: (*a*) particular terms, (*b*) general terms. The first denotes only a single object, the latter is applicable to any one or all of any indefinite number of objects. This is what is meant by the expressions general and particular.

1. THE DEDUCTIVE METHOD is the method of reasoning from the general to the particular, thus: All frogs croak; this animal is a frog; therefore this animal croaks. Or, all fungi are plants; this is a fungus; therefore this is a plant.

The general is supposed to contain all the particulars; and, consequently, it is assumed that, knowing the general, the particular can be inferred. Hence, also, the expression, from the abstract to the concrete.

The disadvantage of this deductive method lies in the fact that, in many cases, we may be led by our enthusiasm, indifference, prejudice, or carelessness, to assume the general to be true when it is not. Thus: A hat is passed around in church for contributions to the mission fund. It is assumed that this contribution is to be money. After the collection an account of the money contributed is to be rendered to the assembly. You take out one contribution after the other, and finding one nickel after another, you jump at the conclusion, not only that (1) everything in the hat is money, but that (2) it is all nickels. It turns out, however, that this is an error; for one rascal, having no sympathy with missionary activity, has contributed a button instead of a nickel. Hence the discrepancy in results. Conclusion (1) is a result of error in deduction, and (2) error in induction. Then, too, we may select unconsciously such a major premise as will sustain the conclusion sought. General terms are often misleading, therefore, because (1) they may have more than one meaning, (2) they may be supposed to include what they do not include.

This method may interfere with observation, the mind being satisfied with the inference drawn from the general idea, which is too often merely a vague one.

Its advantages lie in the fact that, if the major premise, the general, is true, the conclusion must be true also. It is equivalent to a mathematical demonstration; and it is often said that nothing short of such a demonstration can be considered positively true. Manifestly, unless we assume that the general is innate, the mind has first to acquire the general notion or arrive at the general concept; and, consequently, this method should be avoided until such a time when the general idea is really present in the mind. Hence its advantages become most apparent when used in connection with the inductive method.

2. THE INDUCTIVE METHOD is passing from the particular to the general. Thus by observing a number

of horses we finally get the general idea that all horses neigh, perhaps; or that all horses have a mane. Or more definitely: Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, and Sunday contain less than twenty-five hours. These are all the days of the week; therefore all the days of the week contain less than twenty-five hours.

Induction is the mode by which all the materials of knowledge enter the mind, and are analyzed. It is sometimes defined as inference from the known to the unknown; or, as passing from the concrete to the abstract.

The disadvantages of this method are: (1) It requires sound sense-organs; (2) physical strength besides mental activity; (3) states of consciousness may affect the peripheral sense-organs; (4) it is a slow and laborious method. It requires less effort to assume the truth of a general proposition, and then to proceed to draw conclusions about everything included in that general, than to carefully examine each particular thing individually, and, from many such examinations, to draw general conclusions. The inductive method suggests the laboratory, with all its arduous work; while the deductive method suggests the drawing-room and the easy-chair, possibly the library. (5) Unless all particulars are thus examined, general conclusions may not be absolutely true.

Consequently there are: (*a*) *perfect induction* (all particulars examined); (*b*) *imperfect induction* (only a large number of particulars examined). Perfect induction is sometimes said to be no induction at all, because, if all particulars are examined, there is no gain from an inference, all being gained through experience. The object of an inference is to pass beyond what can be immediately perceived.

The advantages of induction are gained from the imperfect induction referred to above. A permanency or constancy of natural law is assumed. Consequently, from an examination of a large number (not all) of particulars, the truth of the general is assumed; as, what is true of many of a kind is probably true of all. Thus, if after examining a large number of horses we find they have incisors in both jaws, we infer that all horses have incisors in both jaws. The truth of this inference depends on the constancy of the natural law. Should that constancy fail, our inference would be erroneous.

There is, too, what may be called (*a*) *conscious*, (*b*) *unconscious* induction. It is very probable that many of our general ideas appear in consciousness as a result of sense experience and subconscious cerebrations, with no conscious effort, on our part, to form such ideas. This is doubtless true in the earliest years of child-life. Manifestly such unconscious induction is subject to such errors as result from unguided activity. Thus, subjective states often influence the physiological activities of the senses, as in hallucinations; and, as when a child sees ghosts. People are sometimes said to see what they want to see, i. e., the sense-organs may be affected by the states of consciousness, making the testimony of the senses unreliable; hence, carelessness, prejudice, preconceived notions, over-enthusiasm, indifference, and, above all, slovenliness, are liable to vitiate results.

Conscious induction may, perhaps, be best described as inference from material of knowledge, gained through the senses, under the control of the will. Manifestly such conscious induction must follow the unconscious induction, and is, perhaps, only possible after general ideas have arisen by the unconscious processes. Conscious induction may, therefore, be partly a voluntary application of the senses for the purpose of proving or disproving the correctness of our general conceptions gained through unconscious induction.

3. THE INDUCTIVE-DEDUCTIVE METHOD is, as the name implies, a combination of the two methods already described. This is probably the method used by all those who achieve success in science. Indeed it is difficult to conceive of true scientific work with either of those methods used alone. This method consists in first gathering the material of knowledge by observation. From this a general idea is formed and assumed *tentatively* to be true. Deductions are then made from this general hypothesis, and induction again employed to verify the truth of those deductive inferences. Thus, careful observation shows that plants grown in sunlight are usually green; the inference is that all plants influenced by sunlight develop chlorophyll. This assumption is held tentatively till further induction, as to the effect of sunlight in producing various pigments, as tanning the skin, is secured. It being found that sunlight has this effect, further observations are made, which reveal the fact that plants grown in darkness do not develop chlorophyll, etc., from which the soundness of the original inference, having been tested, is pronounced true.

The advantage of this combined method is that the benefits of each of the other methods are secured, but the disadvantages eliminated. Far more, too, can be accomplished by this combination. The inductive method is used for the accumulation of material for the general idea; and, this knowledge being gained, is again employed in the discovery of new truths.

General Considerations. Observation and experiment, the method of science, naturally results from this inductive-deductive method of reasoning. The successful man of science is (*a*) a good observer, (*b*) a good thinker, (*c*) a good worker. Many students observe well and reason well; but, as they put no energy into their work, accomplish but little. Others work, but do not observe well; and still others work and observe well, but lack that power of reasoning which is necessary to make diligent observation and experiment effective.

The inductive method, alone, makes the mere observer; the deductive method is chiefly the method of the philosopher and the dreamer. Students often become mere observers, because they lack the general notions which give meaning to the observations which they make. The true incentive to effort is thus wanting. This can often be remedied by calling attention to the larger problems underlying the subject of study. Thus a general idea of the theory of evolution by natural selection, is the chief cause of that remarkable activity in biological research which has been so marked since the appearance of Darwin's "Origin of Species." There is hardly any phase of biological investigation to-day that does not owe its fascination to the stimulus which that theory gives, and to the light which new observation adds to the factors of organic evolution.

No adequate idea of the full import of this great generalization can be conveyed, directly, by means of language, as is frequently supposed. But some phases of it, such as the struggle for existence, can be comprehended from observations on plant and animal societies. Whether it is wise to develop this conception in the pupil's mind is a question which the teacher must decide according to circumstances. It certainly gives new meaning to many facts in plant and animal life which otherwise are meaningless. Darwin's great work was the result of the inductive-deductive method. The writer knows, from his own experience as a student, that many teachers of advanced science are failures, as teachers, because they do not arouse in the student's mind those great conceptions which give meaning to things observed by the student, and add that intellectual interest which makes arduous labor a pleasure. Sentimental appreciation is a poor substitute for that intellectual pleasure which arises from the discovery of truths, revealing themselves as connecting-links between the known and the great unknown.

IX. General Methods of Teaching.

1. The Discovery Method might also be called the *seeing method.* It is the method which the savage uses in obtaining his empirical knowledge of his surroundings. It may be characterized as negative rather than positive, inasmuch as a controlling general idea or hypothesis is wanting, and no conscious attempt at system is made.

This is also the natural method of the child. It is natural for the child to move around freely among objects, without any reason known to it, save that of a natural restlessness accompanying a superabundance of energy, or that of a vague curiosity. In this way the child makes many discoveries. The liberty enjoyed is wholesome, and therefore such activity is interesting. The observations and discoveries thus made give the keenest pleasures, because they are the results of its own spontaneous activity. Mere seeing, if carried no further, however, would be of little value; but, as an introductory step, it is of the utmost importance. The method and some of its results are beautifully expressed by Whittier as follows:

O! for boyhood's painless play,
Sleep that wakes in laughing day,
Health that mocks the doctor's rules,
Knowledge never learned of schools:
Of the wild bee's morning chase,
Of the wild flower's time and place,
Flight of fowl, and habitude
Of the tenants of the wood;
How the tortoise bears his shell,
How the woodchuck digs his cell,
And the ground-mole sinks his well;

How the robin feeds her young,
How the oriole's nest is hung;
Where the whitest lilies blow,
Where the freshest berries grow,
Where the ground-nut trails its vine,
Where the wood-grape's clusters shine;
Of the black wasp's cunning way,
Mason of his walls of clay,
And the architectural plans
Of gray hornet artisans!
For, eschewing books and tasks,
Nature answers all he asks;
Hand in hand with her he walks,
Part and parcel of her joy,
Blessings on the barefoot boy.

2. THE INVESTIGATION METHOD differs from the preceding in that something definite is looked for or sought. It requires the exercise of the will and therefore is work. There is in the mind a hypothesis, or a question, that needs solution or confirmation; just as in algebra the problem often is to find the value of x. A general idea, a general question is, therefore, the underlying motive; and this guides and directs activities, making them systematic, for the accomplishment of an end in view.

The race may be said to have entered on the scientific stage of its development when it began to use this method of studying nature. So the individual may be said to pass from the primitive condition of the child, the amateur, and the dilettante, to the working scientist when he adopts this method.

It differs from the preceding discovery method in substituting the law of necessity for the law of liberty; reason for caprice; the hypothesis for curiosity; intellectual pleasure for sentimentality; and the will for listlessness. It means a body directed by the mind, and work performed under the influence of the will. It differs from the preceding method, therefore, in (*a*) the motive to exertion, (*b*) in its orderly proceeding, (*c*) in its final results. Thus it is often said of Columbus that he was an adventurer, who merely from idle curiosity, from a natural shiftless disposition, for mere excitement, crossed the unknown waters of the Atlantic, and thus, by accident, discovered a new world—such would be the discovery method.

On the other hand, it is also claimed that Columbus was a student of geography, astronomy, and navigation; that he had thus been made to believe the world to be a sphere, and, consequently, formed the hypothesis that, by sailing west, the eastern coast of Asia could be reached. He directed his ships in the light of that hypothesis, and found the new world. In the latter case he employed the investigation method. It makes us think of Columbus as a scientific investigator rather than as an adventurer.

Investigation means the search for new truth by the light of what is already known. *Research*, as applied to advanced scientific work, means the investigation of phenomena hitherto unknown to humanity; or the attempt to solve those problems that have thus far eluded solution. To do such work the student must first appropriate the sum of human knowledge in that particular department of knowledge; for it is only on arriving at the borderland separating the known from the unknown that valuable original research can be done. Not the least of the task such a student has before him is the understanding of the problem, after the problem has been found; for it is only by mere chance that the solution to a problem can be found without knowing what that problem is.

Work like this is, of course, the work for specialists, and may, therefore, seem to have no bearing on methods of nature study. But it may be that the conditions for the gaining of new knowledge are the same for all of us, and that methods, in nature study, cannot entirely ignore the suggestions which advanced work may yield. In mathematics, for instance, we do not set the pupil to work merely to manipulate figures, according to directions for each step. We usually state the problem, and seek to develop the self-activity and ingenuity of the pupil in manipulating figures according as the conditions of the problem may require. It is difficult to see how an experiment in nature study can be performed without some similar method. Indeed one of the essential conditions to the performance of an experiment is to *state the problem*. The problem may be stated by the teacher; but, better still, the pupil may be led to state his own problem, after having discovered that a problem exists.

The disadvantages of the investigation method in nature study arise from the fact that the pupil has neither the knowledge nor the training to enable him to derive the most benefits from its use. In many cases the necessary skill in manipulation has not been acquired; knowledge of the simplest elements of the subject may be wanting. He may not even have enough of a general idea of the subject to know what the work means, and is, consequently, very much like a child lost in the woods.

Some of the advantages of the investigation method are, that it develops independence and self-reliance; it develops originality in solving difficulties and gives freedom to the creative instinct. It is well suited to those rare pupils who succeed best when let alone; and, consequently, give greatest promise of future success.

3. THE THUMB AND RULE METHOD is a method sometimes employed even by teachers of advanced science. It consists in laying down rules for each step to be taken without stating the object in view, and then insisting that the student do the work, according to explicit directions, sometimes given orally, sometimes even printed. Laboratory outlines are occa-

sionally used, in which the pupil is told how and when to pick up a dissecting-needle, and just where to insert it. This is sometimes taken to be the investigation method, but erroneously so. The most successful teachers of advanced science never use it.

The *disadvantages* of such a method are many. It suggests the reform school; it is mechanical and often develops in the pupil a feeling of helplessness, and is, consequently, discouraging rather than encouraging; it is contrary to the nature of the normal pupil, and consequently destroys rather than increases interest. In withholding from the pupil the object of the work and the end to be attained, it is contrary to common sense; which even a child realizes, when it insists that nothing is worth doing for the mere sake of doing it. It is especially distasteful to those pupils who feel that they have some ability of their own.

It also has its *advantages*. It is especially useful to those who lack all experience, and who are deficient in self-confidence; it may develop in the pupil proper habits of work, such as neatness, carefulness, and attention to details; it may encourage those who naturally need encouragement, and who are unable to exercise any amount of originality; it may restrain the reckless and compel those who are inclined to shirk their work to do their proper share of it and do it in the right way; it may help to develop systematic habits.

It is very useful as an introduction to a subject, provided it be abandoned as soon as proper habits have been formed. A period or two at the beginning is often sufficient, as it enables the pupil to know what is expected of him. It is doubtless true here, as elsewhere in life, that freedom should be granted as soon as it has been earned. Nothing could be more absurd than to continue using this method when it is not needed, especially in a subject where original investigation is the aim.

4. The Text-book and Recitation Method is too familiar to need any extended notice. It consists in assigning lessons in a book, and in due course of time calling on the pupils to repeat what they have learned. This is virtually reading about nature, and then often merely repeating what the author has said on the subject. On the part of the teacher the recitation consists in asking questions on the various chapters assigned; or else in merely asking the pupil to discuss such and such a topic labeled in the book with its appropriate title.

In this form it is the crudest way of teaching nature study. When we consider that a text-book is at best only a collection of the thoughts about natural objects of some one individual, we must feel that this is not nature study at all. It is book study. The word comes before the idea, and the pupil is either merely interpreting symbols, reading his own confused thoughts into the author's language, or else merely repeating words which mean nothing to him. *Nature study is reacting to the real object*, coming face to face with the thing, and getting ideas, or the elements of ideas, through actual sensation. Before this has been done the text-book is merely a riddle, taxing the pupil's ingenuity to guess what it all means. It is very much like asking a child to tell all about a thing, but insisting before dcing so that he must not see, hear, touch, taste, smell, or handle it.

The best that can be said of this method is that it is better than nothing at all, especially if the text is illustrated and the meaning of the illustration explained by the teacher. Pupils often consider figures in text-books as mere ornaments, not realizing that the figures are intended to explain the text. Manifestly nature study, in this form, cannot be introduced before the pupil has learned to read. This again is reversing the order of nature. For one important object of nature study is to make reading possible to the pupil. The order of development as it is now understood is this: (1) object, (2) sensation, (3) idea, (4) word, (5) language, (6) book. The text-book method reverses this order. Considering the place which the text-book has held throughout the ages, in all school work, it is difficult to suppress the thought that education in the past has been realized, in the primary schools, in spite of their methods rather than by their aid.

Yet this method is not without its *advantages*. It enables a teacher, whose little learning is a dangerous thing, to hear lessons in nature study. She may buy a book on natural history and learn something about what others know about the subject.

There is a second way of using the text-book which is not so objectionable. This consists in using the text-book as supplementary to the objects themselves; or else in assigning lessons in the book, but supplementing the latter by object study, so as to render the meaning of the book intelligible. This, of course, is possible only in the upper grades. Indeed some eminent teachers and investigators insist on the use of a text-book in lower classes. When accompanied with object study the book adds definiteness to the work and variety to the method. It also serves as a program and as a course of study, enabling the teacher to determine by tests just what the pupil has accomplished, and consequently what more can be done for him. A judicious combination of the text-book and laboratory method seems very desirable in the upper grammar grades.

5. The Laboratory Method is a general term frequently used in contrast to the text-book method; i. e., the study of the object itself. It refers to the fact that the work is often done in a laboratory—a place often, but not necessarily, distinct from the recitation-room, and supplied with material and apparatus for

carrying on the work necessary to a thorough study of the object. Thus there are chemical laboratories- physical laboratories, biological laboratories, and psy, chological and physiological laboratories.

Physiology, studied by the laboratory method, means the study of the actual organs of plants and animals by means of apparatus, determining the rate of the heart-beat, of the pulse, the contraction of muscles, and the effect of various stimuli on nervous action, and the action of the various digestive fluids on various kinds of food, etc.

The concrete study of human beings in society, such as cities, penal institutions, schools, railroads and factories, etc., is sometimes called sociology or economics by the laboratory method.

A well-equipped laboratory for nature-study work is, of course, desirable, but not absolutely essential. The ordinary school-desks can be made to suffice for all the nature-study work of the grades. Simple dissecting-needles, with hand-lenses and a compound microscope if possible, will suffice as apparatus. It is needless to say that a better equipment would be advantageous and very often possible.

The recitation is used, also, in connection with the laboratory method. The aims of these recitations may be arranged in two groups, according as the object is mainly (*a*) to instruct or (*b*) to test. These two aims cannot be absolutely separated in practice; yet it is clear, that, in work of this kind, where so much depends on methods of manipulation, skill in seeing, etc., the instruction should come much earlier than the final test of knowledge.

The methods used in recitation may be the *Socratic*, *Catechetical*, and *Developmental*. These terms are frequently used synonymously; but it is desirable to distinguish between the first, or *Socratic method*, and the Catechetical or Developmental methods.

6. THE SOCRATIC METHOD was first used by Socrates as the term suggests. He was a philosopher whose chief aim, as a teacher, was instruction. The method consists in dialogue between the teacher and the pupil. The questions, on the part of the teacher, are so put as to lead the pupil to see things from different points of view; to develop in the pupil's mind certain lines of inquiry, which involve definite problems, and hence lead the pupil, not only to ask pertinent questions, but also to discover how those very questions can be answered by his own skill and effort. This may not seem very much like instruction; yet it is the kind of instruction which is ultimately of most value; because it does not supply immediate needs, as when you give the indigent bread; but rather creates that unsatisfied feeling which spurs on to renewed effort; as when you enable the indigent to take pride in earning his own livelihood.

The advantage of this method lies in the freedom of *discussion*. The pupil is not made to feel, at the outset, that his inner consciousness is being pried into; or that he is exposing his own fearful ignorance. He is rather made to feel that he is adding his mite to that of the teacher's, in devising means and finding solutions to problems. It is, therefore, a valuable means of correcting errors in methods of observation, by indirectly leading the pupils to see things in a new light; and, consequently, to realize their own errors and shortcomings, on the one hand, and, on the other hand, a valuable introduction to the experimental part of the work. An experiment might be defined as one's attempt to solve one's own problems by manipulation of nature. Of course, before such experiment is possible, there must be a question or a problem in the mind. The definite *statement of the problem* should be one of the results of the discussion.

The chief difficulty to be guarded against in this method is the proneness to answer the questions that arise, instead of so arranging matters that the pupil can succeed in finding the answers by his own ingenuity and efforts, after the questions have been clearly comprehended by him. Thus: Is there any difference between the upper and lower surface of a leaf? Has this difference anything to do with the relation of the two surfaces to sunlight? These questions can be answered by referring the pupil to the leaf, and leading him to see the position of the leaf on the plant, with reference to the source of light; and then, comparing that leaf with a different leaf having both surfaces equally exposed. The answer in this case is not so important, educationally, as is the power developed in finding the solution.

7. THE CATECHETICAL OR DEVELOPMENTAL METHOD consists in asking questions, to be answered by the pupil, orally; the aim being, (1) to *test* the pupil's success in learning his lesson, (2) to *develop* the subject in the pupil's mind, so as to make the relation of one fact to another clear to him. It is self-evident that an opportunity for acquiring the material for knowledge must be provided, before such a test can be required. Furthermore, the facts and the images of objects must be present in the mind before that material can be developed into a consistent whole.

The disadvantage of this method is that it is the easiest method for the teacher to adopt, requiring least effort, least skill, and least preparation. Except in metaphysics and higher mathematics, it is a vicious method if allowed to usurp the place of all other methods. Many teachers abuse it, by assuming that what has never entered the child's mind through the senses, or has no foundation in his experience, can, nevertheless, be coaxed out of his inner consciousness much as a system of logic is elaborated.

The method is *useful* in nature study for at least two purposes, provided it is adopted at the proper time, in the investigation of a given subject. First, it is valuable in testing the pupil's knowledge of the subject, after he has completed his observation. This testing is of very great importance; for many pupils, like most mortals, need the touch of the stern hand of necessity to spur them on to meet an emergency and do their best work. Second, it is useful in promoting a proper assimilation of materials of knowledge, gained through experience. By it facts are recalled, the subject reviewed, and the meaning of the whole often made clearer, by the order in which the questions arise in the course of the natural development of the subject.

8. THE LECTURE OR TELLING METHOD is the method of communicating ideas by means of oral language. The teacher speaks to the class about the subject, answering those questions which hc imagines to arise, naturally, in the pupil's mind; and giving such information, in a connected way, as he believes the pupil ought to know.

This method is liable to *abuse,* because the word is apt to come before the idea; the symbol for the thing signified. Thus the lecture very often becomes a meaningless harangue, by which no real communication of ideas actually takes place. This is especially true when the lecture deals with things lying outside of the actual experience of the pupil, and when conveyed in language or in terms that are unfamiliar to him.

It has the *advantage* of affording the teacher an opportunity to impress upon the pupil his own personality, by voice and gesture, and to arouse feelings and enthusiasm for the work. It also is an admirable means for summarizing a subject, the details of which are already familiar; for putting things into their logical connections, and thus assisting the pupil in bringing order out of chaos. The contention that this telling method should never be used, in nature study, is foolish. There are many facts that the pupil cannot discover for himself, which can be supplied in this way, and which are often necessary to render the student's own observations clear. Care must, of course, be taken not to use terms or language with which the pupil has not become familiar. For, strictly speaking, men can communicate with each other only in a common language, and with ideas that are already familiar to both. The idea must come before the word; but new combinations of ideas can be produced by a carefully prepared lecture. It is safe to say, also, that, in arranging such a lecture or summary, the teacher derives fully as much benefit as does the pupil; and a growing teacher is always an inspiration, even to a child.

9. THE CONFIRMATION METHOD is the method of seeing what has first been told the pupil. Thus a subject might be introduced by a lecture, in which it is pointed out what is to be found in the object and where it is to be found. Laboratory guides are frequently used for such a purpose.

This method has the *disadvantage* of robbing the pupil of the pleasure of discovery and invention; and of making him a mere machine for seeing what is already known. It is certainly not well suited to develop the investigator; although, for mature students, as well as for the teacher, it may not be as harmful as in the lower grades.

Where lack of time exists, as is so often the case with the teacher, it may be of *advantage* to him to use this method in preparing for his work. Knowing enough about the subject to understand the lecture or the book, time can be saved by confirming, by observation and experiment, what the author or authority has said on the subject. It may occasionally be used, also, but with caution, in the lower grades. Demonstrations by the teacher in connection with the telling method partake of the character of this confirmation method.

X. Special Method of Teaching Nature Study.

INTRODUCTION.—It seems self-evident that all of the methods considered in the previous section are good when properly used; and, of course, bad when improperly used. In most cases, the latter is true, when any one of those methods is used exclusively. Teachers are so apt to get a tardy idea now and then, which seems like a revelation to them. In nine cases out of ten it is only a belated view of the other side of the mountain.

In forming a method of our own that shall possess a maximum of the valuable and a minimum of the worthless in existing methods, we have to consider, from all sides, three important factors: (*a*) the pupil, (*b*) the object to be studied, and (*c*) the method.

If our aim in nature study were merely to give the pupil a knowledge of the object studied, we might say that our task in forming a method is to so bring the pupil and the object together as to develop in the former an understanding of the latter. This might, perhaps, answer in the case of advanced science teaching, where it is virtually assumed to be the sole aim; but it is a conception too narrow for nature study.

A subject in nature study has many sides, many divisions, offering each its own problems, which require their own specific method of treatment. Inasmuch as the pupil, too, has his many-sidedness, which we have to keep in view, we shall do best if we succeed in making such a combination of methods as the laws of psychology would dictate on the one hand,

and the nature of the subject require on the other hand.

I.

The Object.—What are the natural divisions of an object of study, and which of our general methods is suited to each of these divisions, on the one hand, and, on the other hand, suited to the variously developed powers of the pupil?

1. Each living thing can be studied (*a*) as consisting of *parts*, or (*b*) as a whole, and (*c*) as having relation to other things, *environment*.

2. Both as a whole and as parts, the object may be studied, (*a*) as regards its morphology (origin, history, form, or structure), (*b*) as regards its physiology (use, function, or work).

3. The study of an object in each and all of the divisions above may consist (*a*) in ascertaining the isolated facts. But this gathered material (*b*) must be combined with what is already in the mind, must be assimilated, and generalized or apperceived.

4. When facts have been thus built up into a system of knowledge, there still remains the step of expressing the ideas gained (*a*) orally (recitation), (*b*) by the hand (drawing), (*c*) by the pen (writing).

II.

The Pupil.—Normal development is a general concept, which implies: (*a*) physical development, (*b*) intellectual development, (*c*) moral development.

1. We have a right to assume that the pupil has (*a*) some power, (*b*) some knowledge. He needs more of both. Are we to assume that all knowledge and all power which the pupil is capable of can be developed by merely "drawing it out"—merely spinning it out of his own inner consciousness? Then we have no need of nature study.

That which the pupil has not, because he has been unable to get it, must be imparted.

2. We have a right to assume that the pupil has some power of (*a*) sense perception, (*b*) thinking, (*c*) judgment, (*d*) imagination, (*e*) expression. But these powers are inaccurate.

Such inaccurate use of powers must be remedied by training.

3. We have a right to assume, also, that the pupil has at least the germs of the principal moral elements, (*a*) ethical, (*b*) æsthetic, (*c*) ideals, (*d*) character. But these, very probably, are rudimentary. *Such rudimentary elements must be developed.*

4. To briefly summarize, then, our task seems to be: (*a*) *to impart* (knowledge, power); (*b*) *to train* (sense-perception, thinking, judgment, imagination, expression); (*c*) *to develop* (the sense of right and truth, the sense of the beautiful, higher ideals, character). Let us keep these things in mind in developing our method!

III.

The Method.—A method is not for its own sake. It is for the purpose of accomplishing an end in view. Teaching should have an aim. Too often that aim is the ease of the teacher. The pupil is a living, growing thing. The true aim of education and a rational method for realizing that aim cannot be comprehended until the laws of life and growth are understood. Teachers, because they have not understood life and growth, have all along been playing with ideas, much as "children play marbles for keeps." Ask them what these ideas are, or how they come to be at all, of course, they do not know. That ideas do appear, with or without a teacher, with or without a book, is certain.

Life and growth implies change. A method to be adapted to such conditions, must also be capable of change. Such an ideal method can exist only in the sane mind of the earnest teacher. The only true method is the method arising spontaneously in the mind, that comprehends fundamental principles, and is able to adapt means to ends. The proper use of a method requires (*a*) intelligence, (*b*) earnestness, and (*c*) energy.

A formal method, such as the one here proposed, may serve other purposes than that for which it is ostensibly intended — *practical use.* Indeed, many apologies would have to be made for presenting such a general formal scheme as this one, if it were not confidently believed that it may lead the teacher (*a*) to think, (*b*) to plan, (*c*) to execute according to his better judgment and the circumstances amid which he is placed.

Thus, if we realize the fact that the simplest natural object is very imperfectly understood by the wisest among us, and that the way to get a knowledge of it, combined with the power which the getting of that knowledge implies, is to study that object properly, we shall not waste much time in deciding what to study. If our course of study is neither convenient nor practicable for our locality, we need but take that natural object which at the time is convenient and adapted to our grade of work.

A more difficult question is that as to how to study it—(*a*) *how to begin*, (*b*) *how to continue*, and (*c*) *how to end.* The following generalizations may aid us in forming a guide in this the most difficult part of our work.

Tentative Generalizations and Guiding Propositions.

1. The most general aim of nature study is to promote normal development.

2. It is not a mere pastime to be resorted to in

school, on those rare occasions when there is nothing else to do.

3. Nature study is first on the program of life; it should be first on the program of the school.

4. Nature study is the study of original sources; and implies knowledge of things, and the power to manipulate them.

5. With the knowledge of things and with the ability to manipulate them, come the arts and sciences, the three r's, and geography.

6. Development must begin at the bottom of the scale—not at the top.

7. In nature study we rise; we do not sink.

8. Physical development may be promoted by proper manipulation of the object studied.

9. Mental development may be promoted by proper observation and interpretation of things.

10. Moral development may be promoted by the proper estimation and appreciation of things.

11. Knowledge and power are mutually dependent; we cannot get out of a thing what has never been put into it.

12. Sense perception, thinking, judgment, imagination, and expression are forms of activity. These activities are being trained when properly exercised in connection with things.

13. The ethical sense is developed by constant discrimination between truth and fiction.

14. The child, like its mother, nature, is artless. This artlessness is the badge of truth.

15. Nature cannot be deceived; it is the deceiver who is deceived.

16. The love of truth increases with the pursuit of it.

17. A false art is that art which violates the natural ethical and moral law.

18. The æsthetic sense is developed by the repeated discovery of the fitness of things.

19. Nature study is not the end of arts and science; it is the beginning of them.

20. Higher ideals are developed by the discovery of the laws underlying the fitness of things.

21. Expression of appreciation of things unknown to us is much ado about nothing.

22. The things we appreciate are a measure of our standards of judgment.

23. Ideals do not float around in the air on winged words; they are a promise within us of better things, because of our growth towards what is ideally good.

24. Encouragement, not discouragement, accompanies healthy growth.

25. Character is developed through contact with natural forces, and by the exercise of the will in doing that which ought to be done, and doing it in the right way.

26. We all sooner or later have to become conscious of three laws: (*a*) the law of love, (*b*) the law of liberty, and (*c*) the law of necessity.

27. Liberty is an achievement; and belongs to those who have earned it, by showing their fitness for self-rule.

28. To realize the existence of the law of necessity, is the most important step towards that moral freedom of personality which we call character.

29. Neatness and accuracy in our work, like per-

sonal cleanliness, often indicate a clean and well-regulated mind.

30. We fail in our work if our pupils are not interested.

31. Mystery is an element in child interest; hence, living things are more interesting than dead ones.

32. Consciousness of success in overcoming difficulties increases interest.

33. We prize results that have cost us some effort.

34. Few pleasures equal that of an original discovery.

35. The power to achieve, resulting from well-directed effort, is of greater value than a single achievement.

36. Knowing and doing—mind and body—cannot be separated without fatal consequences to both.

37. We learn to do by doing, to spell by spelling, to draw by drawing, to write by writing, provided that in each case we first know what we want to do, what we want to spell, what we want to draw, and what we want to say.

38. The child should have something to say before it is called on to say something.

39. Sense-organs, like brains, were made for use.

40. The idea should come through experience, before the word is given.

41. Education implies change; and change in the living world is brought about by action and reaction.

42. We have ideas because we have brains, and language because we have ideas to express.

43. Language is the result of ideas, not the cause of them.

44. We are able to get out of a book just as much as we are able to put into it.

45. Study the word "abomalihari" as long as you please; it means nothing to you.

46. Time spent in silent contemplation of an object is well spent.

47. He who hesitates to express himself about facts, when in doubt, usually hesitates to tell a lie.

48. Fools jump at conclusions; the prudent arrive at them.

49. It is often more important to be able to begin work than it is to finish it; for it cannot very well be finished before the beginning has been made.

50. First steps are important ones; they often determine the final result.

51. The teacher should be sure she has something worth saying before saying it.

52. One generalization is worth a hundred facts; but the hundred facts must be had before the generalization can safely be attempted.

53. From fact to theory is normal to the child mind; from fact to theory and from theory back to act is normal to the scientific mind.

54. There is one instance in nature study when it is a disgrace to the teacher to admit he does not know —when he is too lazy to find out.

55. An unanswered question is often more useful to the pupil than an answered one, provided means be devised for its solution.

56. There is little danger of knowing too much about nature; the danger is all on the other side.

57. He is a poor teacher who does not prepare his work.

58. There is a limit to the pupil's power of attention.

59. Interest in school work can be measured by its manifestation outside the school.

60. Observation and experiment is the method of science.

61. In the pursuit of knowledge it is absurd not to use all proper means at our command.

62. Every object is a part of a larger whole—its environment—and is itself composed of parts. The same method of study can, therefore, be used both for the whole and for its parts, thus:

Apple-tree. Step I, II, III, IV, V, VI, VII, VIII, IX, X.	root	(step I, II, III, IV, V, VI, VII, VIII, IX, X);
	stem	(step I, II, III, IV, V, VI, VII, VIII, IX, X);
	leaf	(step I, II, III, IV, V, VI, VII, VIII, IX, X);
	flower	(step I, II, III, IV, V, VI, VII, VIII, IX, X);
	fruit	(step I, II, III, IV, V, VI, VII, VIII, IX, X).

63. Proceed from the more extensive to the more intensive study of things.

64. The basis of interest in lower grades must be variety; this should gradually give place in upper grades to a desire for thoroughness.

65. The teacher who is neither thorough nor en-

thusiastic in this work can hardly expect his pupils to be so.

66. The teacher should gradually become unnecessary to the pupil; just as this guide should gradually become unnecessary to the teacher.

XI. Teacher's Guide for Handy Reference.*

Step I.—SEEING (*Discovery*)

- 1. As a whole
  - 1. color
  - 2. form
  - 3. size
  - 4. lines
  - 5. angles
  - 6. surfaces.
- 2. As parts
  - 1. color
  - 2. form
  - 3. size
  - 4. lines
  - 5. angles
  - 6. surfaces.

Step II.—DISCUSSION (*Socratic*)

- 1. As a whole Meaning of
  - 1. Color
  - 2. form
  - 3. size
  - 4. lines
  - 5. angles
  - 6. surfaces
  - 7. properties
  - — origin and history.
- 2. As parts Variations of
  - 1. color
  - 2. form
  - 3. size
  - 4. lines
  - 5. angles
  - 6. surfaces
  - 7. properties
  - — causes effects uses.

Step III.—COMPARING (*Thumb and Rule*)

- With related objects as regards
  - 1. color
  - 2. form
  - 3. size
  - 4. texture
  - 5. covering
  - 6. movements
  - 7. properties
  - — uses and classification.

* See Part I, Chapter IV, Section XII.

Step IV.—FIELD LESSON (*Confirmation*) Relation of the object to

- 1. plants, 2. animals, as
  - 1. food
  - 2. homes
  - 3. neighbors
  - 4. societies
  - 5. instincts
- 3. elevation
- 4. temperature
- 5. movements of air
- 6. light
- 7. moisture
- 8. soil
- 9. man
  - 1. economic uses
  - 2. æsthetic, educational, and moral uses
  - 3. characters essential to its uses
  - 4. characters essential in struggle for existence
  - 5. how influenced by man
  - 6. what general influence on man, etc.

Step V.—EXPERIMENTATION (*Investigation*) effects of

- 1. soil
- 2. light
- 3. heat
- 4. moisture
- 5. gravity
- 6. air
- 7. electricity
- 8. chemicals

functions tropisms of organs and organisms

Step VI.—RECITATION.

1. (*Catechetical*)

- 1. *Morphology*
  - 1. history
  - 2. form
  - 3. structure
  - 4. origin

  of
  - 1. whole
  - 2. organs

2. (*Developmental*)

- How related to work of 2. *Physiology*
  - 1. function
    - 1. nutrition
    - 2. circulation
    - 3. respiration
    - 4. secretion
    - 5. excretion
    - 6. motion
  - 2. uses of
    - 1. food
    - 2. light
    - 3. heat
    - 4. soil
    - 5. water
    - 6. chemicals
- How related to 3. *Ecological factors*
  - 1. struggle for existence
  - 2. adaptations

Step VII.—SUPPLEMENTARY INFORMATION (*Lecture, Telling*)
- 1. facts reviewed in natural order
- 2. meaning of observed facts
- 3. new facts and new relation of facts
- 4. some truths emphasized
- 5. subject vitalized by the teacher
- 6. the whole summarized
- 7. reference to literature

Step VIII.—REPRESENTATION (*Drawing*)
- 1. As a whole — artistic (distant)
  - 1. color or shade
  - 2. form or outline
  - 3. size
- 2. as parts — real (near)
  - 1. color or shade
  - 2. form or outline
  - 3. size
  - 4. structure
  - 5. appendages
- 3. Stages of growth
  - 1. whole
  - 2. parts

Step IX.—EXPRESSION (*Writing*)
- 1. *prose*
  - 1. spelling
  - 2. penmanship
  - 3. composition
    - 1. sentence
    - 2. paragraph
  - 4. punctuation
  - 5. capitalization
- 2. *poetry*
  - 1. *nature poetry*
  - 2. understanding
  - 3. appreciation

Step X.—READING
- 1. composition — 1. criticism; 2. grading
  - 1. form
  - 2. language
  - 3. facts
  - 4. terms
  - 5. spelling
  - 6. penmanship
  - 7. expression
- 2. supplementary sources — on topic
- 3. nature poetry and stories — on topic

PROGRAM FOR STEP I (*Seeing*).

Motto: "*Because our understanding cannot in this body found itself but on sensible things, nor arrive so clearly to the knowledge of God and things invisible, as by orderly conning over the visible and inferior creature, the same method is necessary to be followed in all discreet teaching.*"—Milton.

Analysis—*seeing*
- 1. as a whole
  - 1. color
  - 2. form
  - 3. size
  - 4. lines
  - 5. angles
  - 6. surfaces
- 2. as parts
  - 1. color
  - 2. form
  - 3. size
  - 4. lines
  - 5. angles
  - 6. surfaces

1. PREPARATION: (*a*) Provide plenty of fresh specimens, showing all essential features; (*b*) provide each pupil with paper and pencil.

2. TIME: From one to several periods, depending on attention and interest. (See Primary Method, Chapter IV, Section XII.)

3. METHOD: Discovery (1). (See Part I, Chapter II, Section IX.)

4. AIM: (*a*) To encourage self-activity; (*b*) to stimulate interest; (*c*) to enable the pupil to estimate his own powers. (See Primary Method, Chapter IV, Section XII.)

5. POINT: Superficial characters are the first to attract attention.

6. PRESENTATION: (*a*) Let the pupil observe silently; (*b*) let him note down each observation in a separate, well-formed sentence, numbering each; (*c*) teach the use of capitals and period; (*d*) give directions for the next lesson. (See Chapter IV, Section XIII.)

7. PREPARATION FOR NEXT STEP: Ask each pupil to bring fresh specimens of the same kind.

8. NOTE: *When pressed for time one grade may be doing this work as seat work or occupation, while the teacher is occupied with other grades.*

PROGRAM FOR STEP II (*Discussion*).

Motto: "*Nature wills that children should be children before they are men. . . . Childhood has ways of* *seeing, thinking, feeling peculiar to itself; nothing is more absurd than to wish to substitute ours in their place.*"—Rousseau.

Analysis—*discuss*

- 1. as a whole meaning of
  - 1. color
  - 2. form
  - 3. size
  - 4. lines
  - 5. angles
  - 6. surfaces
  - 7. properties
  - } origin and history
- 2. as parts variations of
  - 1. color
  - 2. form
  - 3. size
  - 4. lines
  - 5. angles
  - 6. surfaces
  - 7. properties
  - } uses, causes and effects

1. PREPARATION: (*a*) Decide from the work of the first step what assistance the class as a whole needs; (*b*) decide what individual instruction and criticism should be given; (*c*) in matters that are too obscure for the pupil unaided arrange questions in such a way that the pupil can see it by re-examining the specimen.

2. TIME: One period. (See Primary Method, Part I, Chapter IV, Section XII.)

3. METHOD: Socratic (6) (See Part I, Chapter II, Section IX).

4. AIM: (*a*) To arouse curiosity; (*b*) to sharpen discrimination; (*c*) to cause questions to arise in the pupil's mind; (*d*) to lead him to suggest means of testing those questions; (*e*) to cause him to look for particulars that might aid in the solution of more general problems; (*f*) to suggest better methods of seeing and taking notes; (*g*) to show him the importance of carefulness and neatness; (*h*) to encourage him. (See Chapter II.)

5. POINT: (*a*) A question in the mind often enables us to see things that otherwise escape us; (*b*) the

relation of one thing or fact to another is as important as the thing or fact itself.

6. Presentation: (*a*) Lead the pupil to ask such questions as, how did this and that arise; (*b*) of what use are the different parts; (*c*) how did different parts come to differ; (*d*) what is the cause and what the effect of the difference; (*e*) what would be the effect if things were not what they are? (See Chapter IV, Section XIII.)

7. Preparation for Next Step: Ask pupils to bring different specimens showing one or more resemblance to the one studied.

8. Note: *Do not answer the pupil's questions at this time, but suggest ways in which the answer could be found by comparison and experiment.*

Program for Step III (*Comparing*).

Motto: "*The education of a naturalist now consists chiefly of learning how to compare.*"—Agassiz.

Analysis—*compare with related objects* as regards	1. color 2. form 3. size 4. texture 5. covering 6. movements 7. properties	uses and classification

1. Preparation: (*a*) Study related forms noting specific and generic differences; (*b*) provide plenty of fresh specimens of those different forms.

2. Time: As many periods as there are specimens compared.

3. Method: Thumb and Rule. (3.) (See Part I, Chapter II, Section IX.)

4. Aim: (*a*) More care in seeing; (*b*) sharpen discrimination and train judgment (see Chapter II); (*c*) form the habit of discovering similarities and differences; (*d*) develop the habit of using what is already known, in discrimination of less obvious distinctions,

and in the discovery of new facts; (*e*) develop the idea of class, order, genus, species, with their characters.

5. Point: Things differ because of difference (*a*) in heredity, or difference in seeds; (*b*) because of differences in their surroundings; (*c*) these differences are usually adaptations to conditions; (*d*) in case of dead things, of course, other reasons apply.

6. Presentation: (*a*) Have pupils arrange their results in the form of a comparative table like those shown in Chapter IV, Section XII; (*b*) from the table let the pupil write definitions of the forms compared, stating the class characters, etc., as shown by the table; (*c*) teach pupil how to use the dictionary in identifying forms. (See Chapter IV, Section XIII.)

7. Preparation for Next Step: Ask pupils to discover whether similar objects are associated in groups or whether scattered.

8. Note: (*a*) *What is the effect when a living thing is not adapted to the conditions amid which it is placed?* (*b*) *Can a living thing in nature be out of harmony with its environment?* (*c*) *What about man?*

Program for Step IV (*Field Lesson*).

Motto: "*Work should never be treated as if it were play, nor play as if it were work.*"—Rosenkranz.

Analysis—*relation of object to*
- 1. plants, 2. animals — as
  - 1. food
  - 2. homes
  - 3. neighbors
  - 4. societies
  - 5. instincts
- 3. elevation
- 4. temperature
- 5. movement of air
- 6. light
- 7. moisture
- 8. soil
- 9. man

- 1. economic uses
- 2. æsthetic, educational, and moral uses
- 3. characters essential to its uses
- 4. characters essential in the struggle for existence
- 5. how influenced by man
- 6. what general influence on man, etc.

1. PREPARATION: (*a*) Determine beforehand where the object studied can be found; (*b*) let pupils know before taken out what the purpose of the exercise is.

2. TIME: From one to several periods or whole days.

3. METHOD: (*a*) Discovery; (*b*) investigation; (*c*) confirmation. (1), (2), (9) Chapter II, Section IX.

4. AIM: (*a*) To discover new facts; (*b*) to find answers to some problems that have arisen in preceding steps; (*c*) to confirm conclusions already reached; (*d*) to cultivate interest and appreciation; (*e*) to train in close observation; (*f*) form some habits of the naturalist; (*g*) to develop a consciousness of relationship and harmony in nature; (*h*) enjoyment; (*i*) make collections of specimens. (See Part II, Chapter IV, Section XI.)

5. POINT: (*a*) Species and varieties have similarities and differences correlated with difference in habits, and with differences in their relation to environment; (*b*) living things often form societies or colonies, the conditions of which are interesting subjects for study.

6. PRESENTATION: (*a*) Dictate a few leading questions to which answers are to be found; (*b*) let pupils understand that they will be called on next day for their answers; (*c*) accompany pupils to the locality selected. (See Chapter IV, Section XIII.)

7. PREPARATION FOR NEXT STEP: Encourage pupils to bring such things from home as may be of use in their experiments.

8. NOTE: (*a*) *What connection is there between plant and animal societies and human society?* (*b*) *Encourage pupils to preserve specimens bearing on the questions discussed.*

Program for Step V (*Experimentation*).

Motto: "*The teacher is needed for those steps which the children cannot take alone.*"—De Garmo.

Analysis—*experiments on effects of*	1. soil 2. light 3. heat 4. moisture 5. gravity 6. air 7. electricity 8. chemicals	functions and tropisms of organs and organisms

1. Preparation: (*a*) Use material brought by the pupil if fresh; if not, supply plenty of fresh material to work with; (*b*) provide such simple apparatus as may be needed, or supply material from which apparatus can be constructed.

2. Time: From one to several periods.

3. Method: Investigation. (2.) (See Part I, Chapter II, Section IX.)

4. Aim: (*a*) To develop the inquiring mind; (*b*) to develop the habit of answering one's questions and settling one's doubts by experimental tests; (*c*) to develop the habit of inquiring into the questions of use and functions of the forms seen; (*d*) to train in the use of the hypothesis; (*e*) to develop a judicial mind; (*f*) to develop skill in construction and manipulation of apparatus; (*g*) to promote a scientific understanding of the subject.

5. Point: (*a*) Facts are correlated; (*b*) solutions of special problems aid in understanding more general ones; (*c*) the more simple and primitive the apparatus the better.

6. Presentation: (*a*) Distribute pencil and paper for notes; (*b*) place on the board or dictate a few general questions that are suited to guide observation; (*c*) lead pupils to talk about general problems, such as how do living things differ from dead ones; what are the evidences of life; how is it maintained,

modified, and brought to a close; what relation does form, color, size, structure, properties, instincts, movements bear to the maintenance of life? (*d*) how do the various organs contribute to the maintenance of life? how are these organs affected by physical influences? and how does each organism minister to the life of the social community? etc.; (*e*) lead pupils to suggest experiments to test the questions asked, assist when necessary in performing the experiment. (See Chapter IV, Section XIII.)

7. Preparation for Next Step: Refer pupils to literature, etc.

8. Note: *The value of an experiment in this work lies as much (or more) in the habits formed as in the results obtained.*

Program for Step VI (*Recitation*).

Motto: "*The mind must ever rise from clear individual to distinct general notions.*"—Pestalozzi.

Analysis— (1. *testing*, 2. *teaching*)

- 1. *Morphology*
  - 1. history
    - 1. origin
    - 2. development
  - 2. form, 3. structure, 4. origin — of
    - 1. whole
    - 2. parts or organs
- How related to work of 2. *Physiology*
  - 1. function
    - 1. nutrition
    - 2. circulation
    - 3. respiration
    - 4. secretion
    - 5. excretion
    - 6. motion
    - — of organs and systems
  - 2. uses of
    - 1. food
    - 2. light
    - 3. heat
    - 4. soil
    - 5. water
    - 6. chemicals
    - — to organisms and organs
- How related to 3. *Ecological factors*
  - 1. struggle for existence
  - 2. adaptations
  - — of organs and organisms

1. PREPARATION: (*a*) Fix in the mind the cardinal points around which all other facts cluster; (*b*) examine pupil's notes, noting excellences and defects.

2. TIME: One period. (See Primary Method, Part I, Chapter IV, Section XII.)

3. METHOD: (*a*) Catechetical; (*b*) developmental. (7) See Part I, Chapter II, Section IX.

4. AIM: (*a*) To test knowledge and skill; (*b*) to promote generalization; (*c*) awaken interest; (*d*) call attention to new facts and their relationship; (*e*) correct errors of all kinds; (*f*) show the larger bearings of the subject.

5. POINT: (*a*) Everything is related to all other things; (*b*) adaptations to work, and to other things exist which have a natural explanation. (See Part II, Chapter II.)

6. PRESENTATION: (*a*) Call for statement of facts; (*b*) when a word is needed supply it; (*c*) begin with a central fact and call for statements of other facts related to it; (*d*) criticise the pupil's results as shown by his written notes. (See Chapter IV, Section XIII.)

7. PREPARATION FOR NEXT STEP: (*a*) Refer pupils in higher grades to scientific literature, on some phase of the subject; (*b*) refer pupils in lower grades to nature poetry, and stories about the subject studied; (*c*) teach older pupils how to use the dictionary.

8. NOTE.—*For one period it is best to take some phase, as morphology, then in the next period, physiology, and in the next ecology, etc.*

PROGRAM FOR STEP VII (*Supplementary Information*).

Motto: "*The main difficulty in the way of the application of the science of teaching is the ignorance on the part of teachers, of the subjects they pretend to teach.*"—Parker.

Analysis:
1. facts reviewed in natural order
2. meaning of observed facts
3. new facts and new relations of facts
4. some truths emphasized
5. subject vitalized by the teacher
6. The whole summarized
7. Reference to literature and biography

1. PREPARATION: (*a*) Read and confirm what the best authors have to say on the subject; (*b*) arrange what you wish to say with the needs of your pupils in view; (*c*) develop in yourself some enthusiasm for the work.

2. TIME: One period.

3. METHOD: Lecture (telling). (8) See Part I, Chapter II, Section IX.

4. AIM: (*a*) To review important facts; (*b*) to arrange facts; (*c*) to create enthusiasm; (*d*) to prepare the pupil by actual example for the logical arrangement and the clear expression of what he knows about the subject; (*e*) to impart such knowledge as has escaped the pupil or may be too difficult to discover; (*f*) to remind the pupil how much more there is to accomplish.

5. POINT: (*a*) The dryest facts may be so combined and arranged as to make a clear picture, about which an enthusiastic teacher can relate the important incidents of an interesting story. (See Part II, Chapter I.)

6. PRESENTATION: (*a*) Have something to say before you say it; (*b*) use good language, but avoid technical or unfamiliar terms; (*c*) illustrate on the board, with colored crayon, as you speak, thus holding the attention by appealing to both eye and ear; (*d*) use the animated conversational style, and let your enthusiasm express itself in your features, and in the modulations of the voice; (*e*) do not talk around the point, to the point; (*f*) stop talking when you have nothing to say worth mentioning; (*g*) a question

now and then when the interest flags will restore attention. (See Chapter IV, Section XIII.)

7. Preparation for Next Step: (*a*) Refer pupils to library sources of information, pointing out passages of special importance and interest; (*b*) point out any literary selections that may be of interest in the light of what has been found out.

8. Note.—(*a*) *In the lower grades the teacher may read simple, interesting selections to the class, and have them reproduce in writing the substance of the selection. This will add needed variety to the exercise.*

(*b*) *It may often be desirable to give library references earlier in the work, as at the close of Step II.*

Program for Step VIII (*Representation*).

Motto: "*Now there is nothing in the understanding which was not before in the sense. And, therefore, to exercise the senses well about the right perceiving the difference of things will be to lay the grounds for all wisdom and all wise discourse and all discreet actions in one's course of life.*"—Comenius.

Analysis—*drawing.*	1. *As a whole*	1. color or shade 2. form or outline 3. size (proportion)	artistic (distant)	
	2. *As parts*	1. color or shade 2. form or outline 3. size (proportion) 4. structure 5. appendages	real (near)	stages of development.

1. Preparation: (*a*) Supply fresh material; (*b*) provide paper and pencil or water colors, etc.

2. Time: One to two periods.

3. Method: Drawing. (See Chapter IV, Section XIII.)

4. Aims: (*a*) To cultivate accurate observation; (*b*) to train the eye and the hand; (*c*) to represent what cannot otherwise be well expressed; (*d*) to cultivate the

habit of distinguishing between the real and the imaginary; (*e*) to hold attention in training judgment.

5. POINT: (*a*) Objects are vaguely generalized when at a distance; details become evident as we approach the object.

6. PRESENTATION: (*a*) Let the pupil know what he is to draw; (*b*) show the pupil the effect of holding an object at a distance; (*c*) after having drawn the whole object as seen from a distance, have each part drawn with important details as they appear when closely examined. (See Chapter IV, Section XIII.)

7. PREPARATION FOR NEXT STEP: (*a*) Ask pupils to bring each a fresh specimen.

8. NOTE.—(*a*) *This work can be done as seat work or occupation after the directions are given;* (*b*) *the pencil often needs close attention.*

PROGRAM FOR STEP IX (*Written Expression*).

Motto: "*The exceptional fact of the period is the genius of Wordsworth. He had no master but nature and solitude.*"—Emerson.

Analysis—*writing*
- 1. *prose*
  - 1. spelling
  - 2. penmanship
  - 3. composition
    - 1. sentence
    - 2. paragraph
      - 1. punctuation and 2. capitalization
- 2. *poetry*
  - 1. *nature poetry*
  - 2. understanding
  - 3. appreciation

1. PREPARATION: (*a*) Pupil's notes should be corrected; (*b*) supply pen and ink, paper and pencil. (See Primary Method, Part I, Chapter IV, Section XII.)

2. TIME: One to two periods or, as busy work, as much time as is faithfully spent.

3. METHOD: *Writing.* (See Part I, Chapter V.)

4. AIMS: (*a*) To summarize and fix facts; (*b*) to develop systematic habits; (*c*) to cultivate habits of accuracy and neatness; (*d*) to serve as a test of the

pupil's success in his work; (*e*) to correlate with other subjects, such as *spelling*, *penmanship*, *composition*, and *literature*; (*f*) to develop that clearness and accuracy of thinking which comes from clear and accurate expression of thought; (*g*) to serve as a natural foundation for the cultivation of the art of reading, and the use and interpretation of language.

5. POINT: (*a*) Neatness in writing and accuracy in thinking are essential to a clear legible composition; (*b*) each sentence should express only one leading thought.

6. PRESENTATION: (*a*) Provide fresh specimens for re-examination when in doubt; (*b*) let pupils refer to their notes; (*c*) place upon the board or dictate as many general questions (or a suggestive outline) as will cover the work done, and have pupils answer by description or otherwise each question in a *separate* paragraph; (see Part I, Chapter V, Section XIV and XV); (*d*) ask pupil to copy, at the end of his composition, that stanza, or two, from a selected poem or other subject, giving him expressly the liberty to choose that stanza which most appeals to him; (*e*) preserve the best of these compositions after they have been read as a mark of distinction; (*f*) number your leading questions, and have the corresponding paragraph provided with a similar number (see Part I, Chapter V, Section 14, 15); point out to the pupil how the natural parts of an object might each be described in a paragraph. (See Chapter IV, Section 13.)

7. PREPARATION FOR NEXT STEP: Assign literature bearing on the subject to be read.

8. NOTE.—(*a*) *This work can be done as seat work or occupation when the teacher is crowded with other work. But it is not to be slighted as it is a very important step*; (*b*) *the descriptive part should be strictly scientific.*

PROGRAM FOR STEP X (*Reading*).

Motto: "*A man cannot have the power of language without things to apply it to; but his fulness of expression may be out of proportion to his knowledge of the things expressed.*"—Bain.

Analysis—*reading*
- 1. *composition*
  - 1. form
  - 2. language
  - 3. facts
  - 4. terms
  - 5. spelling
  - 6. penmanship
  - 7. expression
  - (1–4) 1. criticism; (4–7) 2. grading
- 2. supplementary sources } on topic
- 3. nature poetry and stories } on topic

1. PREPARATION: (*a*) Provide supplementary reading—poetry, prose—bearing on the subject, to relieve the monotony of the reading exercise.

2. TIME: One to several periods.

3. METHOD: Reading.

4. AIMS: (*a*) To allow pupils to compare their own work with that of others; (*b*) to relieve the teacher of of the task of so much reading; (*c*) drill in pronunciation of scientific terms; (*d*) to correlate with reading; (*e*) to provide for a beneficial emulation in the class; (*f*) to give the teacher an opportunity to estimate the quality and quantity of the work done, and to give due credit for merit arising from carefulness, diligence, neatness, etc.

5. POINT: In reading their own composition, pupils should be able to read with an intelligent expression.

6. PRESENTATION: (*a*) Ask pupil to read his paper; (*b*) note arrangement of subject-matter, use of terms, expression, etc.; (*c*) ask other members of the class to criticise the facts; (*d*) give criticisms and suggestions; (*e*) to break the monotony of the exercise, let a member read the library selection quoted, or any

other supplementary reading bearing on the subject. (See Chapter IV, Section XIII.)

7. NOTE.—(*a*) *Grade the work by these papers, and from your impressions of the pupil's diligence and general success;* (*b*) *this step may be omitted wholly or in part whenever the exercise becomes too monotonous;* (*c*) *parents of children will often be pleased to see these papers on visiting the school.*

CHAPTER IV.

Suggestions and Course of Study.

XII. Suggestions to the Teacher.

On the Teacher's Preparation. The teacher's preparation for this work may be extensive or very limited. Too much can hardly be known about nature; but one need not be discouraged about knowing so little, since no one can exhaust the subject. One's attitude towards the subject is often of more consequence than the extent of knowledge. If the teacher is as interested in a new page of nature's book as some are in the latest novel from the press, she will learn while she labors on, inspiring her pupils with the warmth of her enthusiasm. Nature study is not entirely for the sake of nature study, but for the sake of the pupil. The method and some of the spirit of the investigator will soon overcome many of the difficulties that are sure to be met in beginning this work.

On Using the Guide. In using the guide, observe the following points: (1) Make yourself familiar with its plan before attempting to apply the method. (2) Study the aims to be attained. (3) Endeavor to comprehend from a psychological and scientific point of view, (*a*) the different steps outlined, (*b*) the order in which these steps should be taken. Careful study of the foundations may help you in this. (4) Some points there made are fundamental; yet they are intended as suggestions. Do what you can by your own reading and reflection to assimilate and integrate them into a consistent theory of education.

The distinctive features of this method of teaching nature study are: (*a*) it does not recognize the teaching of nature study as wholly synonomous with the teaching of pure science, but primarily as a means to natural mental growth; (*b*) it, therefore, places the individual to be taught uppermost in the teacher's mind, giving the subject-matter a subordinate though important place; (*c*) it recognizes, on the one hand, the laws of mental growth; and, on the other hand, places the subject-matter on a scientific rather than a pseudo-scientific basis.

Some advantages of this method are: (*a*) it gives that variety which is so essential in maintaining interest; (*b*) it is systematic; (*c*) it relieves the teacher of much useless waste of time in planning the general steps to be taken; and enables him or her the better to arrange the minuter details of the work; (*d*) it gives the teacher every opportunity for originality; (*e*) while it is a method it is not one that is liable to result in machine teaching; (*f*) being natural, it becomes a pleasure to observe it when properly understood.

On the Order of Presentation. There is a natural, as well as an unnatural, order of presenting the various aspects of a subject. The best order is, of course, the natural one. For instance, it would be unnatural to take step seven before taking step one, because it is contrary to the law of development, both in the individual and in the race. The nature of the pupil and the aims we have in view determine what the natural order is. The character of the particular subject studied may determine the order to be pursued during a given period; but even in these minuter divisions a natural order can be detected. Within a single lesson we have (1) preparation—arousing the pupil's interest and recalling to his mind related topics with which he is familiar; (2) the presentation of the matter so as to guide the pupil's mind by sensation to sense-perception or to percepts; from percepts or individual notions to recepts or unconscious generalization; from recepts, or unconscious generalization to concepts or general notions—conscious generalization; (3) and finally leading the mind from generalizations to their further application, *i.e.*, their use in interpreting new percepts.

The steps outlined in the guide may be taken in all the grades except, perhaps, the lowest. Occasionally some of the steps, as the tenth, may be omitted in the upper grades. Each step may require several recitation periods. Each lesson should be planned before beginning it. A mere haphazard arrangement, on the spur of the moment, cannot yield satisfactory results.

In planning the work, the teacher should keep in mind not only the matter to be presented, but, also, the special training which each aspect of the subject is especially suited to give; also the general aim, as well as the special aim, to be attained.

The following rules may be useful: Proceed (1) from the simple to the complex; (2) from the more apparent to the less apparent, or from the known to the unknown; (3) from the extensive to the intensive; (4) from the concrete to the abstract; (5) from the particular to the general; (6) from form to structure; (7) from structure to function; (8) from facts to the relation of facts; (9) from individuals to the community of organisms. Give the pupil a general survey of the whole, if possible, before introducing the study of parts.

There must be a correspondence, also, to the order of development of the child's powers; and to the order in which these are employed in the pursuit of knowledge, both by the individual and by the race. Thus we first observe, second infer, third compare, fourth assimilate, fifth generalize, sixth appreciate, seventh express our knowledge and appreciation and, eight, apply our knowledge in the regulation of our lives and in the pursuit of new truths. These processes involve (1) the reception of external impressions through the senses, (2) the elaboration of those impressions into knowledge, (3) the training of the body to the efficient execution of the decrees of our better judgment.

The pupil's interest in this work has much to do with its success. This is especially true in the lower grades. The choice of suitable subjects is an important matter in the lower grades. Familiar living things seem often to be most interesting. Variety, too, is demanded by children. As the pupil advances in the grades, mere curiosity, the chief stimulus in young pupils, should gradually yield to love of knowledge for its own sake. A more intensive study of things in the upper grades is thus made possible and less variety is required.

Planning the work, so as to economize time, is the teacher's chief work. Such planning need not reduce the work to routine. It can be so done as to escape the attention of the pupil; he feeling the wholesome stimulus of spontaneity and freedom, while unconsciously pursuing the course outlined. Unsystematic work with no aim or purpose on the part of the teacher, is not worthy to be called school work; since it partakes of that chance value which belongs to the undirected activities of the playground. The higher the grade the more systematic the work should be made. Nature study becomes scientific in proportion as it is made systematic. It is doubtless true that systematic work gradually secured through the pupil's spontaneous activity is a result greatly to be desired. Lawlessness may be a necessity with the very young pupil, but it is inconsistent with anything that can be called a study of the laws of nature.

The course of study should be followed when a practicable one has been provided. But it must be surbordinate to the interests of the pupils. Even a desert affords considerable material for nature study. It is very true that "all is in all."

Where no course of study is provided for the school, one can easily be made by taking the one presented here as a model, merely inserting the appropriate object, at the time when convenient in that particular locality, and indicating the amount of work given to it in each grade.

How much work to be given to a subject in a particular grade, *i.e.*, the thoroughness to be demanded, must depend on the pupil's ability. The method presented here requires no limit to be fixed by the teacher, as the pupil's powers are allowed freedom of action, and consequently determine the degree of thoroughness that can be attained. With the work well planned and the interest sustained such a method must bring the work up to the highest capacity of the pupil.

No written examination or uniform test for promotion is contemplated according to this method. The pupil's written work, in step nine, is a fairly good test of his ability and success, and, together with his diligence and success in manipulation, may afford a basis for grading.

First Primary Method. When the pupil first enters school the teacher's problem usually is (1) to keep him busy, (2) to teach him to read and to express himself in as many ways as possible. At this stage in his school work, he cannot, of course, pursue nature study as systematically as this method prescribes. The principles underlying the method, however, are the same here as in the more advanced grades; namely, getting ideas through sensation and actual experience, and then connecting these ideas with symbols that may be expressed by (1) orally, (2)

COURSE OF NATURE STUDY FOR PRIMARY GRADES.

Grade	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	Apr.	May	June
First	1. Sweet-pea 2. Aster 3. Golden rod 4. Fly 5. Fish	1. Leaves 2. Harvest-man 3. Spider 4. Cricket 5. Seeds	1. Canary 2. Goose 3. Feathers 4. Mouse 5. Cat	1. Wig-wam 2. Coal 3. Wood 4. Sheep 5. Wool	1. Water 2. Ice 3. Snow 4. Salt 5. Sugar	1. Iron 2. Copper 3. Lead 4. Silver 5. Gold	1. Wool 2. Cotton 3. Leather 4. Cloths 5. Potatoes	1. Bread 2. Cow 3. Butter 4. Milk 5. Cheese	1. Pussy-willow 2. Robin 3. Violets 4. Dande-lion 5. Butter-cups	1. Beetles 2. Butter-flies 3. Bugs 4. Ants 5. Blue flag
Second	1. Clover 2. Bees 3. Moths 4. Larvæ	1. Barley 2. Wheat 3. Oats 4. Corn	1. Chickens 2. Pigeons 3. Ducks 4. Turkeys	1. Cat 2. Dog 3. Horse 4. Cow	1. Clouds 2. Wind 3. Dew 4. Rain	1. Sun 2. Moon 3. Stars 4. Earth	1. Days 2. Weeks 3. Months 4. Year	1. Seasons 2. Occupa-tions 3. Seeds 4. Soils	1. Bean 2. Pea 3. Clover 4. Corn	1. Toma-toes 2. Cherries 3. Currants 4. Rasp-berries
Third	1. Locust 2. Red Clover	1. Pods 2. Ferns	1. Hawk 2. Eagle	1. Squirrel 2. Nuts	1. Burning candle 2. Burning wood and coal	1. Alcohol 2. Acids	1. Bell 2. Tuning fork	1. Birds 2. Soils and seeds	1. Buds 2. Leaves	1. Flowers 2. Straw-berries
Fourth	1. Dande-lion	1. Seeds	1. Eggs	1. Park and land-scape	1. Land-scape relief	1. Land-scape objects	1. Kinds of wood	1. Orchard trees	1. Orchard insects	1. Garden vege-tables

drawing, (3) making, (4) writing. Writing must be learned chiefly by imitation. Hence the teacher is more necessary here than in the upper grades.

The work here must be combined with reading and writing, and used as a basis for teaching these arts. Indeed we may say that nature study in this primary class is to be used chiefly with a view to teaching reading, writing, and numbers. This use of nature study was formerly called object-lessons.

The method here is as follows: (1) Lead each child to make a statement about the object. If possible try to have him use both a subject and a predicate, as "The rose is red"—not a phrase, as a red rose, or merely a word rose—hence a complete sentence. It is well not to be too particular about this at the beginning, for it is natural for children, like many savage tribes, to talk in phrases instead of complete sentences; as, when the child says "water," meaning: I want water; or give me water. (2) Write the statement on the board (neatly of course); (3) then let the pupil read the sentence from the board; (4) when a number of sentences have thus been placed on the board, let the class copy the sentences with a pencil on paper; (5) at the beginning of the next lesson have the pupils read what they have copied and then proceed as before. Number work should be introduced here (1) by counting objects, and the teacher placing the corresponding figure on the board as, I have three (3) flowers; (2) counting the parts of objects as the petals of flowers or the lobes of leaves. Then, too, number the sentences on the board and let the pupil copy as before.

This copying what has been placed on the board in this way may be done as busy seat-work or occupation, without the attention of the teacher.

The lesson itself, therefore, need occupy only from ten to fifteen minutes, but should be repeated at least four times a day.

COURSE OF NATURE STUDY FOR GRAMMAR GRADES.*

Grade	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March.	Apr.	May	June
Fifth	1. Flowering plants and Insects		1. Wild Mammals		1. Domestic Animals		1. Soils and Cultivated crops		1. The Apple-tree	
Sixth	1. Algi and Fungi		1. Sponges and Jelly-fishes		1. Corals and Star fishes		1. Clams and Snails		1. Liverworts and Mosses	
Seventh	1. Fishes and Reptiles		1. Ferns and Horse-tails		1. Earthworm or Grasshopper		1. Crayfish		1. Wild Birds	
Eighth	Bean					Frog.				

* Substitutions or additions may be made to this according to circumstances of Seasons and Locality.

XIII. Suggestions on the Steps.

1. Seeing.

The First Step, being taken by the pupil unaided, requires an abundance of fresh material. A large supply of material is always better than a limited one. To see a young teacher trying to make a single flower serve for a large class, when the lawn just outside is covered with them, does not tend to develop a favorable opinion of that teacher.

The gathering of the required material should be made part of the work in nature study. But it should not be made compulsory, as it may often be impossible for the pupil to find the desired specimen. As a rule pupils are eager to bring specimens. It has an educational value. It cultivates the habit of observation and attention in the ordinary affairs of life, and will lead to increased appreciation of interesting natural objects.

The teacher should not rely exclusively on the material brought by the pupils. They often fail to respond when material is most needed. The teacher herself will derive much benefit from collecting material.

The first thing to do is of course to set the pupil at work. Let him know what is expected of him. So long as the pupil remains busy, he may be left to his own resources. Attention is evidence of interest, and time spent in this uninterrupted self-activity is well spent. He is probably not only seeing, but may also be thinking. The secret of success in all teaching seems to be the gaining of this self-activity, which reveals itself in attention to the subject in hand. It is said that the distinguished Louis Agassiz, than whom none have obtained better results, placed a specimen before his pupil, told him to go to work on it; and then disappeared for weeks, returning only to inquire of the student how he was getting along. His were mature students, however; yet the principle of self-activity as the source of power is doubtless as true of the child as of the mature man.

Observing an object means that the pupil be allowed to use all his senses (sight, hearing, touch, taste, smell, etc.), on it. Plenty of time should be allowed, for the pupil is getting sense-impressions, the primary elements of knowledge.

Too much should not be expected in this first lesson; for what the pupil is able to discover is largely a matter of chance, since he lacks, it may be, that controlling idea which guides research and makes work systematic. Nevertheless this first step is very important, because it may contribute in various ways to the enjoyment of the work. Thus (*a*) he enjoys freedom, the free exercise of his power; (*b*) he enjoys that success which need not be wanting when his powers are freely exercised; (*c*) he is stimulated by discovery. Nature study owes much of its fascination to the great variety of facts that can be found by careful observation, even in the most familiar object

2. DISCUSSION.

The Second Step in the study of an object must be. directed largely by the teacher. The pupil has now a few isolated facts. They mean little or nothing to him. He may feel that he has exhausted the subject. The few facts he has discovered probably have little or no relation to one another so far as he is aware. Yet every fact is related to every other fact; and it is the consciousness of that which leads to systematic observation. Much more can be seen when once this connecting thread has been discovered. In the first step, no premeditated plan of work precedes the discoveries made. All is chance. When such a plan is first consciously or unconsciously made, the result is investigation. Such planning is the result of generalization, by which questions are developed to be solved by careful experimentation and clever manipulation. Back of all investigation is a suggestion which acts as a stimulus to further inquiry. If systematic activity is to result from the work of this step, it must be stimulating rather than satisfying. A desire for more information must be aroused, and, when aroused it should not now be satisfied by the teacher's answers.

Nature is truly suggestive. But the teacher can assist in making the pupil's mind susceptible to its suggestions. Questions are useful for this purpose. (*a*) A really suggestive question does not relate exclusively to particulars that can be seen at a glance. (*b*) They must be general questions requiring not only observation but also a complex process of inference and reasoning. (*c*) They should be connected, at least remotely, with what the pupil already knows. (*d*) They may be accompanied occasionally with suggestive information, tending to arouse thought and create interest. (*e*) But they should be of such a nature that the pupil cannot answer them offhand. (*f*) It is perfectly proper, therefore, with this purpose in view, to ask questions that are as yet unanswerable.

Thus, to take *a concrete example, the dandelion*, the following questions would be suggestive: (1) Is the dandelion alive? (2) If dead, what is the cause? (3) How then does it differ from the living? (4) What is life? (5) How do we distinguish between a dead and a living thing? (6) Did the dandelion spring from dead matter? (7) Where did it come from? (8) What finally becomes of it? (9) How does it differ from an animal? (10) Why do we call it a plant? (11) Why has it not the same form and color as the apple blossom? (12) Why does it grow in some places rather than in others? (13) Why does it change its appearance? (14) Why has it different colors at different times? (15) Why does it not grow larger? (16) Why does it disappear in winter? (17) Why and whence does it return in spring? (18) Why does it wither when plucked? (19) Why do children like the dandelion? (20) Why do bees like it? (21) Does the dandelion like water? (22) Where do the little bright drops of water come from? (23) How is the milky substance inside produced and of what use is it? (24) Why does it close up in the evening? (25) Why do people try to exterminate it?

Such questions should lead the pupil to turn the specimen over, so to speak, and view it in a new light and from a different point of view. No answer need be given to these questions. The pupil may be made to understand that it is often prudent to say we do not know, but that it is equally commendable to say I'll try to find out.

In the meantime, the teacher should use the sources of information at her command, and should acquire a knowledge of the generally accepted views on such questions. Without this knowledge, the teacher lacks perspective, and will be tied down to mere particulars that in themselves are often worthless. It is such great fundamental problems which stimulate research, and which if properly understood may redeem nature study from that routine of mere counting isolated and meaningless details which doubtless provokes in many well-disposed individuals the feeling that it is all a fad.

3. Comparison.

Step Three introduces the pupil to a new phase of his work, that of comparing one object with another, one fact with another fact. Isolated facts that do not enter into a generalization are very much like undigested food. They are a dead weight on the memory so long as they do not enter into vital relation with other facts. Mental power can be measured by the ability to assimilate facts and to build out of them a complex structure, a general idea.

Facts properly assimilated reveal a relationship to one another, the one appearing to grow out of the other as cause and effect, or as links in a long chain of development. The discovery of these relations and the understanding of their importance is mental assimilation, because facts become thus interwoven in our mental fabric, and hence vital elements in our mental life. We are not merely to haul stone, lumber, and mortar for a building leaving it piled up in ugly, disorderly heaps; we are not merely to gather the unwashed fleece or the crude fibers of the cotton plant, but we are to build from these materials a beautiful structure, and a fabric both delicate, refined, and enduring.

The means by which the facts of experience are built into a connected system is comparison and discussion. The discovery of similarities and differences develops the idea of interdependence and relationship and the tracing of these relationships is provocative of that self-activity commonly called thought. The teacher can do much to stimulate thought, provided she is able to rise above the isolated fact and to interpret it in the light of a more general idea.

The teacher should cultivate in herself that versatility which makes it possible to view facts from the standpoint of the child without becoming childish; and, also, from a philosophic standpoint without becoming abstruse. Nothing can help her so much in this as a thorough scientific mastery of the subject. Such a scientific training ought to give her a knowledge of the underlying laws and principles. Knowing these she will have that freedom in handling facts which conduces so much to clearness and interest.

She will hardly, then, commit the mistake of making the work a mere quiz on the facts committed by the pupil, but will so arrange the material as to enable the pupil to discover relationship for himself. The writer has found tables like the following very convenient in this step. They are inserted here to suggest the form, which can be multiplied and varied according to the nature of the subject. Pupils should be first instructed how to make the tables by the teacher giving the dimensions in inches and fraction of inches. A proper notebook for each pupil in which to record his notes and keep such tables is convenient.

IV. Field Lesson.

The field work of Step Four may be done partly during (*a*) the extended Saturday excursion of the class, or it may be done (*b*) during a regular school period.

The excursion must be regulated by the teacher according to the season and the nature of the weather. Perfect freedom should be given the class in these excursions, since recreation and enjoyment is one important object of them. Yet, having something definite in view need not interfere with this primary object. A problem may be given the class, and the pupils should be encouraged in making collections. They should be properly instructed as to what equipment is necessary for the excursion. (See Part II, Chapter IV.)

In the latter or outdoor recitation period both the teacher and the pupil should have something definite in view. The period is not to be wasted by merely strolling about idly. It is part of the regular work, and should not be omitted, except for unavoidable reasons, such as unfavorable weather.

Besides this regular field-work, in which the teacher takes part, the whole school may be made to take inter-

COMPARATIVE TABLE OF ORDERS OF INSECTS.

	1	2	3	4	5	6	7	8
	Body	Head	Thorax	Abdomen	Eyes	Mouth	Wings	Limbs
Grasshopper.........	segmented	distinct	distinct	ten segments	simple and compound	biting	two pr. membranous	six jointed
Bug.	"	"	"	seven segments	"	piercing	two pr. half chitinous	"
Bee................	"	"	"	six segments	"	lapping	two pr. membranous	" "
Beetle.............	"	"	"	seven segments	"	biting	first pr. chitinous second pr. membranous	"
Fly................	"	"	"	five segments	"	lapping	one pr. membranous	" "
Butterfly...........	"	"	"	nine segments	"	sucking	two pr. scaly	"
Dragonfly	"	"	"	ten segments	"	biting	two pr. membranous	"
Resemblances........	body segmented	head distinct	thorax distinct		simple and compound			six jointed limbs
Differences in........				number of segments		mouth	number and kinds of wings	
Definition of the class..								
Distinctive characters of the orders.								

COMPARATIVE TABLE OF ORDERS OF INSECTS.—*Continued.*

	9	10	11	12	13	14	15
	Feet	Covering	Color	Class	Order	Genus	Species
Grasshopper........	two clawed spiny	hairy and chitinous	reddish brown	Insecta	Orthoptera	Caloptenus	femurru-brum
Bug........	"	"	black and red	"	Hemiptera	Anasa	tristis
Bee........	"	"	yellow and black	"	Hymenop-tera	Apis	Mellifica
Beetle........	"	smooth and chitinous	brown	"	Coleoptera	Lachnos-terna	fusca
Fly........	"	hairy and chitinous	greenish black	"	Diptera	Musca	Vomitaria
Butterfly........	"	scaly chitinous	black and yellow	"	Lepidop-tera	Papilio	rutulus
Dragonfly........	"	hairy and chitinous	greenish black	"	Neuroptera	Diplax	elisa
Resemblances........	feet spiny two clawed			Insecta			
Differences in........		character of external covering	color		order	genus	species
Definition of the class........							
Distinctive characters of the orders.							

COMPARATIVE TABLE OF CLASSES OF ANIMALS.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Body	Head	Thorax	Abdomen	Eyes	Mouth	Wings	Limbs	Feet	Covering	Color	Class	Order	Genus	Species
Grasshopper..................															
Galleyworm..................															
Crayfish....................															
Spider......................															
Harvestman..................															
Earthworm..................															
Mussel......................															
Resemblances................															
Differences..................															
Definition of the classes........															
Distinctive characters of the orders..................															

COMPARATIVE TABLE OF RELATED PLANTS.

	1	2	3	4	5	6	7	8	9	10	11	12	13
	Root	Stem	Leaf	Tendrils	Spines	Flower	Corolla	Color	Fruit	Seed	Order	Genus	Species
Pea													
Bean													
Sweet Pea													
Lupine													
Vetch													
Clover													
Alfalfa													
Locust													
Resemblances													
Differences													

COMPARATIVE TABLE OF SEEDS.

	1 Color	2 Size	3 Shape	4 Seed coats	5 Cotyledons	6 Effect of 12 Hours' Soaking	7 Time necessary for Germination	8 Fate of Seed coats	9 Average growth in a Week
Corn									
Wheat									
Barley									
Oats									
Clover									
Timothy									
Squash									
Bean									
Pea									
Morning glory									
Resemblances									
Differences									

COMPARATIVE TABLE OF DOMESTIC MAMMALS.

	1	2	3	4	5	6	7	8	9	10	11	12
	Size	Cover-ing	Head	Feet	Teeth	Food	Chew-ing	Voice	Move-ments	Habits	Dis-posi-tion	Uses
Sheep.												
Dog.												
Resemblances.												
Differences.												
Sheep.												
Cow.												
Resemblances.												
Differences.												
Horse.												
Cow.												
Resemblances.												
Differences.												

COMPARATIVE TABLE OF WOODS.

Wood	1 Color	2 Grain	3 Hardness	4 Toughness	5 Cleavage	6 Absorption of Water	7 For what Used
White Pine.							
Yellow Pine.							
Cedar.							
Black Walnut.							
Cherry.							
Hickory.							
Oak.							
White Wood.							
Maple.							
Willow.							
Resemblances.							
Differences.							

COMPARATIVE TABLE OF SOILS.

Soils	1 Color	2 Microscopic Appearances	3 Absorption of Moisture	4 Retention of Moisture	5 Surface Crust	6 Rate of growth of Seeds	7 Penetration of Roots
Loam.							
Compost.							
Alkaline soil.							
Sand.							
Gravel.							
Clay.							
Resemblances.							
Differences.							

est in independent field-work by providing Bird Calendars and Flower Calendars such as the following, for recording observations on birds and flowers during the year. The form of the calendar may be varied, and places for many more items, such as food and habits of birds, inserted in the calendar. It is best made in the form of a chart to be hung on the wall and variously decorated.

A Tree Album may be made in a similar way and used for recording the names of trees and other observations regarding time of flowering, shedding of leaves, locality, condition of soil, how to plant them and care for them, etc.

BIRD CALENDAR.

Room......, School......, Year.......

Bird.	When First Seen.	Where First Seen.	By Whom First Seen.	Color.	Size.	Name.

FLOWER CALENDAR.

Room......, School......, Year......

Flower	When First Seen.	Where First Seen.	By Whom First Seen.	Color.	Size.	Name.

TREE ALBUM.

Room......, School......, Year......

Tree.	Where Growing.	Time of Blossoming.	Time of Shedding Leaves.	Soil.

Some Problems for Outdoor Study.

I. *Relation of the Object to Man:* (1) Whether useful and for what purpose; (2) whether cultivated or not, and how and why; (3) how and in what state or conditions used by man; (4) how far and why man is benefited or injured by it; (5) how its relation to man tends to its preservation or destruction; (6) what characters are most essential to its usefulness, or detrimental as the case may be; (7) how those characters are preserved by man's selection; (8) what variations are observable between different forms of the same object and what the probable cause may be; (9) what means it has for self-preservation; (10) how man's influence affects it.

II. *Relation of the Object to Animals:* (1) What relation it bears to animals in general or in particular; (2) what those animals are; (3) how they mutually minister to each others needs; (4) how they tend to destroy each other if that be true; (5) what characters make them useful to some, or injurious to others; (6) what mutual service is performed; (7) what adaptations to that service exists; (8) what characters are essential to the continuance of this relation; (9)

what elements of plan, purpose or beauty can be discovered in this relation; (10) how this relation affects man if such be the case.

III. *Relation of the Object to Plants:* (1) What relation it bears to plants in general or in particular; (2) what characters are the basis of this relation; (3) how the relation can be mutually advantageous; (4) how one party to the relation may get most benefit; (5) what that benefit may be; (6) how the relation can be dispensed with; (7) how the destruction of one would affect the other; (8) how other factors modify this relation; (9) what evidence of plan or purpose exists; (10) what elements of beauty can be discovered and what ethical principle does the relation reveal.

IV. *Relation of the Object to the Soil:* (1) With what kind of soil it is associated; (2) what are its relation to other soils; (3) what quality of the soil is most essential to this relation; (4) how it behaves when severed from this relation; (5) by what causes this might be brought about; (6) what adaptations exist with regard to that particular relation; (7) what influence these adaptations might have; (8) what effects would possibly follow if these adaptations did not exist; (9) how these adaptations are dependent upon other causes; (10) how other adaptations would influence this relation.

V. *Relation of the Object to Moisture:* (1) How this relation affects the object; (2) what characters are chiefly advantageous in this relation; (3) how it tends to perpetuate itself; (4) under what circumstances, if any, the relation does not exist; (5) how moisture affects it; (6) what amount of moisture is most favorable; (7) what changes occur as a result of changes in the amount of moisture; (8) how important characters in the object vary with the amount of moisture; (9) what adaptations serve to modify the influence of moisture; (10) how the amount of moisture affects the struggle for existence.

VI. *Relation of the Object to Light:* (1) What effects are due to the light; (2) what the results are when light is withdrawn; (3) whether the object seeks the light or avoids it, turns towards or away from the light; (4) what adaptations exist to secure the light; (5) what adaptations to avoid the light; (6) how the particular locality may increase or diminish the light; (7) adaptations to secure uniform light or to avoid too strong light; (8) how parts differ according to the amount of light received; (9) how different parts differ as their relation to light differ; (10) how the relation to light differs at different periods.

VII. *Relation of the Object to Heat:* (1) How variations in temperature affect it; (2) how the locality favors uniform temperature; (3) what is the effect of low temperature; (4) what provision is made to avoid too low or too high temperature; (5) other adaptations to this relation; (6) behavior due to temperature; (7) how temperature produces the effect; (8) how different seasons affect it; (9) how it changes with variation in temperature as in summer and in winter; (10) how other objects affect its temperature; (11) how locality is affected by winds and hence by difference in temperature.

VIII. *Relation of the Object to Elevation:* (1) Whether elevation has any influence directly; (2) changes corresponding to elevation; (3) effect of elevation modified by changes in temperature; (4) effects of elevation modified by changes in moisture; (5) effects of elevation modified by changes in light; (6) adaptations to secure elevation; (7) adaptation for anchoring or clinging to the ground; (8) modifications favorable to high or low ground; (9) secondary influences affecting elevation as soil, moisture, temperature; (10) laws showing purpose or design.

V. Experiments.

The Fifth Step may often be omitted when the subject under consideration does not especially favor a physiological or physical treatment. Yet it is an important step and should not be neglected when the problems of the subject require it.

The first thing to be done in performing an experiment is to state the problem. This may be done by the teacher; but better still, the pupil may be led to state it after he has been made to realize that a problem actually exists. *The second* important element to consider is what factors must be present and what ones excluded from the experiment.

The simpler the experiment and the less elaborate the apparatus the more effective usually is the result.

Some Simple Experiments.

I. *On Solutions.* (*a*) Compare salt or sugar with starch. What difference in appearance? (*b*) Fill two tumblers half full of water; put into one a teaspoonful of salt or sugar; stir. The salt or sugar disappears. What has happened? (*c*) Put a spoonful of starch into the second tumbler. It does not disappear. Why not? What would happen if the starch could be changed into sugar?

II. *On the Reaction of Starch.* (*a*) Put some flour into a small quantity of boiling water; treat the paste with a few drops of iodine solution (iodine dissolved in 30% alcohol); it turns blue. (*b*) Treat a small piece of boiled potato in the same way. Any evidence of starch? (*c*) Put a green leaf into boiling water and treat it with iodine. Any evidence of starch in the leaf?

III. *On Diffusion.* (*a*) Put some sugar into a tumbler, and pour into it enough water to fill the tumbler. Allow it to stand. Does the sugar disappear? (*b*)

Take a spoonful of water from the surface and taste. Is it sweet? The sugar, in dissolving, has been broken up into minute particles that become suspended between the molecules of water. The sugar particles do not remain at the bottom, but spread throughout all the water till all parts are equally sweetened. Would this be possible if the sugar did not dissolve?

IV. *On Evaporation.* (*a*) Put a strip of filter paper into water; leave it exposed to the air. It dries. What has happened? (*b*) Hold a spoon containing water over an alcohol flame. The water boils and disappears; what has happened? (*c*) Hold a moistened strip of filter-paper near the flame and another farther from the flame. The former dries more quickly. What difference in the condition of the two strips may account for the difference in effect? Would the sun shining on one of the strips and not on the other have a similar effect? (*d*) Dissolve some salt in a tumbler one-fourth full of water; allow the water to evaporate. Has the salt evaporated? Examine the crystals remaining.

V. *On the Effects of Heat.* (*a*) Fill a tin cup with snow; determine the temperature of the snow by means of a thermometer. Take a spoonful of this snow and hold it over the alcohol lamp. Why does this snow melt while that remaining in the cup does not? (*b*) Stir a considerable quantity of salt into the snow remaining in the cup. Does the temperature remain the same? (*c*) Place the tin cup over the alcohol flame till the snow melts. What is the temperature of the water resulting from the melting snow? Continue to heat the water. Does the temperature rise at once? (*d*) Determine the temperature of boiling water. (*e*) Why do bubbles gather at the bottom of the cup and finally begin to ascend? As the bubbles burst at the surface they give rise to steam. (*f*) Fill a little vial with water and cork tightly.

Expose it to the salt and snow mixture. The water turns to ice. Possibly the vial is cracked. What has happened? (*g*) Take two fresh leaves; suspend one close to the flame. What difference can soon be discovered between the two leaves? (*h*) Take two fresh leaves. Place one in a tumbler of water. After a while, a day or so, what difference can be observed in the two leaves? What has happened to the one exposed to the air? Account for it.

VI. *On Absorption.* (*a*) Take a strip of blotting paper and a piece of common writing paper; put upon each a drop of ink. What is the difference in effect? Allow both to dry; compare the size of the two blots. Account for the difference. (*b*) Take a tumbler filled within half an inch with water; put into the tumbler a small dry sponge and allow to soak. Remove the sponge. What changes have been produced in the sponge? in the amount of water in the tumbler? Account for the increased size of the sponge and for the diminution in the water in the glass. (*c*) Take the withered leaf; place it into the tumbler of water. After a while, what changes have been produced in the leaf? What connection between this and the sponge? (*d*) Put beans into a tumbler of water. What are the results?

VII. *On the Effects of Surface Exposure.* (*a*) Soak two handkerchiefs in water; leave one folded together, but spread the other out. After an hour or so, notice which is dryest. Account for it. (*b*) Soak the sponge and the handkerchief. Expose both to the air for some time, leaving the handkerchief rolled up in a tight ball. After an hour or so, which can be seen to have dried more quickly? Which took up water most readily, and which gave it off most readily? Account for the difference.

What would be the advantage to a plant of small compact leaves? of large porous leaves? Under what climatic conditions would each of these leaves naturally prevail?

What advantages result from having lungs inside the body and gills outside?

VIII. *On the Rise of Liquids.* (*a*) Take a strip of blotting paper or filter-paper, and a strip (same size) of ordinary writing paper; put one end of each into water; notice the difference. How far above the surface of the water is the strip of filter-paper wet? Explain the difference. (*b*) Take two wide-mouthed bottles of equal size and fill both with water. Place the strip of filter-paper into one so as to project two or three inches; cork both bottles gently. After a day or two which bottle contains most water? Explain the difference. (*c*) Repeat the experiment after filling both bottles as before; but this time place the wet sponge on the cork next to the strip of filter-paper. After the same lapse of time how do the results agree with the previous ones? Account for it. How would a moist and a dry atmosphere respectively affect the disappearance of water in the two bottles? (*d*) Fill the two bottles again; place a strip of filter-paper as before in each bottle, and cork both lightly. Put one of the bottles into a tumbler containing half an inch of water. Invert another tumbler over the top. Leave the other exposed to the dry air of the room. Which loses most water? Explain the difference. How would a moist climate affect the amount of water transpired from the leaves of plants? (*e*) Fill a tumbler with water; take a card board and make a round opening in the center large enough to allow the small end of a hen's egg to reach the water but not pass clear through the opening. Remove the shell very carefully from the small end of the egg, care being taken not to tear the thin egg-membrane underneath; an area a quarter inch square will suffice. In the opposite end of the egg, make a small opening into which insert a small glass tube and fix with sealing wax; allow to stand for twenty-four to forty-eight hours. The contents of the egg has risen to the top of the tube and flows out. Osmosis through animal membrane. Explain the result.

In a similar way roots and root hairs take in water and dissolved substances from the soil and cause it to rise in the stem of the plant.

The last experiment is a clear case of pressure caused by osmosis. The experiment with the filter paper is an illustration of the effects of capillary attraction. Both of these forces are active in plants, causing the flow of sap. Evaporation from the leaves of the plant increases the rapidity of the upward current; just as the exposure of the strip of filter-paper to dry air increases the loss of water from the bottle.

IX. *On Transpiration.* (*a*) Invert a dry tumbler over a bunch of fresh white clover; observe the cloudy appearance on the glass, due to *transpiration.* (*b*) Wind a piece of sheet rubber tightly around one finger. Note the moist skin on removing the rubber—*perspiration.* (*c*) Take two bottles; fill one with water. Place into the bottle a few short branches or stems of white clover bearing leaves. Some also into the empty bottle. After a day or two note the difference. Why does the water in one bottle prevent the wilting of the plant?

X. *How Excessive Transpiration is Regulated.* Take two potatoes of unequal size; peel off the outside of the larger one till its weight is equal to that of the smaller one. Expose both to the air for a week or so. Which is now the heavier? How was evaporation and drying prevented in the unpeeled potato?

Why are plants and animals covered with an outer cuticle? Corks are made from bark; put one into water; does it become soaked? Of what use is bark on stems when absent from leaves?

XI. *On the Parts of Stems that Convey the Sap.* (*a*) Take a young plant, root and all (bean or shepherd's purse), put it into a bottle containing a weak solution of eosin (red ink will do). Allow to stand for three or four days. *Observe:* the root turns red, the stem does not. Why? Are the veins of the leaves colored? (*b*) Make transverse and longitudinal sections of the root and stem. *Observe:* what areas are affected by the stain? the fibrovascular bundles? It is through these, then, that the upward flow of sap takes place. Would the sap be so apt to reach the leaves if evaporation were not prevented by the cuticle and bark on the stem?

XII. *On Respiration.* (*a*) Immerse some water-plants (chara, spirogyra) in a beaker or tumbler full of water; place in sunlight. *Observe:* bubbles rising. (*b*) Place a funnel over the plants under water, and over the funnel invert a test-tube filled with water. *Observe* the bubbles rising into the test-tube and displacing the water. After some days, when the test-tube is half emptied of water, the upper part of the tube being occupied by the bubbles, light a long splinter and after it has burned for some time blow it out and insert the glowing point of the stick into the test-tube. It bursts into a flame. This is evidence of oxygen. The plant has been exhaling oxygen. (*c*) Breathe through a glass tube or straw immersed in a tumbler of water. *Observe:* bubbles rise as in the case of the plant. Put into the tumbler clear lime-water instead of fresh well-water. On breathing into this, for some time it turns cloudy. Evidence of carbon dioxide CO_2. (*d*) Take two tumblers or beakers filled with water; put into each the same kind and quantity of water-plants. Place one in bright sunlight, the other in shady place. In which are the most bubbles produced? What conclusion is to be drawn?

Remarks: Plants, like animals, exhale carbon dioxide, because they waste; but, in sunlight, the oxygen given off because of the breaking up of carbon dioxide and water to form starch, is much in excess of the carbon dioxide. Exhalation of oxygen in plants is due to photosynthesis, the formation of starch from H_2O and CO_2.

XIII. *On Germination.* (*a*) Make a moist-chamber from a common plate and a bell jar (a saucer with a tumbler inverted over it will do). Place in the bottom of the chamber a circular piece of filter-paper not so large as the cover. Moisten well, and place upon the moistened paper the seeds that are to be studied. Place a second moist paper over the seeds till they are well sprouted. Keep the papers moist. (*b*) In a tin basin filled with black soil or sawdust, place the seeds to be sprouted. Moisten the contents and keep moist. (*c*) If convenient let each member of the class stir up a little patch of ground in the school-yard and plant seeds of various kinds, such as peas, beans, flax, wheat, corn, and flowers.

XIV. *On Tropisms, Direction of Growth.* (*a*) In a tin basin or wooden box filled with black soil or sand, plant some beans. Keep moist. As the plants come up, notice the curvature of the stem, and how it gradually straightens out. Leave the dish in the same position for a week or two. *Observe* how the plants bend towards the window, the source of light (heliotropism). (*b*) Take a coarse sponge; soak it and squeeze it dry; fasten a pin, bent into a hook, to a strong cord; hook the pin securely into the sponge; fill the pores of the sponge with kernels of wheat; invert over the sponge a funnel, passing the cord through it; suspend by the cord and keep the sponge moist by pouring water through the funnel tube; the funnel prevents the sponge from drying too rapidly. *Observe* the seeds sprout and produce plants growing upside down. What can be inferred? Does gravity or moisture determine the direction of growth of the roots? In this case the effect of gravity is neutralized.

XV. *On the Influence of Environment.* Take two bottles; fill one with water; into each bottle put a few fresh stems or branches of white clover bearing leaves; allow to remain for some weeks. *Observe:* one wilts, the other does not. Examine the stem in the water and notice the new adventitious roots. On what part of the stem are these produced? How has water produced this effect? Compare with the plant in the empty bottle. (*b*) Now pour water into the empty bottle; allow to remain. Are new roots produced on the withered stem?

Remarks: Not water alone, nor the plant alone, can account for the production of new adventitious roots (as the experiment shows), but the living plant reacts to the moist environment, and this reaction results in the growth of new roots; hence the importance of action and reaction in producing changes in living things.

VII. Lecture.

Step Seven should rarely be omitted. Life is too short to attempt to gather all facts at first hand. We are fortunately able to profit by the labors, thought, and experience of others, provided we have already gained enough by our own self-activity to be able to interpret language through which the knowledge of the race is communicated The empirical work already done on the subject in hand should have contributed to the power of interpreting language. It is because nature study does this that it is justly regarded as the foundation of all other work of the school. How absurd it would be not to use this slowly acquired power of interpreting language!

In the preceding steps, ideas needing names have been felt by the pupil and noticed by the teacher.

By this time each important idea should be associated with a symbol, a word or name, which when heard will recall the appropriate image. The object has suggested the idea, the teacher has supplied the word. Consequently the word should mean something now to the pupil.

In gaining additional information through the medium of language, the pupil has to reverse the natural processes. He must now gain an idea from its symbol; translate, so to speak, language into ideas.

Such supplementary information can be gained by the pupil in two ways; first, by oral communication by the teacher; second, by reading books on the subject. Hence the lecture and the library.

The amount of library work to be done in connection with any subject must depend on the facilities obtainable. The teacher, at least, should have a nature-study library. Scientific works on natural history are not expensive (see list in Part II, Chap. IV). Aside from the additional information gained from books on any one subject, there is the more general benefit derived from the habit of using works of reference, not to mention the power of gathering knowledge from the printed page.

The book of reference may be used in two ways: (1) the pupil may consult the book; (2) the teacher may read to the class important passages bearing on the subject studied. Such readings may sometimes be substituted for the lecture, especially in the lower grades.

Many teachers feel that the lecture is out of place in nature study, and would perhaps maintain that the work should be all observation work and developmental work. That would be very true if the first steps had not already been taken. It is not true when the first part of the work has been properly done.

In the first place, the teacher should be able to get more than the pupil can out of even an unfamiliar subject. In the second place, she is assumed to have a more general store of knowledge than the pupil, and the ability to see the relation of things in a truer light. Hence she is supposed to be able to arrange the material gathered in the preceding work into a logical and consistent whole.

Most pupils enjoy a lecture by the teacher when adapted to their needs and properly presented. In the primary grades the lecture should resemble a story; in the grammar grades statements should be more concise. If facts are properly arranged they are usually interesting in themselves. The baby-talk of the kindergarten and the primary grade is not necessary and should never be tolerated in the upper grades. The teacher in these grades should find the source of interest in the facts themselves, not in imaginary and fictitious resemblances, and should endeavor to awaken in her pupils a delight in truth for truth's sake. This often requires effort and careful preparation.

The amount of matter to be presented orally in this way must depend on the grade, or rather the general maturity of the pupil. After an intensive study of the Bean Plant for several weeks, including the first seven steps, as prescribed in the course of study for the eighth grade, the teacher might give the following summary of The Principal Facts in the History of a Plant (See Plants, Part II, Chap. I).

VIII. Drawing.

In Step Eight the pupil makes his first attempt to express in part, either by pencil, crayon or colors, the ideas he has gained in the preceding work. He is at once confronted with the question whether to make a pretty picture as it seems to him it ought to be, or whether to represent the real thing regardless of its general effect. If this question does not at once occur to him, effort should be made to lead him to understand that objects may be drawn as they really are, or they may be idealized, just as an object may be considered scientifically as to fact, or emotionally as to real or imagined meaning and beauty. Which of these criteria should prevail is often a serious question for the teacher to decide.

Pupils who have been trained in the ordinary free-hand drawing often experience most difficulty in representing minute details in form and structure. They are apt to make a few bold strokes which may look well enough at a distance, but which convey no true picture of the reality. Shall this mode of drawing be allowed or must it be prohibited?

To answer this, we may ask, what is the object of drawing? In the first place, ideas of form, color, shade, and structure can be better expressed in this way than by means of language. If it is a part of nature study, those ideas should correspond to the reality and should be so expressed as to accurately represent the reality. But this expression is not the final object of the work. It is supposed to have an educational value, as it involves various judgments and many neural and muscular activities. Now, the object is the ability to form true judgments, and the ability to so control the hand as to exactly represent or execute what the judgment has found to be true. The benefit of this part of the work lies in the fact that it puts the body into proper relation to the activities of the higher centers and the mind, making the hand execute what the mind dictates. The more completely this is realized, the more effective is the training. But the dictates of the mind must receive their sanction from the testimony of the senses; otherwise the drawing would represent mere imaginary creations instead of a real thing. In imaginary representation there is no true judgment involved; and no exercise of the will in controlling the hand in the execution of a definite task. The moral effect of the training in that case is lost.

By carefully comparing his drawing with the object, the pupil is enabled to detect shades of difference in structure, form, and color which would otherwise escape him, and enables him the better to measure his success. This in itself adds interest to the exercise and gives a training in accurate seeing which is indispensable.

In the lower grades, all kinds of allowances have to be made; yet the principle is the same here as in all other steps, namely, progress should be made from the original lawlessness towards more and more fidelity to truth. Neatness and accuracy must be the criterion for criticism.

As a rule, it seems desirable to allow the pupil to use his creative and artistic instinct in an elaborate representation of the whole as a general frontispiece to his composition, but to insist on extreme accuracy in representing the finer details of structure. (See Pupil's Compositions, Part I, Chapter V). It is often desirable to have the drawings made or copied on separate slips to be inserted in the composition in its appropriate paragraph.

Even when no attempt at systematic drawing is made, as in many rural districts, good work can be obtained by means of pencils. Pencils should be well sharpened but not to a fine point. The point may be rounded off by rubbing it on paper. Stubs may be made by the pupil by rolling up into a solid pencil, strips of ordinary writing paper wound with a string. Forcing the center of this roll down produces a point which can be used to transfer the lead from the paper used in trimming the pencil to the drawing to be shaded.

IX. Writing.

Step Nine cannot be taken by pupils who have not learned to write. At the very beginning of the pupil's school work, nature study should be used chiefly with a view to teaching reading and writing. (*See Primary Method, Section* 12).

Writing in connection with this work is important. It not only affords means of expressing ideas that cannot well be expressed in drawing, but it is the most natural way of learning spelling, penmanship, and composition. Written work possesses the character of permanence more strongly than oral language, and hence is more favorable to accuracy and deliberation in the statements. Errors can be marked and the object re-examined without the risk of losing sight of the problems. The written work should also command more forethought in arranging the matter to be communicated, and thus contribute to a better assimilation of the knowledge gained.

The question as to the place of the imagination in this part of the work is the same as in oral speech. The two aspects of the subject should be separated as sharply as possible. We naturally make allowances in extemporaneous speech, but instinctively demand greater accuracy and deliberation in written work. There is no reason why the pupil should not conform to this law of our nature. Again, allowances must be made as in the case of drawing. In dealing with the facts let the pupil confine himself to them, but give him the opportunity to express his appreciation at the end in whatever manner his fancy may dictate. We are entitled to liberty when we have earned it, and may properly use exclamations after we have shown that there is something to admire.

The educational value of that deliberation and carefulness in statements of facts and that accurate discrimination between the finer shades of meanings of terms used can hardly be overestimated. It is the final product of a well-ordered mind, and has not only a scientific but also an ethical value. It is well for the teacher in the grades to realize that his pupils are to become men and women, and that even in the sixth, seventh, and eighth grades they are by no means mere babies.

X. Reading.

Step Ten may be omitted occasionally when classes are so large as to render repetition monotonous. It should not be omitted in the lower grades where intelligent reading is one of the principal aims of the work. If the writing is worth while, the reading should be. The intellectual and physical processes involved in writing and in reading are opposites and supplement each other. Thus in writing, the pupil puts his own ideas into symbols, while in reading he converts those same symbols into ideas resembling his original ones. In the latter process he naturally acquires the power of gaining ideas from the printed page. Having previously expressed the same ideas, he should be able to read intelligently from the beginning.

Supplementary reading in natural history is very interesting to pupils of most grades, and may often be introduced as reading exercises instead of the pupil's own compositions. Then, too, the best compositions may be preserved, and variety secured, by having them read at the end of a certain division of the subject.

In the primary grades number work may be introduced in connection with the object studied, thus making the object the central thing in all the pupil's school-work.

CHAPTER V

Examples of Pupils' Work in Nature Study

XIV. The Apple-tree. By J. S. M.

(*Guiding Outline.* Supplied by the teacher.)

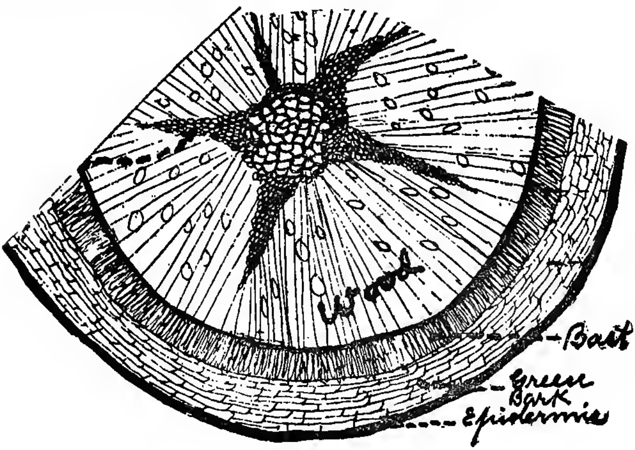
1. *Introduction:* (*a*) distribution; (*b*) economic uses; (*c*) uses of the plant.
2. *Roots:* (*a*) uses; (*b*) kinds; (*c*) effects of moisture.
3. *Stem:* (*a*) form; (*b*) size; (*c*) kind; (*d*) composition; (*e*) grafting; (*f*) pruning; (*g*) function; (*h*) struggle for existence among branches.
4. *Leaves:* (*a*) arrangement; (*b*) color; (*c*) form; (*d*) margin; (*e*) venation.
5. *Flower:* (*a*) arrangement; (*b*) numerical plan; (*c*) form; (*d*) adnation; (*e*) position; (*f*) use.
6. *Fruit:* (*a*) kind; (*b*) appearance; (*c*) relation to flower.
7. *Relation to environment:* (*a*) effects of neglect; (*b*) relation to soil; (*c*) relation to air; (*d*) relation to light.
8. *Relation to animals.*
9. *Relation to other plants.*
10. *Poetry.*

1. Apple-trees are found nearly everywhere in the temperate zones. They grow also as far north as the Arctic circle and as far south as Northern Africa. Their chief economic use is as a food, the fruit being juicy and delicious to the palate. They are also used for medicinal purposes. The primary use of the fruit, however, is not for man's benefit, but for the distribution of the seeds, which are the

plant's final product, and the variety of which determine the kind of tree to be developed.

2. The roots of the apple-tree are arboreous, spreading over the surface or growing down deep, according to its environment. They are perennial, and, like all such roots, serve to absorb and store up moisture and food from the earth.

3. The stem is upright, ranging from three and a half to four or five feet in length. It is stout and woody, having all the parts found in exogenous plants, namely, pith, medullary sheath, wood, bast fibers, green bark or cambium, and outside bark or epidermis.



Section of Wood.

It is in the cambium or green-bark layer that growth takes place. Grafters have made use of this by uniting the cambium layer of one tree with a branch of some other tree. There are numerous ways of grafting, but the success of any depends upon the union of the cambium layers. By means of this process a frail but excellent variety of fruit may be made to grow strong and hardy. The apple-tree is delinquescent and its shape is determined by the branching. Naturally, it is inclined to branch out from the center, but cultivation has increased this inclination, and thus made the top rounder. This is done by pruning; the middle branches and superfluous outside twigs are cut off and the outside branches left to take the lead. There are generally five main branches coming out from the trunk, and from these grow others smaller in size. The branching would go on and on, becoming very complicated and tangled if it were not for the natural selection taking place all the time. The branches that get the best start in the beginning take up most of the nourishment stored in the stem and roots, and hence by their growth are able to crowd out the less fortunate and shade them from sunlight. This is the reason for the numerous little branches and twigs scattered here and there throughout the tree. The function of the stem and branches is threefold; first, to lift the plant above the ground so that the leaves may be in the sunlight, and the flowers and fruits may receive opportunity for fertilization and distribution; second, to conduct the raw sap from the roots to the upper extremities of the tree; third, to distribute the food material wherever needed.

The Apple Leaf.

4. The leaves are of the alternate, two-fifths arrangement. They are deep green in color. Their general form is ovate with rounded base, acute apex, and doubly serrate margin. They are pinnately veined, and have short petioles and free stipules.

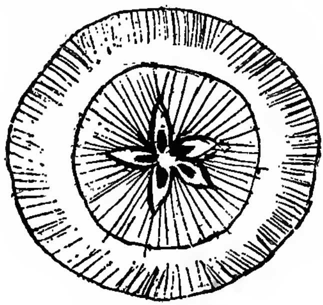
5. The flowers of the apple-tree are arranged in flat compound curves. They are built on the plan of five and vary from three-fourths to one and one-fourth of an inch in diameter. The calyx is turbinate in form and has

five bright green sepals of united cohesion, semi-inferior to the pistil. The delicate pink corolla consists of five petals of distinct cohesion and superior adnation. There are usually twenty stamens inserted with the petals on the throats of the calyx. The base of the calyx, however, is united with the base of the pistil or ovary, which has five cells, with two ovules in each cell. The pistil has five styles, with a rounded stigma on the end of each. As in all plants, the flower of the apple bears a definite relation to the stem and branches. The flower buds and the leaf buds arise in the same position. The sepals, as shown by their form and color, are but modified leaves; so also are the petals, though their appearance does not show it so plainly. The pistils and stamens, too, are merely modifications of leaves. The apple-blossoms by their fragrance attract the bees and thus, through the agency of these insects, cross-fertilization takes place.

Apple-blossoms.

6. The fruit of the apple-tree is an indehiscent pome. It matures late in the summer and during the fall. The skin is generally smooth and variously colored, being red, yellow, brown, or striped, according to the variety. The apple is really the matured calyx of the blossom. In the center is the core, which in a cross-section appears as a star-shaped figure of five points. These are the ovary cells, and they contain the seeds. The seeds are brown when ripe and their coats are not very hard. The kernel has a rather rich taste not at all unpleasant.

7. The apple-tree is a rather hardy plant, adapting itself quite readily to circumstances. It grows best in a comparatively dry, sandy soil. That is to say, its fruit is apt to be larger and more palatable under such conditions because then there is less inducement for the very great development of the roots and stem, a thing that always takes place in an extremely moist soil. While not requiring very great care in comparison with that necessitated by many other trees, the apple-tree, if neglected long,



A Divided Apple.

will produce very tiny fruit. Its branches grow more upright, and the twigs become spine-like. The trunk is generally quite sturdy and strong, not easily broken by wind-storms, though often the shape of the whole tree is bent so as to become one-sided, on account of the wind.

8. The honey-bees and yellow-jackets are the insects found in the greatest numbers about apple-trees. They are harmless, however, and aid in the fertilization necessary for reproduction. Often the caterpillars will take possession of an apple orchard and destroy all the leaves and fruit, leaving nothing but the bare branches of the trees, which but a short time before were beautiful masses of green foliage and fruit.

9. The family to which the apple-tree belongs is the *Rosaceæ*. Related to it we find the common and familiar strawberry, blackberry, rose, pear, and cherry, all exhibiting great variety of shape and size, and yet similar enough to be placed in one single group.

10. William Cullen Bryant, in his poem, "The Planting of the Apple-tree," expresses some very beautiful thoughts. The following stanzas are especially well put:

An Apple.

"What plant we in this apple-tree?
Fruits that shall swell in sunny June,
And redden in the August moon,
And drop when gentle airs come by
That fan the blue September sky;
While children come, with cries of glee,
And seek them where the fragrant grass
Betrays their bed to those who pass
At the foot of the apple-tree.

* * * * * * *

Each year shall give this apple-tree
A broader flush of roseate bloom,
A deeper maze of verdurous gloom,
And loosen when the frost clouds lower
The crisp brown leaves in thicker shower.
The years shall come and pass, but we
Shall hear no longer where we lie,
The summer's songs, the autumn's sigh
In the boughs of the apple-tree."

XV. Grasshoppers. By B. H. B.

(*Outline. Supplied by the teacher.*)

1. *Introduction, anecdotes;* 2. *body;* 3. *eyes;* 4. *antennæ;* 5. *mouth-parts;* 6. *thorax;* 7. *wings;* 8. *legs;* 9. *protective resemblances;* 10. *color;* 11. *sense of hearing;* 12. *abdomen;* 13. *reproduction;* 14. *internal organs,* 15. *respiration;* 16. *conclusion.*

1. Most of us like the cry of the grasshopper; it brings to mind the warm, dry, sunny days, the time of fruit and flowers.

He likes to sing, is fond of moonlight, likes the shade and the cool, still places under the green herbs.

When you see the large long legs stretched out behind, and the long feelers waving to the wind, you will know this is a grasshopper, the joyful, happy singer of the meadow.

The name of the insect at once tells you something about him. He lives much in the grass; his chief motion is in hops and long jumps.

Not all grasshoppers live in the grass however; some spend most of their time in trees, some live in garden walls, or under the leaves, and in the grass of the dusty wayside. Some also live in woods, among the pine- and fir-trees. In South America there are large and splendid grasshoppers;

their wings are so gay that when they fly they look much like butterflies.

The grásshopper is a musical insect. He hhas anoter name, the murmurer; this is because of the noise or song he makes. He sings to the female grasshopper in loud, shrill tones. It is made by rubbing his wings one upon the other. He has a little skin, like a tight drumhead, set in each wing. As he moves his wings, this tiny drum vibrates, or trembles, and makes the shrill sound. This is called stridulation.

The female grasshopper does not have this drum in her wings. She has, however, at the end of her body, a nice little sword, called ovipositor. She is called the jumper with the sword. This little sword opens into several blades. She uses it to place her eggs snugly into the ground. The sword blade opens and the eggs slide safely down between them, into the little earth-bed. There they lie until the young grasshoppers hatch out.

The grasshopper generally dies near where it was born. Frost and cold kill it. It does not outlive the winter, like bees and butterflies.

Grasshoppers feed chiefly on grasses of different kinds, including most of the cultivated grains. They feed on almost any green part of plants. Some are gregarious and may be very destructive. They sometimes appear in great numbers, and when they do they damage the grass and young crops. But they do not usually go in swarms as locusts do, who are their near relatives.

There is a grasshopper called the Rocky Mountain grasshopper, because the old grasshoppers go to the mountains to lay their eggs. The little ones live in the mountains until their wings are strong, and then all the grasshoppers leave the mountains together, flying and jumping along in such numbers that they terrify the farmers in the plain below, for they eat up every green thing in their way, fields of corn and wheat, and grass.

Insects comprise the six-footed Arthropods, nearly one-half of the animal kingdom, there being about two hundred thousand species.

The Class Insecta are distinguished by having a body in three parts, head, thorax, and abdomen distinct. Three pairs of jointed legs. One pair of antennæ and generally two pairs of wings. The order to which the grasshopper belongs is *Orthoptera*.

The name grasshopper is applied to several families closely related—grasshoppers, locusts, crickets, cockroaches, etc. Their body is usually flattened, prothorax large and squarish, mouth parts adapted for biting. Metamorphosis often incomplete; pupa often active; larva flattened, often resembling the adult. This order is called the straight wings because the insects belonging to it do not fold their wings crosswise. There are six families of the straight wings, but the grasshopper, locust, and cricket interest us most.

A locust is not a grasshopper, but much like a grasshopper. It is his nearest relative. We do not like locusts because they do great harm. They are generally larger than grasshoppers and much more greedy. They destroy all plants that come in their way, even to the bark of trees. Locusts live in swarms. Instead of dying and living where they were born, they are given to travel. They generally live in hot lands, as Asia and Africa. In Europe and the eastern part of the United States they are not common, but in the Western States they have done much harm.

His feelers are shorter than those of the grasshopper. The female locust has no sword for placing her eggs; she lays them in the earth in long tubes. Many boys make a living by digging them from the earth and selling them to be destroyed.

People try many ways of killing locusts. Sometimes deep trenches are cut and filled with water so that young unwinged locusts, as they run along the ground, will fall in and be drowned. They are in such numbers that the drowned ones soon fill the trenches. The others run safely over the dead bodies. Sometimes great fires are lit across their path. Then the hordes of locusts crowd on, and at last the fires are put out by the burned bodies. After that the others pass on unhurt.

One great trouble about locusts is, that when a full-grown swarm passes through a place the ground is left full of eggs. The next year these hatch and the larvæ and pupæ eat up all that has grown since their parents ravaged the land.

Famines of two or three years' duration have been caused in this way. Foreign locusts are splendid to look at. They are dressed like soldiers in crimson and blue. Their fierce eyes shine and the rush of their wings makes a sound like the coming of an army. We can scarcely believe or understand what we are told about the multitudes of these insects which appear in the East. The Bible says that John the Baptist fed on locusts and wild honey. Locust is the Bible name for grasshopper.

In the far East even now people catch grasshoppers, roast them, and grind them into meal which they think very good; they eat them fried in oil and salt.

People hear with terror that locusts are coming. They know their crops will be eaten up, then food will be scarce and people will be poor. They fill the sky like a great cloud, so that the day is darkened. When they see a green place they settle to feed. In a few minutes the green is all gone. The place is as bare as if a fire had swept over it. Locusts fly with the wind and are often driven into the sea and drowned. The coast of Africa has been found covered thick with them for a space of fifty miles.

They are very strong on the wing, some species being very large. A great swarm of locusts was met by a ship twelve hundred miles from shore. They surrounded the ship and hid the sun. They are so strong that they can go from one country to another. They fly in the daytime when the air is hot and dry; towards evening they run along the ground and eat everything in their path.

The front of the locust's head is harder and thicker than the grasshopper's. The hind legs are also thicker and stronger than even the big, strong ones of the grasshopper. The locust sometimes makes loud, shrill sounds by rubbing the inner surface of the hind legs against the outer surface of the front wings. Sometimes the sound is very loud. Locusts are land pirates and not welcome visitors in the regions where they abound.

The cricket is as happy and harmless as the locust is destructive. He may be seen creeping out of the hearth and waving his long feelers gently in the heat. There are house-crickets, field-crickets, and mole-crickets. They have a shrill, gay little song. The body is not as slender as that of the grasshopper, but is short and thick. He also has a little thin drumhead for his music. His name suggests the noise he makes.

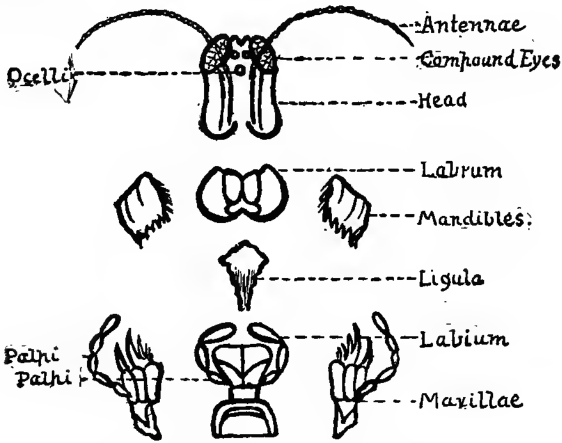
The French call him cri-cri. The field-crickets sing all day, the house-crickets and mole-crickets sing only at night. The cricket has strong jaws, sharp teeth, and a thick round tongue. His feet are not broad and thick like the grasshopper's. He does not run up plants as the grasshopper does. The cricket runs about the ground; he has sharp thin feet. Sometimes he has stiff hairs on them.

Crickets are fond of moisture, they are thirsty creatures, they will drink any liquid left in the way; they are also greedy and will eat anything, even to woolen clothes. Once a cook laid upon the grass a large piece of woolen blanket on which she had spilled some bread sponge. She left it there thirty-six hours; when she went for it the crickets had eaten nearly all of it. The blanket was so full of holes it was like a net. There were more holes than there was blanket.

Crickets do not like to change their homes; they prefer to stay where they were born. Unless they fly to move from home to home they do not use their wings. They walk or hop.

The poets or story-tellers are very fond of crickets. Many people think it lucky to have them sing in the hearth. They like new houses, where the mortar is not too hard for them to pick some of it out and make their little home; the field-cricket does this in the fall, choosing the kitchen or well-warmed rooms to live in. Little French children fish for crickets by tying an ant to a thread and dropping it into the hole. You can also make the cricket come out by poking a blade of grass into his hole.

The field-cricket lays his eggs in the ground. In Spain the people like the cricket's song so much that they keep crickets in little cages to sing for them. If they have plenty to eat and drink they will sing and be happy. Each cricket will need a cage all for himself. Crickets, like grasshoppers, if shut up together, will fight, until one is killed, then he is eaten by the victor. Crickets always live alone.



Head and Mouth-parts of Grasshopper.

2. The *body* of the grasshopper is made of chitin, protecting the delicate parts within. This integument is at intervals segmented or jointed, the segments are more or less like rings, which in turn are subdivided into pieces. The body consists of seventeen of these segments—four in the head, three in the thorax, and ten in the hind body or abdomen. The organs of sense are in the head.

3. The head also carries the compound eyes, which are composed of a large number of hexagonal cornea, or facets, often many thousands. They are so round that the grasshopper can see in all directions at once. That is why it is so hard to catch one even when you come softly up behind him. The ocelli or simple eyes are three in number, two posterior and one anterior ocellus. Insects see objects best when moving.

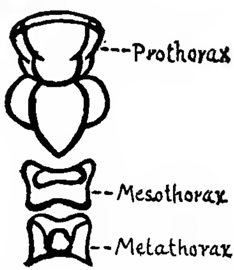
4. The antennæ or feelers are inserted in front of the eyes, and between them is the anterior ocellus, or simple eye. All are tubular and jointed. They are supposed to be organs of touch and also sensitive to sound.

There are long-haired and short-horned grasshoppers. The Katydid, which is the green grasshopper, has antennæ longer than its body. The song of the Katydid seems to exist in these words repeated again and again with a slight variation.

5. The grasshopper is a great eater; you will be surprised to find how quickly he will eat a clover leaf. His jaws are very sharp and strong; he works them sideways (horizontally) instead of up and down. He has a number of mouth parts which help him get the leaf into his mouth and he uses his front legs besides, so it is not strange that he can eat up the leaf so fast.

The upper lip is called the labrum. The true jaws are the mandibles, which are single-jointed; they are also broad and short, with a toothed cutting and grinding edge, adapted for biting. The mandibles are situated on each side of the mouth.

Opening behind the mandibles are the maxillæ, which are divided into three lobes, the inner armed with teeth or spines, the middle lobe unarmed, while the outer forms a five-jointed feeler called the maxillary palpus. The maxillæ are accessory jaws and probably serve to hold and arrange the food to be ground by the true jaws. The floor of the mouth is formed by the labium; to each half is appended a three-jointed palpus. Within the mouth, situated upon the labium, is the ligula or tongue, which is large and membranous; with chitinous spines on it to hold the food. The tongue extends back to the pharynx and narrows towards the back.



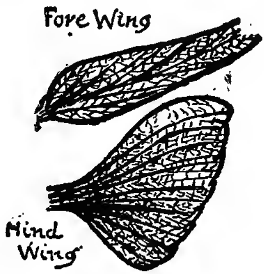
6. The motor organs belong to the thorax, which is composed of three parts.

The prothorax or fore part of the chest is a large horny collar, saddle-shaped, which carries the first pair of legs.

The front pair being shorter than the others, hinders him in walking on a level surface but helps him in walking up a tree or small plant or wall.

The mesothorax or middle part carries the second pair of legs and fore wings, which are longer, narrower, and thicker than the other two.

The metathorax or hind ring of the chest bears the hind wings and legs which are twice as long as the others. The thigh or upper part is very long and strong. By means of these big legs the grasshopper is a famous jumper. The hind wings are most active in flight; they are broad, thin, and membranous, being folded up like a fan when at rest, and tucked away out of sight under the fore wings, which act as wing covers.

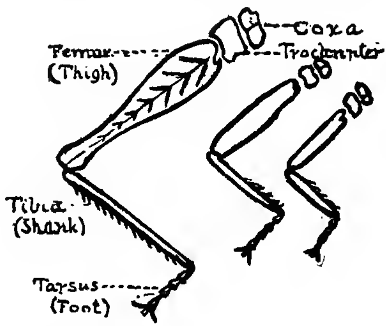


7. The wings are simple expansions of the skin, or crust, being composed of two delicate films of the epidermis, stretched upon a network of tubes or trachæ. Where the wings join the grasshopper's body you will find the drum-plate used in stridulation. The wings are used by muscles inside the thorax.

8. The six legs of the grasshopper, like those of all insects, have five parts. At the end of the big thigh we find the two strong hooks, coxa and trochanter. This is the hip to which the leg is inserted. The thigh is the femur; the shank, tibia; and tarsus is the foot. The tarsus is usually sub-divided into five joints and pair of claws.

You cannot feel their muscles, for their skeletons are on the outside of their bodies, and like coats of armor cover all their muscles.

In locomotion the fore legs are directed forward and the two hinder pairs backward. In motion the fore and hind feet on one side, and the middle one on the other, are moved simultaneously and then the remaining three.



The grasshopper pushes against the support on which he is resting and away he goes just as you think you have him. He is not easy to find when he moves away from you for he looks so much like his surroundings.

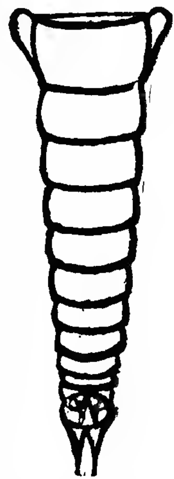
9. Protective resemblances are strikingly exemplified in insect life. In the order *Orthoptera* the phenomena are carried to an extent elsewhere unsurpassed in the animal kingdom. Adaption to surroundings is noticed in insects by which a species is rendered practically invisible amongst its surroundings on account of its resemblance to a leaf, stone, twig, etc., to remain immune from attack from other insects.

10. When a grasshopper lives on a dusty road, he is dust-colored. When he lives on a speckled rock he is black or gray, and when he lives in fields he is green or mottled green and brown like the grasses. Some are fine fellows with soot-colored wing cases, and brilliant wings.

The color of the grasshopper does not seem to be laid on the surface of his coat, as that of the beetle or scales of a butterfly, but is dyed through and through the wings and the body.

11. The grasshoppers are a very timid family, and are very sensitive to sound. The organs of hearing may be situated either on the fore legs, as in the green grasshoppers, Katydids, or at the base of the abdomen.

12. The abdomen contains the vegetative organs. It is composed of chitin, attached to the thorax. It has ten joints, which are more or less movable, and sword-like blades at the end called the ovipositor.



Abdomen.

13. The grasshoppers like to lay their eggs in dry, hot places. In the fall you may see hundreds of them in dry pastures or along the roadside, making holes in the ground to put their eggs in. The female grasshopper has four sharp points at the end of her body. She puts these together to make one point, which she thrusts into the ground, and then while it is in the ground she spreads the points and pushes the earth away; then again she puts the points together and thrusts the one point further down, and so by pushing the point down and opening it over and over again, she makes a hole nearly as large as her body and lays her eggs in a case made of something like glue. Then she closes up the hole, and the eggs lie all winter safe in the ground. In the warm spring days the larvæ hatch from the egg, and creep out of the ground and begin to eat the first green things they find.

They are very small but shaped much like the parent, only they have no wings. They molt and change their skin several times. At first the little ones are all alike, but after several changes of skin the larvæ become pupæ. New coats grow on them, while the old ones get too small. The old one splits down the back, and the young grasshopper steps out of it. He may have five new coats before he is a grown grasshopper. The first and second new coats have no wings on, the third you can see the coming wings under a little sheath. The fourth has small wings; after shedding the fifth coat he looks just like his parents.

About six or eight weeks after hatching the final change is made. The perfect insect comes out of the last shed skin. It has two pairs of wings. Insects only grow during the larval, or caterpillar, state; molting is confined to that period. The young grasshopper develops from the young larvæ to the winged adult stage without changing its mode of life. When larvæ and pupæ they are very greedy; they eat all the time. When they are grown they do not give all their time to eating.

14. The digestive apparatus of the grasshopper consists of a pharynx, gullet, gizzard, stomach, and intestine. The blood, which is a colorless liquid, circulates on the dorsal side of the body in a long pulsating tube beneath the skin. This dorsal vessel, or heart, as it is called, is open at both ends and divided by valves into compartments, permitting the blood to go forward but not backward.

The blood enters the cavity of the abdomen, and mingles with the chyle which transudes through the walls of the alimentary canal. This mixed fluid is drawn into the dorsal tube through the valvular openings as it expands, and upon its contraction all the side-valves are closed and the fluid is forced towards the head. Passing out at the front opening it is again diffused among and between the tissues of the body.

The brain is formed of several ganglia massed together, and lies across the upper side of the throat, just behind the mouth. The main cord lies along the ventral side of the body, with a swelling for each segment; besides this there is a visceral nerve representing in function the sympathetic system of vertebrates.

The gizzard is lined with horny teeth. The grasshopper has no true liver, but its functions are performed by little cell-masses in the stomach. The kidneys are also groups of tubes.

15. Respiration is carried on by trachæ, a system of tubes opening at the surface by a row of apertures called spiracles—generally nine on each side of the thorax and abdomen. Respiration is performed by the movements of the abdomen. These pipes or tubes ramify the most

delicate organs. To keep the pipes ever open, they are provided inside with an elastic spiral thread, like the rubber tube of a drop-light. It also has air-sacs in the head.

The nerves or veins of a grasshopper's wing consist of a tube within a tube; the inner one is a trachæ carrying air; the outer one sheathing it is a blood-vessel. So perfect is the aeration of the whole body, from brain to feet, that its blood is oxygenated as soon as it is carbonized. It therefore has only arterial blood.

This is the life of the happy wayside insect. When the glad summer of his life is done he dies. He does not live to be sick, or hungry, or cold; he is the happiest of living things. He does nothing but dance and sing, eat fresh leaves, and drink cool dew, from early spring to late autumn, where they can be found by any grassy roadside.

I would dwell with thee,
  Merry grasshopper,
Thou art so glad and free,
And as light as air;
Thou hast no sorrow or tears,
Thou hast no compt of years,
No withered immortality,
But a short youth sunny and free.
Carol clearly, bound along,
Soon thy joy is over,
A summer of loud song,
And slumbers in the clover.
What hast thou to do with evil
In thine hour of love and revel,
In thy heat of summer pride,
Pushing thy thick roots aside
Of the singing flowered grasses,
That brush thee with their silken tresses?
What hast thou to do with evil,
Shooting, singing, ever springing,
In and out the emerald glooms.
Ever leaping, ever singing,
Lighting on the golden blooms?

—*The Grasshopper.* TENNYSON.

I love to hear thine earnest voice,
  Wherever thou art hid,
Thou testy little dogmatist,
  Thou pretty Katydid!
Thou mindest me of gentle folks,—
  Old gentle folks are they,—
Thou say'st an undisputed thing
  In such a solemn way.

Thou art a female Katydid!
  I know it by the trill
That quivers through thy piercing notes
  So petulant and shrill;
I think there is a knot of you
  Beneath the hollow tree,—
A knot of spinster Katydids,—
  Do Katydids drink tea?

—*To an Insect*, OLIVER WENDELL HOLMES.

The poetry of earth is never dead:
When all the birds are faint with the hot sun,
And hide in cooling trees, a voice will run
From hedge to hedge about the new mown-mead;
That is the grasshopper's—he takes the lead
In summer luxury—he has never done
With his delights; for, when tired out with fun,
He rests at ease beneath some pleasant weed.
The poetry of earth is ceasing never;
On a lone winter evening, when the frost
Has wrought a silence, from the stove there shrills
The cricket's song, in warmth increasing ever,
And seems to one in drowsiness half lost,
The grasshopper's among some grassy hills.

—*The Grasshopper and the Cricket*, JOHN KEATS.

XVI. The Sage-brush Galls and Their Inhabitants.

By V. M. G.

Galls are abnormal growths caused by insects upon the parts of many plants. They are of various sizes and shapes and furnish a home and sustenance for the larva which develops within them. Some one has said that Lowell must have thought of these when he wrote:

"Never a blade nor a leaf too mean
To be some happy creature's palace."

Why this peculiar growth should take place we cannot say; but authorities have told us *how* a gall is formed. Comstock says, "The female gall-producing insect stings the plant and lays an egg in the wound. It is believed that in some cases there is deposited with the egg a drop of a poison (as in the gall, which we shall study presently) which causes the growth of the gall. But in other cases the gall does not begin to develop until the larva hatches from the egg and begins to feed upon the tissue of the plant.

FIG. 1.—Sage-brush with Gall.

Evidently if there is a poison in such cases it must be secreted by the larva. Though the explanation of why galls grow is not clear, we know this much, that each species of gall-making insect makes a particular kind of gall. Hence, one versed in this subject can tell by the form and structure of a gall what species of insect produced it."

The gall which is of particular interest to us here in Ellensburg is that of the sage-brush. These sage galls, green globe-like bodies, vary in size from one-half inch to an inch in diameter, and are formed from the tip or middle portions of the leaves, as shown in drawing on the first page. The growth is certainly peculiar, for the middle-lines of the leaves may be traced through the galls. I have even found the gall closely surrounded by a group of leaves and formed from a part of each leaf, as represented by drawing, Fig. 2.

In structure, these galls are fibrous and porous within, covered by a thick skin without, the latter being sur-

FIG. 2.—Gall Uniting Several Leaves.

mounted by innumerable grayish hair-like projections causing a fuzzy appearance of the galls. Sometimes the outer surface is smooth and shiny. I have noticed that the galls with such a surface seem to be the oldest. In all probability these smooth galls were once pubescent, like their younger sisters.

In the very heart of the gall there starts from the base a conical capsule, varying in length from one-sixteenth of an inch to one-eighth of an inch, and composed of a thin green skin with a hard crust-like base (Figs. 3 and 4).

Within this lies the small white egg—never more than one-eighth of an inch long—which the insect has laid in the leaf (Fig. 5). Frequently two eggs may be found in one gall, but from observation I can say that each egg has its separate capsule.

Beginning this study with the egg, I had no way of determining the length of time between the deposit of the egg

FIG. 3.—Gall. FIG. 4.—Capsule. FIG. 5.—Egg.

and its metamorphosis into the larva stage. As a usual thing the larva, which is about one-fourth of an inch in length and a grayish-white in color, eats its way out of the gall and spends some time in feeding upon the leaves of the sage-brush (Fig. 6). Upon examining the bushes during the months of May and June, any number of these larvæ may be seen crawling over the leaves or suspended from them by silk threads.

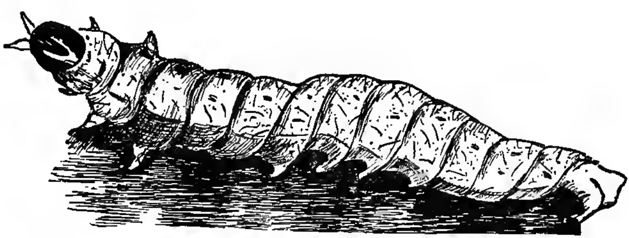


FIG. 6.—Larva greatly magnified; this line (—) shows natural size.

After a time the larva begins to spin itself into a cocoon, fastening it upon the under surface of the leaf. I placed several of the larvæ in a covered glass dish and watched one of them start its cocoon on one side of the dish. It

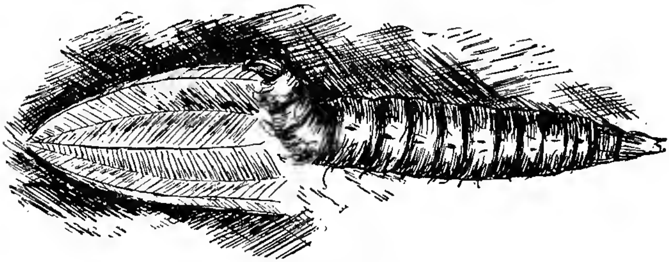


FIG. 7.—Weaving Larva.

worked from side to side, weaving the net-work in front of it as shown in Fig. 7.

Upon finishing about half of the cocoon it broke the thread, and turning about, backed under the partially completed mesh-work; then, drawing its head up and backwards, resumed its spinning.

Just at this point I was unfortunate enough to knock the dish over and drop the larva out. Though I placed it back against its work and tried coaxing and leaving it

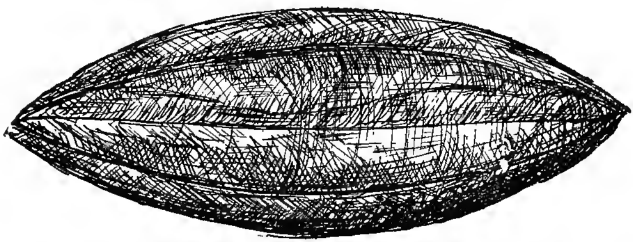


FIG. 8.—The Completed Cocoon.

alone by turns it would not resume its spinning. But on the next day I found the same larva in a new cocoon. On the contrary, when I purposely punctured the cocoon in which a second larva was still weaving, it began immediately to mend the hole.

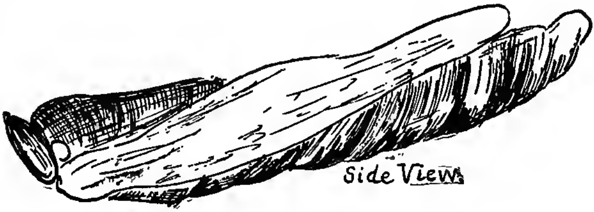


Fig. 9.

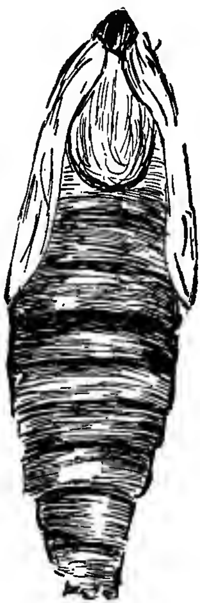
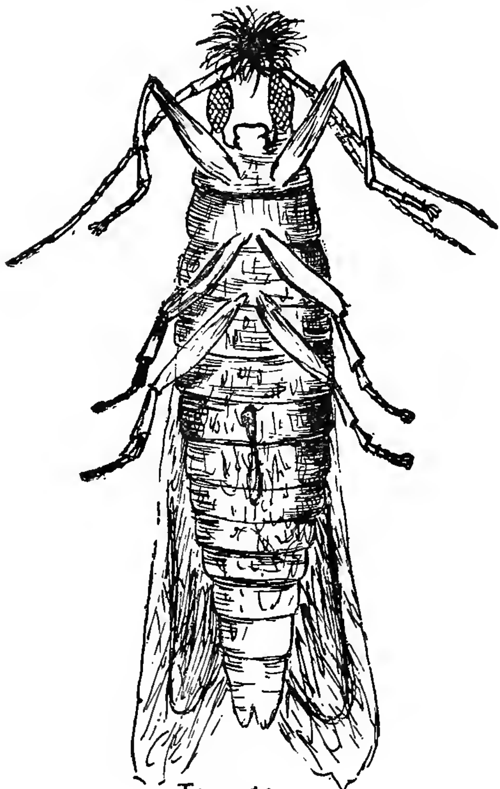


Fig. 10.

Fig. 11.

The cocoon when completed (Fig. 8) is about one-quarter of an inch long, elliptical in form, and loose, like a net-work, in structure. The silky material (a fluid before forced out, becoming thread-like upon exposure to air) is formed in the silk glands, tubes lying on the underside of the body, and opening into the under lip by a common duct, the little



Imago.

FIG. 12.

projection out of which the silk comes being called the spinneret. These facts concerning the silk glands are from statements made by authorities upon the subject of larvæ, for I have not attempted to make a minute study of any particular part. It might be well to say, just here, that this paper is written with the purpose of setting forth the results of my general observations upon this subject.

After about eight days the sleeping pupa began to show signs of life, drawing up its body if touched; its color had changed from white to brown; and metamorphosis had advanced to the stage shown in Figs. 9, 10, and 11.

At the expiration of four or five days more the change was complete, and the imago or adult came forth. It is, on the average, a little less than one-fourth of an inch in length, and gray in color (Fig. 12).

In this drawing of the insect the following characteristics can be seen:

I. The head:
  1. Antennæ or feelers.
  2. Pon-pon or tuft (silvery white hairs).
  3. Compound eyes.
  4. Mouth parts.

II. The thorax:
  1. First segment or prothorax.
    a. First pair of legs.
  2. Second segment or mesothorax.
    a. Second pair of middle legs.
    b. First pair of wings (gray and netted).
  3. Third segment or metathorax.
    a. Pair of hind legs.
    b. Second pair of wings.

III. The abdomen:
    a. Ten segments covered with silvery white scales.
    b. Ovipositor.

XVII. The Biology of the Paramecium. By F. T.

(*Outline* supplied by the teacher.)

1. Introduction. *a*, Classification; *b*, habitat in nature; *c*, how cultivated, etc.

2. Morphology. *a*, Form, size, and general appearance; *b*, appendages; *c*, organization, etc.

3. PHYSIOLOGY. *a*, Movement, reflex action, and spontaneity; *b*, nutrition; *c*, digestion, respiration, and circulation, etc.; *d*, reproduction, conjugation, and division; *e*, death.

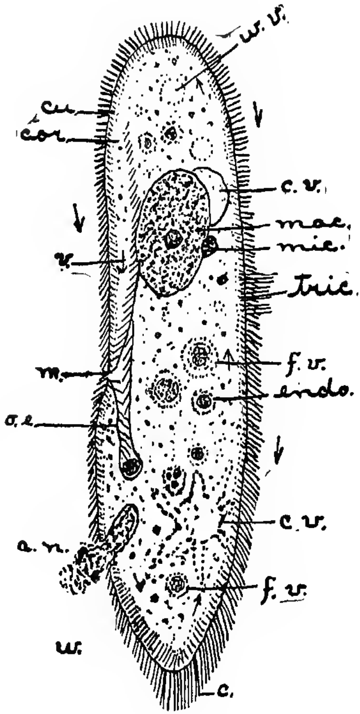


FIG. 13.

Viewed from the ventral side, showing the anal spot; arrows inside the body indicate the direction of protoplasmic currents, those outside the direction of water currents caused by the cilia.

w., water; a. n., anal spot; c.v., contractile vacuoles; f. v., food-vacuoles, m., mouth; œ., œsophagus; v , vestibule; mac., macronucleus; mic., micronucleus; cu., cuticle; cor., cortex; vric., trichocysts; c , cilia; endo., endoplasm; w. v., water-tacuoles.

1. INTRODUCTION. *a. Classification.*—The Paramecium or slipper animalculi is a ciliated infusoria which exhibits a considerable amount of differentiation within the limits of a single cell. It belongs to the kingdom of protozoa, class infusoria, and order ciliata. The kingdom of protozoa represents the lowest branch of animal life. It is characterized by the fact that after fission each cell becomes a distinct individual. The infusoria is the most highly specialized of all protozoa showing a differentiation of protoplasm unattained by any other member of this group. The Paramecium is one of the largest and most common of the infusoria. The ciliata are characterized by the possession of hair-like processes called cilia, which are present during young and adult stages.

b. Habitat in nature.—The Paramecium is found in ponds and ditches amongst decomposing vegetable matter. It is also found in multitudes in hay infusion or water containing decomposing remains of Nitella and other water-plants. It is found in both fresh and salt water.

c. How cultivated.—Paramecium may be cultivated by filling a can with water; then place a small handful of pieces of hay or dead moss in the water and allow it to stand in a warm place for about a month. After a few days a white film will appear upon the surface of the water and if the lower edge of this film be examined where it touches the can great numbers of rapidly moving white animals may be seen. Large quantities may be reared by collecting conferæ and water-seeds in summer weather, placing them in a jar of warm water covered by a glass and leaving them to rot.

2. MORPHOLOGY. *a. Form, size, and general appearance.*—The Paramecium has an elongated, somewhat flattened, soft, flexible, transparent body, about $\frac{1}{100}$ of an inch in length, with a rounded anterior end and somewhat pointed posterior end, the maximum breadth being near the latter.

When viewed from above and below it is oval and somewhat slipper-shaped in side view. The posterior end is bluntly pointed and forms the toe of the slipper, while the anterior end is rounded and twisted so that the outline of one side of the anterior end is bent into a shape somewhat like a figure eight. As this side is generally uppermost it is called the dorsal. The entire surface of the body is covered with hairs or cilia, which are in constant vibratory motion. Along the edges of the body this can be seen without difficulty, but upon the surface they are visible only as fine dots. The cilia are of two kinds: The locomotor cilia, which are quite small and cover nearly the whole of the body; at the posterior end of the body there is a small tuft of much larger cilia. Around the edges of the eight-shaped outline of the anterior end is a row of much larger cilia. These give rise to current by which floating particles of food are carried into the mouth which is situated on the posterior end of the figure eight.

b. Appendages.—The appendages of the body are of four kinds and they all are processes of the cuticle. (1) The fine cilia which serve for swimming. (2) The cirri. They are placed on the ventral surface of the body and serve for locomotion in pediform motion. Hence called legs. The cirri are the stoutest cilia. (3) Membranellæ which are short flattened cilia which when ending in a point are hard to distinguish from cirri. They create the whirlpools by which the food is brought to the mouth. (4) Undulating membranes placed in the mouth to assist in taking in of the food.

c. Internal organs and structure.—The Paramecium is a mass of protoplasm representing a single cell. The surface of the body is covered by a thin, delicate, transparent cuticle and beneath this lies the cortex. These two constitute the ectoplasm. The cilia are processes of the cortex which protrude through holes in the cuticle. A great number of radial striations in the cortex mark minute oval sacs, the trichocysts, from which long, fine, stiff filaments are shot forth and project beyond the cilia when the animal is irritated. Their function is that of offence and protection. The Paramecium possesses a distinct mouth and œsophagus which open to the exterior through an oblique funnel-shaped depression known as the vestibule situated at one side of the body. This short ciliated tube leads into the endoplasm. Within the cortex is the endoplasm. It is much more granular than the ectoplasm. It usually contains oil-globules, colored particles, and various foreign bodies which are not found in the ectoplasm. The endoplasm contains structural constituents of the cell-body, such as the trichocysts and the macro and micronucli, which lie just above the mouth. The macronucleus is a relatively large structure. It has a definite nuclear membrane which appears to be filled with minutely granular contents. The micronucleus is a small ovoid body, placed alongside of and close to the macronucleus.

Also two large contractile vacuoles occupying a constant position in the deeper part of the cortical layer, one near either end of the body. Each contracts alternately with great regularity at intervals of about 10–20 seconds. Just before contraction the vacuole appears as a large clear space in the ectoplasm; its walls come together and its fluid contents are expelled to the exterior. The ensuing pause, during which the vacuole is refilled with fluid, is known as diastole. Immediately after the contraction a number of fine canals make their appearance in the endoplasm, radiating from the spot where the vacuole disappeared by closure. These canals reach for some distance into the surrounding cell-body, but those of one vacuole do not communicate with those of the other. The canals become swollen with fluid at their inner ends and slowly empty their contents into the vacuole, which reappears, gradually filling with the fluid poured into it by the different canals till it reaches its largest dimensions, and then it suddenly contracts again. Towards the close of the diastole the different canals, having emptied their contents into the vacuole, become altogether indistinguishable.

The substance of the endoplasm is loaded with a number of granules and particles, the products of assimilation and metabolism. The most noticeable substances in the endoplasm are the food vacuoles and the food they contain. Food and water vacuoles are constantly re-appearing and disappearing. The endoplasm is the seat of the digestive, and to a great extent of the anabolic, activities of the animal.

d. Organization, etc.—The Paramecium shows polarity, that is, its parts are grouped symmetrically with respect to an organic axis passing from pole to pole. Its nucleus, contractile vacuoles, mouth, and œsophagus, are permanent, as is also its shape and form. These facts—that it has polarity and several permanent organs—show that the Paramecium is a definite organization.

3. PHYSIOLOGY. *a. Movement, reflex action, and spontaneity.*—The Paramecium swims about continually in the water by means of its cilia. It uses these as a boy uses his arms in swimming. First, they are struck backward forcibly and quickly and then they are brought forward more slowly. It always moves with the blunt end, the anterior, foremost. The anterior half of the body is slightly twisted in connection with the groove leading into the mouth, and in consequence of this twist the animal spins round and round on its axis as it swims through the water. It swims in a tolerably straight course with uniform velocity. After going for some distance in one direction it stops, turns, seems to hesitate for a moment, and then darts off in a new direction. The Paramecium is flexible and elastic, and in passing round an obstacle it bends its body and seems to squeeze itself through an aperture smaller than its own diameter. When it pushes its body into a narrow space between the particles of sediment in the water, the more fluid endoplasm is pushed back by the obstruction and accumulates at the posterior end of the body, while the ectoplasm still follows the outline of the cuticle. After part of the body has been pushed past the obstruction, the endoplasm, with the particles it contains, flows rapidly through the narrow part into the enlargement beyond. The Paramecium's movement is spontaneous and is not caused by any external influence.

b. Nutrition.—The Paramecium feeds only on organic substances. It feeds chiefly on minute infusoria and flagellata, which are swept into the mouth by the cilia lining, the peristominal groove, and the entrance to the mouth itself, and, as I have already said, the cilia in these regions direct the currents toward the mouth and thus bring the food.

c. Digestion, respiration, and circulation.—The digestive organs can be most satisfactorily studied when the animal has been fed with some colored substance, such as indigo. You can then see (*a*) the currents which are caused by the small locomotive cilia. (*b*) The peristome or 8-shaped line of large cilia at the anterior end of the body, by the action of which the indigo is swept in. (*c*) The vestibule, a widely opened funnel-shaped chamber lined with cilia and situated in the posterior end. (*d*) The œsophagus, a ciliated tube which leads downward and backward into the substance of the endoplasm. In this tube the particles of indigo are gradually rolled into a pellet, and from time to time these pellets are forced, by contractions of the body, out of the inner end of the tube into the endoplasm. One of the pellets, together with a little water swallowed with it, forms a food vacuole, of which several may be seen in different parts of the body. A food vacuole is a spherical space filled with water and containing solid particles of various kinds. As the vacuoles are carried around the body by the circulation of the endoplasm, the water and the soluble parts are digested out, until at last only the indigestible parts remain embedded in the body substance as a food-ball. After a time these particles accumulate at a point upon the dorsal surface about half way between the vestibule and the posterior end of the body. The ectoplasm becomes thin over them, and they are then driven out of the body through a temporary anus. These animals have no sense of taste, as indigestible particles are readily taken in.

Its respiration is carried on through the external surface of the body. It has no special respiratory organs, but it absorbs food and air from the currents of water passing through it or bathing the surface of its body.

The circulation of the food is carried on by the contractile vacuoles. As they contract they force the food out into the surrounding mass.

d. Reproduction, conjugation, division, etc.—Reproduction in the Paramecium is a simple process of transverse binary fission. Both macronucleus and micronucleus elongate prior to the division of the cell-body and undergo mitosis. They first become fusiform, and at either pole of the spindle plates are formed connected by fibrils running the whole length of the spindle. The spindle, then elongated, becomes dumb-bell shaped, and the two swollen ends are connected by a fine thread, which soon snaps in the middle, and thus nuclear division is complete. Constriction divides the cell-body into two equal parts, which separate and form two new Paramecia. A swarm of Paramecia, well supplied with food, will continue to mutliply by binary fission for many generations.

Prior to conjugation the individuals move hither and thither in a rapid and excited manner, as if in search of one another. After a while they come together in couples and conjugate. Two individuals become attached together mouth to mouth, and are closely united by fusion.

Usually the process of conjugation begins during the late hours of night and the early hours of the morning, and lasts till late in the following afternoon. The first consequence of conjugation is that the micronucleus of each gamete goes through a stage of evolution, which doubles its diameter. It also undergoes change of shape, becoming first elongated, then spindle shape, and then doubled up to form a crescent, while its chromatin granules are aggregated in rows to form longitudinal fibrils. But it eventually resumes its original ovoid condition. This structure, increased as it is to twice its former diameter and eight times its original volume, passes through mitosis and divides into two, and each product of division immediately undergoes mitosis and again divides, so that there are now four micronuclei. Meanwhile the macronucleus has undergone no change. The four micronuclei in each gamete are of equal size, and all of these begin to prepare for a new division by elongating to form fibrous spindles; but only one—and it is always the micronucleus which happens to be nearest to the mouth—passes through the further stages of mitosis and divides. The three others are arrested at the spindle stage, and then degenerate and are absorbed. The surviving micronucleus in each gamete completes its division so that each gamete has two micronuclei and one as yet unaltered macronucleus. In each gamete one of the micronuclei is placed close against the mouth, called the female and male pronuclei. Both elongate and form fibrillated spindles, and then the transference of micronuclear material. The transference of nuclear material has now been effected, and the gametes, which have diminished in size, shortly afterwards separate from one another, begin to feed, and recover their original dimensions. Each possesses the original unaltered macronucleus and a large micronucleus called the combination nucleus. Immediately after separation the original macronucleus undergoes changes which lead to its final disappearance.

Meanwhile the combination nucleus in each ex-gamete undergoes three successive mitotic divisions, and there are eight products in the combination nucleus, arranged in two groups of four, one group at the anterior end and another at the posterior end of the body. Of the posterior group three members disappear, one surviving as micronucleus. The four nuclei of the anterior group increase in size and become the macronuclei of the progeny of the ex-gamete. Twenty-four to thirty hours after separation the ex-gamete divides in such a manner that two of the macronuclei pass into one product of division and two into the other, while the micronucleus divides mitotically, one of its products entering each of the two daughter Paramecia. A second division quickly follows, accompanied by the mitotic division of the micronucleus, while the macronuclei are again passively distributed among the products of division. The result is that each ex-gamete has produced four normal Paramecia containing each a macronucleus and a single micronucleus, both derived from the combination nucleus. These Paramecia feed and multiply by transverse division at the rate of two or three divisions in the twenty-four hours.

e. Death.—After four or five days the offspring of a Paramecium, some four thousand in number, become smaller and begin to show signs of decay. Eventually, if they are unable to conjugate, they undergo degeneration and die. Similarly, if the food supply runs short, the members of a swarm of Paramecia become weak and diminished in size, but under normal circumstances the onset of degeneration is arrested by conjugation. Decay and death are the natural accompaniments of existence. The Paramecium may also be killed by bacteria and the application of chemicals.

Part II

Life: Its Forms and Its Manifestations

„Wir haben gesehen, daß alle Organismen aus wesentlich gleichen Theilen, nämlich aus Zellen zusammengesetzt sind, daß diese Zellen nach wesentlich denselben Gesetzen sich bilden und wachsen, daß also diese Prozesse überall auch durch dieselben Kräfte hervorgebracht werden müssen.“—SCHWANN.

CHAPTER I

Life of Plants and Animals

I. Introductory.

In this division is given an account of the more fundamental facts of plant and animal life having relation to the subject of nature study, but too difficult for individual discovery from the object by the ordinary pupil in the grades; also a classification of the more common forms of life which will be likely to be used by the teacher in nature study. The principal theories in regard to organic development are also briefly stated, together with theories and standpoints regarding human development and their relation to the pedagogy of nature study. It is thought that the teacher who is able to take an interest in these more difficult phases of her work will be able to get more out of nature study than she otherwise would.

II. Microscopic Organisms.

ALGI.—In quiet pools of water along the banks of running streams or in tanks of fresh water, and in ditches along the roadside, there is often found during the summer months a green scum floating near the surface of the water. It has a slimy appearance and is therefore called pond-scum. It is a comparatively simple green plant, consisting of an interwoven network of threads, which, under the microscope, show a spiral arrangement of the green coloring-matter or chlorophyl, and is therefore called *spirogyra*.

This plant belongs to a group of simple plants called Algæ. There are numerous kinds of algi living both in salt water and in fresh water. The salt-water forms are often very beautiful and are called sea-weeds. They have various colors, but blue, brown, and red are the prevailing forms, and hence algi are classed as brown, blue, red, and green algi. The coloring-matter enables them to live like ordinary green plants, manufacturing their own food from the inorganic elements of the water by the aid of sunlight.

The algi are related to another group of simple plants called fungi. These are such plants as molds, seen on bread, preserved fruits, leather, horn, and other decaying organic substances, and plants like the toadstools, mushrooms, and puffballs, often found growing on decaying bark or springing from compost heaps. Mildews, rusts, and smuts, also growing on leaves of plants or the ripening fruit of grains and grasses, belong to the fungi.

Fungi.—These fungi differ from the algi chiefly in being devoid of chlorophyl or coloring-matter. They are consequently unable to live like ordinary plants, and must obtain their food already prepared as organic substances from other plants or animals, and are consequently called parasites or saprophytes, according as they attack living or dead forms of plants or animals. Some of these are useful to man as food; but the majority of them are harmful, inasmuch as they often injure the organisms on which they live. Rusts and smuts are parasites that are injurious to cultivated plants such as wheat, oats, and corn.

Both the algi and the fungi contain many microscopic forms that can be studied only by means of the compound microscope. Many of them, however, are easily found, and can be readily studied by the aid of a hand-lens or even with the unaided eye. The fungi are supposed to be degraded forms of algi, which, having become parasitic, have lost their chlorophyl, and consequently are dependent upon other forms of life for their maintenance. Fungi like the molds can be obtained at any time by putting a piece of bread in a moist chamber (a covered bowl or tin pan will do) and allowing it to stand for a few days in this moist condition. Little powdery bodies called spores, produced by these fungi when mature, float around in the air, and, settling on any moist organic substance, like moistened bread, begin to absorb nourishment from the bread, and soon grow into a silky fibrous mass called *mycelium*, each fiber being called a *hypha*.

In the case of rusts and smuts growing as saprophytes on living plants or insects, the mycelium, as it elongates from the spores, grows into the tissues of the host (the organism on which a parasite lives), and, penetrating the tissues, absorbs its nourishment by their aid. When mature, they send up little stalks which enlarge into a ball. It is in this ball or spore-case that the reproductive bodies or spores are produced. The spore-case dries when mature and splits open, allowing the spore to escape. These, then, are carried by the wind to other plants and give rise to new fungi of the same kind.

The effects of these fungi can be seen by examining the black wheat heads that are more or less abundant in wheat-fields while the crop is maturing.

Lichens.—These interesting plants are found growing on rocks, bark, fence-rails, etc. They often occur in great quantities on old trees, especially in moist climates. They are either yellow and hair-like, or else gray, scaly looking bodies suspended from limbs or closely clinging with their flat surfaces to rocks.

These plants are especially interesting, because they are supposed to consist of both algi and fungi, intimately associated for mutual aid and protection. The small algi inside are supposed to manufacture food for the fungus outside, and this latter serves as protection for the algi. Hence this is an interesting case of different organisms associated together, like slave and master, for mutual benefits. Such a relation is called symbiosis, and the parties to the association are called symbionts.

Bacteria.—If a handful of pond-scum or a handful of hay be put into a jar of fresh water and allowed to stand for a week or ten days, the water turns black and emits a foul odor, due to the decaying organic substances in the water. There will then gradually appear on the surface of the water a thin film which gradually thickens into a crust floating on the surface.

If this surface film be examined under the microscope, it will be found to consist of innumerable tiny bodies moving, whirling, wriggling rapidly through the water. To see the individual bodies well requires the highest magnifying powers of the microscope. They are the so-called micro-organisms, germs or *bacteria*.

These micro-organisms are very important ones, notwithstanding their minuteness; for many of them are very useful (nonpathogenic) while many are very harmful inasmuch as they are the cause of many contagious diseases (pathogenic), such as scarlet fever, cholera, yellow fever, diphtheria, lockjaw, and anthrax, etc. They seem to be closely related to yeast, the organism used for raising bread and in the fermentation of liquors. It is not definitely known how yeast does its work as a ferment—whether it be by means of its secretions acting when it is present or whether it be by taking substances such as the starch of the grains used for such purposes into its body and there in a sense digesting it, giving off as a result of disorganization a gas, carbon dioxide, and the active principle alcohol. The bubbles rising from fermenting substances are due to this gas CO_2. In the case of bread-making the gas is imprisoned in the sticky dough and consequently causes the spongy consistency of wheat bread.

Effects somewhat similar to fermentation are doubtless present in the jar containing the hay or the green algi. The bacteria attack the organic substances, causing their disorganization resulting in the emission of gas which, discolorizing the water, escapes as foul odor. This decay or putrefaction is, therefore, due to bacteria. When such disorganization is produced in living things, disease and death result; and the bacteria which attack living things in this way, causing disease and death, are called pathogenic bacteria. Some minute rod-like forms, called bacilli, are the cause of that dreaded disease consumption. The germs of this disease are present in the air; and, when taken into the body, they develop in those organs that are especially weak and consequently unable to resist their action. Almost any organ may thus, when weakened, become the seat of this deadly disease. But the lungs are most frequently affected, in which case pulmonary tuberculosis results.

Another rod-like form, the bacillus of typhoid fever, is found in wells and drinking water that has been contaminated with organic filth. The disease attacks the alimentary canal and is often fatal, giving rise to severe and prolonged fevers, doubtless due to toxic or poisonous substances secreted by the germs.

Other forms of bacteria (nonpathogenic) are useful in promoting digestion of food in the alimentary canal, in giving flavors to articles of diet as butter and cheese, etc. Many forms are associated with the roots of higher plants in the soil, as in red clover, giving to the plant the disintegrated substances, among them nitrogen, resulting from its activity.

One advantage of personal cleanliness is the lessening of the risk of infection and contamination from such injurious microbes. Sterilization, too, by heat or boiling water and disinfectants are for the purpose of destroying disease germs or ferments. The principle of preserving fruits, after boiling and scalding fruit jars, is based on the destruction of these germs by high temperature, and the prevention of the entrance of new ones. Antiseptic surgery, too, is based on this same principle.

The bacteria contained in the film on the jar of water, after a period of activity, finally come to rest, and secreting a gelatinous substance are held together in solid masses, thus giving rise to the surface film. These forms are harmless. Many of them require oxygen and hence develop most freely near the surface. Others do not need oxygen and still others are destroyed by plenty of sunshine and fresh air. They ultimately disappear from the jar when the organic substances are used up. The water will remain pure if the jar be exposed to the sunlight, the activity of the algi keeping the water pure.

Distinction between Plants and Animals.

An examination of the jar containing algi, as above, after the water has turned foul, will reveal a white line, of what at first looks like sediment, on the sides of the jar just below the surface of the water, where the latter meets the sides of the vessel. If the jar be placed in the sun, the naked eye can detect millions of rapidly moving bodies, which, when examined with a high power of the microscope, look like little slipper-shaped fishes swimming about very rapidly. These are infusoria, a form called paramecium. They are good examples of microscopic animals called protozoa—so called because they correspond to what is called a cell. Bacteria are also representatives of these unicellular organisms, but they are usually regarded as plants.

It is not an easy matter to decide in the case of these microscopic organisms as to whether they are plants or animals. Many forms have been repeatedly transferred from one kingdom to the other, the vital processes in plants and animals being so similar as to make a clear distinction impossible. These difficulties disappear as we ascend in the plant and animal series, the plants being defined as those organisms having an outer covering of cellulose, and possessing the power of manufacturing organic compounds by means of the sunlight; while animals, with few exceptions, are devoid of cellulose, and the coloring matter necessary to utilize the energy of the sun's rays. Hence animals are dependent upon plants for their food.

THE CELL.—Amœbæ, paramecia, bacteria, etc., are only a few representatives of the countless myriads of living things which the unaided eye is unable to detect. It is only after the invention of the microscope that we have become aware of these organisms of the microscopic world. Nevertheless, they are interesting to us because they are among the very lowest forms of life, and represent the primitive living substance of which our own bodies consist. In fact, our bodies are built up from such microscopic cells, and it is in such a minute cell that our bodies have their origin. Nothing can be more important, therefore, for the understanding of the higher plant and animal life, including our own, than the lesson which these minute organisms teach us.

It would, indeed, be a very discouraging matter if it were necessary for us to become acquainted with all these microscopic forms before we could comprehend the vital processes and the laws of life of higher forms. Fortunately the life phenomena in these forms are reduced to their simplest manifestation; and it is easily discovered that the life phenomena are very much the same in all of them. Consequently if we understand the life processes in one form, as for instance, the amœba or paramecium, we shall understand fairly well the life of all; and understanding the life of a cell, we shall so much the better understand the life of a complex body like our own, which is practically an aggregation of cells, very much as we understand society better if we know something about those sciences dealing with the life of the individual.

The cell is the unit of structure of the complex body just as the individual is the unit of the social body. If, therefore, we could discover how the various cells of a complex body, like our own, come to differ from one another and how they become aggregated into organs and associated with each other for the performance of special duties, we should be better able to understand how higher organisms come to differ and how even human beings are impressed with their own specific characters and their own individualities. So important is the life of the cell, therefore, that in recent years a new science of *Cytology* has been created, claiming the exclusive attention of the ablest investigators. While the subject is too difficult for nature study in the grades, yet the teacher should endeavor to know something about cell life, as without such knowledge even nature study must be very much like the blind leading the blind. That even inexperienced pupils can do considerable here, when properly directed, can be seen from the pupil's paper on the paramecium at the end of Part I. That paper was prepared by a pupil in the fourth year of the Normal School with no previous training in this kind of work.

Viewed under the microscope, an amœba, or the paramecium which we have been considering in the jar of water, has a transparent appearance; the amœba has a constantly changing form, the paramecium a permanent slipper-like form. This transparent gelatiinous mass constituting the body of the cell is called *protoplasm*, which has again been defined by Huxley as the Physical Basis of Life. It is the substance with which life and mind are associated, and without which no life is supposed to exist. With substance in this connection, it is necessary to understand not a simple chemical mixture (some physiologists insist that it is a chemical mixture) perhaps, but rather a highly complex organized body consisting of various substances blended and mixed, and held in a permanent interrelation to one another while constantly undergoing change. There is no known chemical formula that can express the structure of protoplasm. Neither is the chemical composition of living protoplasm known; for life ceases as soon as a chemical analysis is made; and the change from living to dead protoplasm is one of the most striking and also most permanent changes in nature. For, while the change from life to death is easily brought about, no case of a transition from death to life is known to science. In other words, these microscopic organisms in the jar do not originate from dead substance, out of nothing, nor spontaneously, but the vast multitude are the offspring of one or more parent organisms like themselves. Thus the bacteria originate from bacteria and paramecia from paramecia. The substance of both is protoplasm, which is so much alike in both that we are unable to discover any profound difference even with the most powerful microscopes. That the paramecia and bacteria, for instance, are so different not only in their size and form, but also in their effects on other organisms, is supposed, by some, to be due to a specific structure of the protoplasm, while some radical physiologists insist that the difference is due to specific chemical substances in the two cases.

Structure of the Cell.

In the amœba there is scarcely any visible evidence of structure, even under the highest power of the microscope; the form is constantly changing; there seems to be no bilateral symmetry or fore or aft polarity; and even the protoplasm itself is constantly flowing like a turbid stream of liquid substance. In the paramecium, on the contrary, there is both permanent form, fore and aft polarity, and bilateral symmetry. Here, too, the protoplasm shows a streaming motion. By staining these organisms with various dyes, an internal spherical body called the nucleus is revealed, showing that, notwithstanding the apparent homogeneity, there are specialized areas within this protoplasm, suggesting organs, and hence a heterogeneity of composition, at the basis of which some primitive structure must exist. In many cells another modified area, having still more the characteristics of structure, has been found; and, for that reason, it is now one of the most interesting little bodies in nature. It is called the *centrosome*. Under the highest power of the microscope it looks like the dot of the letter i, yet in this little dot is centered one of the profoundest issues with which biologists have to deal. The issue is none less than that of form *versus* substance, heredity *versus* variation. A valuable book on this subject is one by E. B. Wilson entitled "The Cell in Heredity and Development." Those who are interested in these profound biological problems will find that work very helpful. The subject cannot be treated in a work of this kind.

Life Phenomena of Cells.

Nothing is more evident, from the examination of the micro-organisms in our jar of stagnant water, than that these single cells are capable of leading an independent existence, of moving, assimilating, growing, responding to stimuli, and multiplying by division. They apparently select their own food, seem to avoid danger, recognize their own kind, and enjoy the power of spontaneous action. Without any evident external cause they are able to arrest motion, to start again, to turn to the right or to the left or to wheel completely about, retracing their steps. No one observing the actions of one of these organisms could fail to be impressed with its apparent intelligence. In fact, this protoplasm moves without muscles, feeds without a mouth or a stomach, and, shall we say, perceives, thinks, wills, and knows without sense-organs or without brains. Inasmuch as these various functions have no corresponding organ, we must conclude that they are various forms of protoplasmic activity.

All these forms of protoplasmic activity are the result of dissociation of complex organic molecules, a breaking-up of complex substances into more stable inorganic compounds, by which the necessary energy is liberated. Such waste of energy must be made good by the taking in of food, for even protoplasm cannot create energy. When the food supply is exhausted, therefore, when the algi put into the jar have been disorganized and their substance used up by the microbes, these necessarily die from starvation, and the water, which at first became foul and turbid, gradually becomes clear, the organisms having themselves been disorganized into a sediment of dead matter. If more food is supplied the organisms continue to live and multiply indefinitely. The waste resulting from metabolism of the protoplasm is excreted by the cell through the outer cuticle, and oxygen, the immediate cause of this metabolism, is taken in in the same way from the surrounding medium. Hence these organisms remain near the surface, where the air comes in contact with the water.

But, even in the presence of a constant supply of food and oxygen, by which the wasted elements are again repaired by nutrition, assimilation, respiration, and excretion, this constant activity cannot continue indefinitely. The mere lapse of time seems to have a specific effect on protoplasm, causing it to grow old and incapable of maintaining an equilibrium between waste and repair. In the case of many of these unicellular forms this inevitable senility is partly overcome by conjugation, the interchange of nuclear material of two distinct individuals. They are consequently rejuvenated periodically. They are thus again capable of multiplying by division, and are supposed to be in a sense immortal.

Even in these unicellular forms, therefore, we perceive that each individual has two very important functions to perform—that of maintaining itself and that of maintaining the race of beings to which it belongs. It is neither wholly selfish nor wholly altruistic, but a little of both. All of their activities seem to have in view these functions, and the success with which the work is performed seems to depend on the success with which an internal adjustment is maintained with reference to the surrounding medium.

Being as yet wholly ignorant in regard to the essential nature of both life and mind it would of course be absurd to try either to prove or to disprove their universal coexistence. Yet it is clear here that what we interpret as life and what appears to us as mental manifestations are so intimately united that a distinction between them is impossible. Both the vital and the mental processes, if such there be, are concerned with such an adjustment of the organism to external condition as shall enable the organism to exist.

One ignorant of the power of the horseshoe magnet, on seeing a needle moving over a sheet of paper, in obedience to the magnet beneath, would be strongly tempted to ascribe to the needle both life and mind. Similarly, in the case of these microscopic organisms, the life and the apparent mind may be due to concealed molecular forces.

There is probably no molecule of matter which is entirely isolated from all else. Everything is subject to the universal law of action and reaction. Countless influences, gravity included, may be brought to bear, and the orbit of every molecule of matter may be prescribed and determined by the sum total of all other forces external to it. Every atom may properly be said to have an ego and a non-ego striving for the mastery. It is possible, therefore, that obscure internal or external influences are responsible for variations in the amount of vibration of the molecules, while at the same time there exists a tendency to re-establish a fixed arc of molecular vibration as soon as these obscure causes of disturbance have ceased operating. The instability of protoplasm which we call irritability is a most fundamental property, giving to it this power of adjustment to external forces and conditions. Through these repeated adjustments the cell gradually changes, so as ultimately to become adapted to the particular conditions amid which it lives. When the cell thus responds to external influences it is said to react.

The Germ-cell or Ovum.

Not only the reproductive spores of algi and fungi, but also the germ-cells of higher plants and animals, like the pollen of flowering plants, are cells. They have most of the characteristics enumerated above, the physiological and many morphological characters being identical.

Like the microscopic organisms, the germ-cells have the power to divide. This power ceases, however, after a certain number of divisions, when the ovum, like the infusorian, unites with another cell, as in conjugation. This process is called pollination in plants and fertilization or fecundation in animals. The effect of this is to cause the ovum to divide, not into separate cells as previously, but into cells that remain permanently associated after cell division. Consequently a colony of what at first seems like similar cells arises. This repeated division continues; but the resulting cells forming the colony gradually become different from one another, like cells becoming aggregated into groups, constituting the tissues of all higher plants and animals. In higher plants the final result of this cell multiplication is the formation of such tissues as bark, cambium, wood, bast, sieve, and tracheary tissues; in animals there result skin, muscle, bone, glands, epithelium, etc. There are two ways by which we can account for this heterogeneity arising out of comparative homogeneity. First, we may assume that the daughter cells arising from cleavage (as this form of cell division is called) are not really similar but really different as a result of unequal division of the mother cell; second, we may assume that the cells are exactly similar, and that they gradually become different because of the varying conditions amid which they are placed. In that case we must assume that the constantly increasing multiplicity of cells introduces a new factor into the life of each cell, inasmuch as it now reacts, not only to external influences, but all the cells, also, react on each other. Every increase in the number of cells causes a change in the environment of every cell, and necessitates a new and different reaction on the part of every cell. Each cell, we will say, is now a member of a social body. Every reaction, we have seen, implies protoplasmic waste, which, even though made good by nutrition, leaves some trace. A constantly shifting environment incident to the multiplication of cells, therefore, naturally leads to differentiation in the nature of each cell. Heterogeneity thus results from comparative homogeneity. Heterogeneity, whether arising from cellular interaction, from reaction to external influences, or from a qualitative differentiation due to unequal nuclear division, leads ultimately to the appearance of the specialized tissues, of which all higher forms are composed.

Heredity and Variation.

The specific property of the original germ-cell, giving it a certain specific power of reaction to its conditions of existence, is the hereditary property of the cell. What this hereditary property consists of, whether it be due to specific chemical substances or to a primitive protoplasmic structure, an organization far more complex than any known chemical formula, is a very important, but as yet a disputed, question.

We know that a hereditary element of some kind does exist. It is due to this hereditary property, whether of the nature of a complex chemical substance or a primitive organization, that the long series of actions and reactions to intrinsic and extrinsic forces finally leads to the formation of an organism resembling the species from which the original germ-cell is derived.

Admitting a hereditary element, therefore, in the original germ does not necessarily imply a total denial of the modifying effect of external influences even on the germ, since both intrinsic and extrinsic factors are involved in the final result.

VARIATION.—If the extrinsic and the intrinsic factors, or the hereditary element and the environment, were always the same, only one resultant could be possible, and all development would necessarily result invariably in identical beings. As a matter of fact, however, both factors vary. The hereditary element is made to vary by the blending of different cells in fecundation; and, as we have seen, the environment is necessarily changed every time the cell divides. Hence heterogeneity (variation) must result not only in the constituent cell of an organism, but in the organisms themselves.

The Life of a Complex Organism.

Complex as the original germ may be, the fully formed organism is infinitely more so. It is in fact a world, so to speak, of heterogeneous vital units, the cells, possessing specific qualities of their own by which each unit not only maintains its own individuality, but contributes to the more complex life of the whole. The whole organism exerts a coercive power over these lesser units, which, in turn, by their specific reactions, may influence the life of the whole. The whole, therefore, is as essential in the developed organism as are the parts, and the part as essential as the whole. Neither can exist without the other. This interdependence is due to the specialization and differentiation which must always exist in a complex organism, and indeed increases as the complexity increases.

The life of such a complex organism, though not perhaps fundamentally different from the original germ-cells, is a resultant of the interaction of many lesser lives, the lives of the constituent cells.

Just as the life of the germ pervades the entire organism, so does this higher, more complex life pervade the entire organism. Inasmuch as the life of the developed organism depends on the life of the constituent cells, any maladjustment of these lesser lives betrays itself in abnormal conditions of the final product.

The healthy life of the constituent cells shows itself in the normal performance of their functions; and this depends, in the first place, on the proper balance between anabolic or constructive processes, and catabolic or destructive processes (normal nutritive processes), and secondly on their normal reaction to impressed forces and influences. Such normal reaction is necessary to the proper performance of function, and is dependent on the proper maintenance of that equilibrium between waste and repair which maintains the integrity of the cell. Every reaction involves waste, which must be made good by nutrition if a similar reaction is to follow. Any failure to restore the nutritive equilibrium shows itself in a modified reaction, as is abundantly shown in muscle fatigue artificially produced by electrical stimulation.

Disease.—Abnormal states of the cells of the body, be it from imperfect nutrition or from other causes, tend to aggravate the disorder by the disturbances this occasions in the organism as a whole. General disease of the whole organism may thus be produced, which, reacting on the constituent cells, aggravates their disorder. In both health and disease, therefore, the relation of a whole to the part and of the part to the whole is most intimate and important.

The Primitive Mind.—The health of the cell reveals itself in the proper performance of its various functions and in its normal reaction to its environment. In the free swimming-cell adaptation to environment often has the appearance of a spontaneous mental act, when disturbing causes are not discernible, and of reflex action when they are evident. We are strongly tempted to infer, therefore, that these reactions to environment are the simplest manifestations of what we call mental processes, and hence to conclude that a rudimentary mind exists even in the cell.

Evidently such a primitive mind revealing itself as a purposeful adaptation to environment, as when an infusorian turns aside to avoid an object or selects the food suited to its nutrition, retreats in the presence of danger, or recognizes and embraces an organism of its own kind, is as much a function of the protoplasm of the cell as are nutrition and motion. The normal manifestation of this primitive mind is coordinated with the normal discharge of the other functions of the cell. Spontaneity ceases when disturbed nutrition or other injurious influences have caused the vital processes to be arrested, from which we infer the close connection between what we call life and what we call mind. The two coexist in a very elementary way in the germ, and consequently have no absolute beginning, but are transmitted with the protoplasm from one generation to the next.

III. The Principal Facts in the History of a Flowering Plant.

Within the little seed there is a tiny plant called the embryo. This is composed of a great number of cells arranged into a caulicle, two cotyledons, and a plumule. The seed has been covered with a thin inner coat and a thick, tough, and impervious outer coat or testa, which have protected the embryo from injury and retained some of its moisture. The embryo, though alive, has remained dormant, asleep, for several years, perhaps (time varies with different seeds from three to perhaps forty years), without suffering serious injury.

The cotyledons are large in the bean because of a considerable quantity of starch which has been deposited there at the time when the embryo was formed.

The formation of the embryo was the result of the fertilization of the flower in which the seed was produced.

So long as the seed remained dry the starch, or albumen, as it is also called, remained unchanged, being insoluble as starch (recall Experiment I, *c*). Hence it could not be used as food by the embryo. As soon as the seed, however, is soaked or placed in moist earth of sufficiently high temperature, water enters the seed (recall Experiment VI, *b*), causing it to swell, and the starch is partly changed into sugar, giving the seed a sweetish taste.

The sugar is soluble (Experiment I, *c*), and is gradually absorbed by the little embryo, which has slowly awakened from its sleep because of the stimulating effect of heat and moisture. The taking in of this sugar, as boys and girls sometimes do, enables the little embryo to grow. As it grows it becomes too large for the original seed-coats; and, consequently, causes them to burst somewhat as a growing crayfish causes his shell to split or a chick causes its egg-shell to crack. Its root lengthens out and turns away from the light; the tiny leaflets of the plumule increase in size; the stem lengthens and carries the leaves upward towards the light, the leaves being green from the presence of a coloring-matter (chlorophyl), the roots being pale white and covered with tiny root-hairs.

While this unfolding of the embryo has been going on, the original food supply has been diminishing, till nothing scarcely but the seed-coats remain. The little plant must now adopt a new method of obtaining food. Like the chick just hatched, it must now begin to find its own food. This it does by means of its roots and root-hairs in the soil.

Physiology of Absorption and Circulation.—In the soil, surrounding the root, more or less moisture is present. This moisture has come down, perhaps, as rain; and, percolating down through the soil, it has come into contact with various salts and gases—carbon dioxide, nitrogen, and others variously combined. These have been dissolved, more or less, and have entered into the water as solutions (Experiment I).

The roots, with their root-hairs, like tiny tubes spread out in the soil, coil around pebbles and sand-grains, and by a process of osmosis (Experiment VIII) drink up the water with its dissolved substances, much as blotting-paper takes up a drop of spilt ink (Experiment VI).

The water then rises through the stem (Experiment III) partly because of root-pressure, due to osmosis (Experiment VIII), and partly by capillary attraction, as in the experiment with the filter-paper. In this way the water is carried up to the leaves, being prevented from oozing out from the side of the stem by the outer layer surrounding the stem like a skin (Experiment X). This cuticle is impervious to water, as can be seen in the experiment with the cork (Part I, Chapter IV, Section XIII).

Transpiration. The leaves, being spread out, offer a large surface, from which evaporation can take place. But they, too, are covered with cuticle. On the under side of the leaf, however—the side usually turned away from the source of light—there are numerous pores or openings in the cuticle, so constructed that they close and open according to the dampness of the atmosphere. These pores are called stomata. They allow air to enter, which, coming in contact with the water in the stem and leaf, becomes laden with the moisture which entered the root from the soil, and carries it away somewhat as vapor or perspiration is carried away from our skin (Experiment IX).

Respiration. Air enters the soil around the roots of the plant when the soil is well stirred. The farmer often has to do this in cultivating plants partly to keep moisture in the soil and partly to allow free circulation of air around the roots of the plants. If air is excluded the plant usually dies. That which enters the stomata passes into air-cavities in the spongy under sides of the leaves; and, from there, into air-tubes found in different parts of the stem. In that way the plant breathes. By the expansion and contraction of this contained air, as the temperature outside rises or falls, with the changes of seasons or day and night, the sap contained in the stem is subjected to pressure, which, if the outer cuticle be removed, causes the sap to flow out from the wounded part. Thus the plant bleeds, in one sense, as animals do.

The air circulating in the leaves and stem of the plant takes up certain waste substances resulting from vital action of the plant, in the form of carbon dioxide, which is exhaled. Otherwise the accumulation of the waste would be injurious or even fatal to the plant. This exhalation of carbon dioxide takes place at all times, but is most in evidence at night or in darkness.

Assimilation. The green substance in the leaf, leaf-green, or chlorophyl, is developed in the living substance in some unknown way through the action of sunlight, somewhat, perhaps, as tan and freckles are developed in our skin when our face is exposed to the sun. If deprived of sunlight it disappears. That can be seen in the white color of clover which has been covered for some time by any opaque body, as a board or a rock. Various patterns can be inscribed on a leaf by covering it with an opaque pattern, as pieces of cork.

Chlorophyl is able to utilize the energy of sunlight in doing chemical work. By the aid of the sun's energy salts and other substances remaining in the sap after water has evaporated from the leaf is made to unite with parts of water and carbon dioxide taken in with the air and form proteids and starch.

The starch is formed in little granules within the chlorophyl bodies during the day. At night it is changed into sugar, which, being soluble in the sap (Experiment I), is taken up by it.

The sap of the leaf, having thus become more saturated than in other parts of the plant, diffusion begins, as in Experiment III, the sugar spreading out and passing downwards into the stem and roots, where it either serves as food for the growing plant, or else is stored there as reserve food after again having been converted back into starch.

Growth. By the action of sunlight on the chlorophyl the plant is able to make its own food from dissolved salts, water, and air, and, by a process peculiar to all living things, called assimilation, is able to convert the food into its own substance. The result of this complex process is growth.

The bean plant increases in size by the roots penetrating deeper and deeper into the soil, and by the stem lengthening out and carrying the leaves with it. It is not definitely known why the stem grows upwards while the roots grow downwards. It has been thought that gravity, the force which causes an apple to fall to the ground, may have something to do with it. That this direction of growth of stem and root can be reversed is shown by Experiment XIV. The upward growth of the stem enables the plant to spread its leaves out and thus expose them to more air and sunshine. It is a clear case of fitness of things, evident adaptation to essential conditions, giving the appearance of intelligent purpose or design.

As the season advances it grows less rapidly, till it ultimately stops growing altogether; but not before developing new seeds containing little embryos, the beginning of a new generation.

REPRODUCTION.—As the rapidity of growth decreases the stem does not lengthen out materially. Hence the new leaves, smaller and more delicate in texture, become crowded together into little clusters arranged in circles, and constituting the flower. The outer part of these flowers, especially the corolla, is beautifully white and delicate. At the base of the stamens and pistil are little glands from which there issues a fragrant, sweet fluid, the nectar.

Bees, guided by the fragrance and color of the flower, pass from one to another, sucking up the nectar. While thus engaged they unconsciously carry pollen from the stamen of one flower to the pistil of another flower, thus causing the cross-fertilization of those flowers.

This having been accomplished, a new seed is formed with its tiny embryo in the ovary at the base of the pistil.

Thus, having passed from the seed through a regular series of changes and growth, the plant produces new seeds and then dies. The new seed, however, is alive, but remains in a dormant or sleeping state, as before, till conditions of temperature and moisture are again suitable for germination. Then there is developed from this seed a new plant resembling the old plant, its parent; but varying, perhaps, in some minor respects, since it is now the result of two plants combined.

Heredity. The similarity of one plant to its parent is due to what is called heredity. The blending of the characters of the two plants in cross-fertilization gives rise, perhaps, to some of the variations or differences which one often sees between different bean plants.

Natural Selection. Those plants whose characters, as the lengthened stem, are suited to the conditions amid which the plant is placed, will grow strongest, and consequently will be able to withstand the encroachments of weeds, that are sure to appear on the scene when the bean-patch is not well cultivated by the owner. The appearance of weeds is much like the arrival of an enemy. A conflict ensues between the bean and the weed as to which shall have most soil, most rain, and most sunshine. The weak bean, which is not adapted to the conditions of life, will succumb in this struggle and will produce no flower and no fruit.

This struggle is called the "struggle for existence"; and the success of the strong bean, the failure of the weak, is called "natural selection" or "Survival of the Fittest."

IV. Some Important Facts in the Life of Animals.

Animals, like plants, are composed of either a single cell, as in the Protozoa, or of aggregations of cells or tissues, as in the Metazoa. The life of the animal, like the life of the plant, resides in this ultimate unit, the cell. The cell is the bridge which spans the chasm between one generation and the next. In the plant this bridge may be a spore, a single cell; or it may be the seed, a large aggregation of cells forming an embryo. In the animal, too, it may be a spore, or an egg, which is often only a cell, but frequently a cell with many accessory parts, and often with a partly formed embryo, as in the hen's egg.

In either case life is continuous, being associated with that primitive organic substance called protoplasm. It is now maintained that all life, plant or animal, springs from some preceding life, the parent, the seeds or eggs being little particles detached, like buds, to give rise to new organisms.

Good examples of these reproductive bodies are afforded by frog-spawn. This is very common in early spring, being found in shallow pools, often floating on the surface of the water, or lying near the banks of quiet streams in large gelatinous masses, or attached to submarine plants in small clusters. Frog-spawn may be put into jars of fresh water and kept in the school-room, where the development of the eggs into tadpoles can be observed.

At first the egg of the frog has a white and a black side, the former the vegetative, the latter, the animal pole. Development begins when the egg has been fertilized.

Fertilization takes place in the water as soon as the egg is oviposited by the female frog. At first two small bodies, the polar globules, are pinched off from the egg. This can be seen by the aid of a hand-lens if closely watched.

Segmentation. Maturation being completed, the egg as a whole begins to divide by the formation of furrows, visible on the surface, and passing at first from the animal to the vegetative pole. Furrows then form at right angles to those first formed. The result of this cleavage, or segmentation, as it is called, is the gradual obliteration of the white vegetative pole by the growth over it of the animal pole, the last stage of which is called the closing of the blastopore.

Formation of the Embryo. Ridges and furrows then make their appearance, which, growing together above, constitute the neural canal or spinal cord and brain. From this stage the egg passes rapidly into the tadpole form, being gradually elongated, a tail forming opposite the head end of the animal. Already the spherical egg has been converted into an elongated animal, having bilateral symmetry and fore and aft polarity. How has it all been accomplished? It is characteristic of the thoughtless to take such things for granted, as if they needed no explanation.

Different Kinds of Eggs. The development of the eggs of all higher animals resembles that of the frog more or less completely, according as the egg contains a large or a small quantity of yolk. The latter is food material stored up in the egg. Yolk varies greatly in amount in the eggs of different animals, being the chief cause of difference in size of different eggs. Most eggs are spherical or oval. The eggs of some insects are greatly elongated or cylindrical, as in flies and grasshoppers. In the latter case the polarity which appears in the embryo is foreshadowed in the undeveloped egg.

Accessory parts exist in many eggs, that are often responsible both for the extraordinary size and the unusual shape of some eggs. In the frog's egg, the gelatinous mass surrounding it, is a secretion of the oviduct, a tube conveying the egg from the ovary, where it is produced. This gelatinous substance corresponds to the albumen or white of birds' eggs, which is also a secretion of the oviduct. In this case, however, it becomes surrounded, later, by a new secretion of the lower end of the oviduct, which hardens into a shell. The shell of the hen's egg does not represent the original cell-wall or membrane, as in the frog's egg, but is an entirely foreign coat added to the egg as it passes down the oviduct.

Both the albumen and the yolk of these eggs are secretions intended for nourishment of the growing embryo. Eggs having but little yolk, as those of mammals, remain attached to the parent in a special organ, the uterus. By this means the deficiency in yolk material is made good by nourishment derived directly from the blood of the mother, and after birth by the mother's milk. The milk glands in mammals may, therefore, be compared, functionally, to the glands in the oviduct of the frog or the hen which secrete the albumen.

All metazoa reproduce by means of eggs. Occasionally the eggs develop without fertilization. They are, in fact, buds instead of eggs in some instances, being composed of a group of cells instead of a single cell.

In protozoa, the cell, of which the animal consists, divides, each half becoming a separate individual; while, in the metazoa, the cells resulting from cleavage of the egg remain associated.

Tissues. By a process of specialization, cells become different, and similar ones are aggregated into groups constituting the tissues of the animal. These may be classified as (1) epithelial, (2) connective, (3) cartilaginous, (4) osseous, (5) dental, (6) adipose, (7) muscular, (8) nervous tissues.

ORGANS, SYSTEMS, AND FUNCTIONS.—The tissues are arranged into organs. The latter are aggregated into systems, carrying on the vital functions of the animal.

The functions may be classed as: (1) nutritive, involving the physiological processes of (*a*) ingestion, (*b*) digestion, (*c*) absorption, (*d*) circulation, (*e*) assimilation, (*f*) secretion, (*g*) excretion, (*h*) respiration; (2) sensation; (3) motion; (4) reproduction.

Sensation and motion are not peculiar to animals any more than the other functions; yet animal intelligence seems to grow out of them, and consequently they may be called animal as contrasted with vegetative functions.

Nutrition in animals, as in plants, is necessary, because living things waste. In animals, as in plants, the loss is made good by food, which is both organic and inorganic. All things taken into the body, serving to build up the body, and to restore wasted energy, may be called a food, provided the organism is not injured by it.

Inorganic foods of animals are chiefly air, water, salts, lime, etc. The organic foods may be either of animal or of vegetable origin.

Many insects, as the beetle, butterfly, and most mammals, are herbivorous. Many protozoa, most cœlenterates, echinoderms, mollusks, crustacea, some insects, arachnids, fishes, amphibians, reptiles, some birds, and the clawed mammals, are carnivorous. A few animals, including man, are omnivorous.

The food of animals is a matter for observation and study, since it not only influences the character of the animals as regards its utility to man, but is suggestive in connection with special adaptations for obtaining food and for preparing the same for nutritive uses in the body.

The alimentary canal is the organ into which food is taken. It exists in all animals except protozoa, sponges, and some parasitic forms like the tapeworm. In these food is absorbed through the outer layers of the body. In all other metazoa the alimentary canal is either a simple bag with a mouth-opening or else a tube passing either straight through the body or variously coiled and enlarged into pouches, such as the stomach. The simpler the animal, usually, the simpler the alimentary canal. Thus in hydra and corals it is a mere bag, not distinctly separated from the body-wall. Herbivorous animals usually have a more complex alimentary canal than carnivorous, the stomach in the latter being less developed, and the intestines shorter.

The length of the alimentary canal, therefore, varies with the diet, and also with the habits of the animals as regards its mode of obtaining its food, whether by its own efforts or through the means of a host, as in the case of parasites. Much can be inferred in regard to the internal structure of animals from an examination of their teeth, there being usually remarkable adaptations of external characters to the habits and mode of life of the animal.

An animal has been compared to a plant turned inside out. By this is meant that the roots of plants, serving for absorption, are spread out and permanently fastened to the soil, from which the plant is nourished. In animals, the absorbing villi, corresponding to roots or root-hairs, are turned inward, thus coming in contact with the food material of the alimentary canal. Thus the animal might be said to carry the soil around with it. The alimentary canal is thus an adaptation to enable the animal to move from place to place to get its food. The freedom of movement thus secured is necessary to the higher development which the animal attains. Some fixed forms of animals, like the sponge, hydra, corals, etc., are comparatively low. Their alimentary canal is a mere bag with a single primitive opening, the mouth.

Digestion. Food, while in the alimentary canal, is really outside the body. To be useful as food it must be absorbed. The alimentary canal is, in all cases, lined by a layer of cells, the epithelium. In the primitive forms this epithelium is variously folded so as to produce pouches either simple or more complex. They are the glands of the alimentary canal concerned in digestion. The principal ones are: (1) the salivary glands at the entrance to the alimentary canal, variously developed according to the food of the animal; (2) the liver, the largest and most constant gland in the animal kingdom, being well developed in mollusks and all animals above them. To these are added the pancreas and gastric glands or glands corresponding to them in the higher vertebrates.

Even the simple tubular glands of the alimentary canal secrete fluids that either serve to soften the food or else produce such chemical changes as will prepare the food for absorption through the wall of the digestive tube.

Absorption and Circulation. The food, when absorbed, passes either into the lymph of the body-cavity, diffusing thence throughout the body, or else enters the blood circulation and is distributed by it. The simplest form of such circulation exists in the jellyfish, where the primitive stomach gives off radiating-tubes. In the sponges the food is carried by currents of water to the individual cells, as in protozoa. In the hydra, sea-anemone, and coral, the food is practically in contact with the body-cells, as the stomach is not distinct from the body-wall. In the starfish and sea-urchin a system of water-tubes, the ambulacral system, seems to serve partly for circulation. But even here a primitive, distinct circulatory system exists.

The Blood is pre-eminently the circulatory medium. It is essentially a liquid tissue with a fluid intercellular substance. In forms as low as echinoderms and mollusks, the blood differs very little from water, having in solution dissolved proteids, salts, and a few corpuscles. In the lower forms, too, it is colorless, and of the same temperature as the medium in which the animal lives. All invertebrate animals, including fishes, amphibians, and reptiles, are cold-blooded.

The Circulatory System of animals consists of tubes. The most primitive, perhaps, is that of the echinoderms, where it is a pulsating-tube lying alongside the alimentary canal, and forming a ring around the latter at the oral and aboral pole. Below the echinoderms a circulatory system cannot be said to exist, though even in protozoa a contractile vacuole is thought by some to serve as a circulatory organ. In worms the circulatory system consists of a dorsal and a ventral tube, united in the anterior segments by anastomosing, pulsating-tubes, or primitive hearts. In mollusks the primitive tube is enlarged into a heart which, by its contractions, forces the blood out at one end and draws it in at the other. In insects the heart is a long tube lying on the dorsal side of the animal, causing an incomplete circulation, inasmuch as the blood-vessels leading from the heart are not continuous with those leading to the heart.

Usually the higher the animal in the scale, the more perfect the circulation. In most mollusks the heart consists of one ventricle and two auricles. In fishes it consists of two chambers, an auricle and a ventricle; in amphibians and reptiles, three chambers, two auricles and one ventricle; while in birds and mammals the heart has four chambers.

The Object of the Circulation seems to be, not only to convey the food material from the alimentary canal to the places where it is needed to build up the wasted parts, but also to distribute the heat in warm-blooded animals, making the temperature uniform. This heat-production depends on the presence of oxygen, which is also necessary to the liberation of other forms of energy, as the energy of motion. The circulation of the blood serves to distribute oxygen to parts where it is needed; and also to remove waste, such as carbon dioxide, and carry it to the respiratory organs, where it is removed from the body.

Assimilation. Inasmuch as all forms of energy expended by an animal, either as heat, chemical energy, or motion, are derived from the animal's tissues, involving their disorganization or dissociation, the loss to the tissues must be made good by assimilation of the food prepared by digestion and conveyed by the circulation. Assimilation is the work of the individual cells of the organism. It is thought to consist in building the living protoplasm of the cells out of the organic food. In both plants and animals the process is probably essentially the same. The power of producing energy resides in the cell; and this varies with the condition, such as age, etc., of each cell. The power of the cell to produce energy and to assimilate food, restoring the waste, is gradually lost by the cell, and this law, from which there seems to be no appeal, is responsible for the old age and final death of all living things.

Secretion. Besides the energy given off in the form of motion and heat, substances are produced by various cells in the body. Such production involves work and consequently waste and repair. Substances produced either by the metabolic activity of the cells, or by filtration of fluids from the blood, that are useful in the body, and apparently intended for use, as in the case of digestive fluids, are called secretions. Digestive secretions of some kind probably exist in in all animals. But there are many other substances that may properly be considered as secretions. Thus the intercellular substance in cartilage and bone is probably a secretion; so, too, the plasma of the blood is originally a secretion. Many secretions harden into protective structures, as the exoskeleton of insects and Crustacea and the shells of mollusks. Even the cell-membrane, where such exists, as in the egg, is to be regarded as partly or wholly a secretion; and we have already seen that the white of the bird's egg, and the gelatinous covering of the amphibian egg, are secretions of the oviduct. The yolk of birds' eggs is probably partly a secretion of the follicle-cells, partly an internal secretion of the egg protoplasm, the egg-shell being a hardened secretion of the oviduct.

Excretion. All activity involves waste. Waste results from the breaking down of complex organic compounds into simple inorganic compounds. Such simple inorganic compounds have no energy that can be used in the body, and consequently are useless so far as maintaining the body is concerned. Hence, if allowed to accumulate, they interfere with the normal processes and must be eliminated. The elimination of waste, whether in plant or in animal, is called excretion. Excretion is performed by the outer covering or cuticle in lower forms, like protozoa, cœlenterates, jellyfish, corals, etc., in connection with special excretory organs, as the segmental organs or nephridia of worms and similar organs in insects. In vertebrates kidneys are present. These are a collection of tubes packed together into a compact organ, the tubes having some resemblance to the nephridia of worms. Besides the skin and the kidneys, the gills or lungs, also, serve as excretory organs, inasmuch as they carry off gaseous impurities.

Respiration. Besides food taken into the alimentary canal as either liquid or solid, the animal body is in constant need of a gas called oxygen. It exists in a free state mixed with nitrogen in the air or else dissolved in water. Oxygen is necessary to all animals, because it is by the union of oxygen with the tissues that energy is set free to produce heat, motion, etc. The plant, too, so far as it does work, needs oxygen; but for building up its tissues it uses carbon dioxide, the very substance which, among other things, animals throw off as waste.

In protozoa and other low marine forms of life, like sponges, corals, etc., the oxygen is obtained from the water through the outer cuticle, there being no special respiratory organs. Many worms, like the planarians and earthworms, breathe wholly through the cuticle or skin. The only provision for respiration, in such cases, is an increase in the vascularity or the multiplication of capillaries under the skin.

The mechanism of respiration in all animals is performed by bringing blood as nearly in contact with pure air or oxygen as possible. The primitive breathing organ is merely a thin layer of tissue separating the blood from the air, the blood being spread out so as to expose as much surface as possible. By the simple law of gaseous diffusion oxygen is taken up by the blood and carbon dioxide is given off. In higher animals a substance called hæmoglobin exists in the red corpuscles; it has a special affinity for oxygen.

The same simple principle of construction is found in the more complex respiratory organs—trachea—of insects; gills of aquatic insects, mollusks, Crustacea, fishes, and amphibians; lungs of land mollusks, amphibians, reptiles, birds, and mammals. The lungs of land snails and those of spiders are hardly more than simple bags, on the walls of which capillaries are spread. In the spider folds are formed resembling the leaves of a book. Gills are either in the form of lamellæ or else in the form of tufts of threads, as in some worms.

All these forms of breathing organs are well adapted to secure a large surface. In marine forms the respiratory surface is usually freely exposed; while in air-breathing forms it is enclosed in the body, as the lungs of higher animals, for the purpose of preventing drying of the surface from exposure to the air.

Sensation.—All living things are more or less sensitive to stimuli, such as contact with other bodies, chemical reagents, heat, cold, electricity, etc. The property of irritability belongs to protoplasm. In the protozoa there is no separate nervous system. The first traces of such a system are found perhaps in the hydra, where some of the ectoderm-cells seem especially sensitive to stimuli. In the jellyfishes the nervous system probably forms a network of cells all over the umbrella of the animal. In the starfish and other echinoderms it forms a ring around the mouth, sending off a nerve-cord into each arm. All invertebrates have this nerve-ring encircling the œsophagus. Worms, Crustacea, and insects have a ventral chain of ganglia, a pair of ganglia for each segment. In vertebrates a more complex nervous system, occupying a dorsal neural tube, is developed, the homologue of which is wanting in the invertebrates. It consists of a spinal cord, from which there proceed spinal nerves to the voluntary muscles of the body.

In the higher vertebrates a brain, consisting of the enlarged part of the cord, the bulb or medulla oblongata, the optic lobes, cerebellum, and cerebral hemispheres, are added to the anterior end of the cord occupying the skull. This part of the nervous system is found to correspond in mass and complexity to the general intelligence of the animal. Hence the cerebral hemispheres are larger and more convoluted in the ox than in the frog. In the fish the optic lobes are very large, comparatively, showing inferior development of the organ of intelligence, the cerebral hemispheres. A comparison of the nervous system of different animals shows a gradual concentration of the nervous matter in the head, where most of the special sense-organs also are developed.

Sense-organs are modified cells at the peripheral termination of nerves. Sense-organs of touch are most numerous, the sense of touch being the most general of all the senses. Even these tend to become aggregated in those parts that are used chiefly as tactile organs, such as antennæ, the lips, tongue, limbs, etc. The more special sense-organs, like the eye and ear, seem to be formed by the union of several simple organs. They are infoldings of the skin. Eyes are at first scarcely more than pigment spots, having the power of responding vaguely to the influence of light. Such primitive eyes can first be seen in medusæ, and are frequently found in worms scattered over the back, as in planarians or flatworms.

Some mollusks have well-developed eyes on the edge of the mantle, others on antennæ or on the head, and the squid and its allies have highly developed eyes. The compound eyes of arthropods are apparently aggregations of simple eyes.

The simplest ear is perhaps that of the ptenophores. It is hardly more than a simple bag, an infolding of the outer cuticle, filled with a fluid containing one or more ear-stones, or otholiths. As in the case of other sense-organs, the ear becomes more perfect as we ascend in the scale. In fishes there is no external ear, but the internal ear is well developed. In the frog the ear-drum or tympanum is naked.

Development in the animal series seems to be accompanied by a development of sense-organs corresponding to development of a central nervous system. The intelligence of the animal is proportional to its power of recognizing external objects and influences through the sense-organs, and of interpreting them by cerebral activity, so as to adjust itself to those influences. Some of that adjustment consists in movement.

Reflex Action and Instinct. The foundation of the intellectual part of animals is sensation and motion. An immediate motor response to a sense stimulation is reflex action. Instinctive action is hardly more than a very complex reflex act, in which the response may have been considerably delayed.

Thus the reflex acts of the lower forms pass gradually into the instinctive acts of the higher. Instinctive acts, too, are not separated by a hard or fast line from intelligent acts.

CHAPTER II

Theories of Development

V. Organic Development.

The Evolution Theory. The evolution theory is popularly attributed to Darwin. He is more properly said to have demonstrated the truth of the *theory of descent* by *natural selection.* This theory of descent, commonly called evolution, was suggested even as early as the ancient Greeks, which is not surprising, since even a child must be able to see that things grow and that one living thing springs from another living thing, as in the case of parent and offspring. It was considerably later that the theory of spontaneous generation was definitely disproved. While the fact of descent seemed so evident within the same group or species, no satisfactory explanation of the origin of species had been given before the appearance of Darwin's work bearing that title.

The explanation which Darwin offered was also given by Wallace at about the same time, and is briefly this: By the blending of ancestral characters variations arise. Such of those variations as are useful are preserved, because they enable that particular organism to survive in the struggle for existence. Owing to the enormous increase in numbers, which is everywhere apparent in living things, some must perish in the struggle for existence; and those that do perish are those least adapted to the conditions of their environment. The natural environment, such as food, temperature, and the like, is supposed to act very much as the farmer acts when he selects those animals in his herd that possess the characters which he wishes to preserve and perpetuate.

According to Darwin, the direct influence of the environment has some permanent effect on the organism, as may also the influence of use or function of different parts. Hence natural selection, which means either life or death, is not solely responsible for organic changes resulting in permanent species, but the chief cause.

Wallace, on the other hand, maintains that natural selection is the sole cause of variation, thus denying the permanent modifying influence of external factors, as well as use or function.

This theory of Wallace, regarding natural selection as the sole cause of variation, has been strengthened, in recent years, by Weismann, who has arrived at the same conclusion from his studies in animal morphology, especially embryology and cytology. Weismann's contribution reduces itself down to a denial of the possibility of transmission of acquired characters, and has given to the theory of evolution a somewhat technical meaning. Evolution, in this sense, means development from within. Weismann postulates in the germ-cells, from which living things spring, certain living units, supposed to reside in protoplasm, more particularly in the cell-nucleus. These, according as they are made to vary among themselves, by an internal struggle and survival, determine the characters of the fully formed being.

Evolution, in this sense of development from within, is now often assumed, not only by social philosophers, but by psychologists. Writers on pedagogy often assume it unconsciously, without considering what share external influences may have in the forming of an adult human being. It is self-evident that such an assumption of an internal perfecting tendency, independent of external influences, must profoundly influence both the theory and practice of teaching. The assumption that the child is born with certain potential possibilities, seeking merely opportunity to unfold themselves, is very similar to the old notion of innate ideas. This theory of Weismann and Wallace is not only contrary to the opinion of Darwin himself, but is admittedly purely theoretical and without positive proof.

If such a theory could be proven true, it would, of course, mean that the race cannot be permanently improved directly by education. The effect of external influences during the life of the individual could not, however, even then be denied. Yet Locke's *tabula rasa* would be proven a fiction, since the mind is present already in germ, needing only to expand under proper conditions.

Such a theory of organic development would logically lead to a hot-house pedagogy, such as we find, in fact, in some modern kindergartens. On the assumption of the truth of such an evolutionary theory, consistency would require that our schools be converted into secluded monasteries, where the inborn virtues of the child could unfold themselves untouched and uncorrupted by the realities of life. The theory is, in fact, supported largely by that class of biologists who have been trained in the humanities instead of physical science. Being *a priori* the theory is humanism in the garb of science.

The theory of evolution, when conceived in this technical and restricted sense, leaves little room for education. It assumes the individual to be a microcosm cut off from external relations, and capable of developing to a predestined goal without those external influences which common experience has found to be so potent in human development. The new education has, in recent years, been largely influenced, unconsciously perhaps, by the theory in this form. Fortunately, pedagogy is not yet sufficiently consistent to carry the theory out to its logical results.

*The Interaction Theory of Development.** Just as the theory of natural selection was adduced to explain evolution by natural, rather than by supernatural, causes, so the interaction theory is intended as a mechanical explanation of the same phenomena. The latter theory is, therefore, not a denial of evolution, in its original sense of continuity of development in organic life, but an attempt to explain that development in more scientific terms, without the assumption of purely imaginary factors that are themselves as mysterious and transcendental as the subject they are supposed to explain.

This theory starts with the recognition of the intimate relationship of living things to their environment. Living things are found to be unstable, capable of reacting to external forces and influences. Through these reactions, changes take place in the living thing. Such reactions are the experiences of the organism. It is assumed that the accumulated effects of these experiences result, as years go on, in the production of new characters which could develop in no other way; that organs are not only developed by use, but are brought into harmonious relations to other organs and to the external world. An initial organization is sometimes assumed, which, constituting the basis of heredity, gives to each being a specific power of reaction. Hence a personal element exists which is an important factor, but not the sole factor; inasmuch as the individual, in the fully formed state, is a

* This theory is presented more fully in the author's work entitled "Vital Processes in Education."

resultant of intrinsic factors and innumerable extrinsic factors, a new formation, rather than a preformation.

It is self-evident that this conception of development, admitting the modifying influence of external forces and relations, offers special inducements to pedagogical activity. It makes greater demands on the teacher, and must have a wholesome influence in raising educational standards. It immediately brings forward the question, What are the influences that should surround the child? What are the desirable qualifications in the teacher; what are the subjects best suited to properly impress the child, and what are the best methods of bringing the child into proper relation to his environment? In the conception of development, as proceeding from within, because of an inborn hereditary principle, and in this conception, as a resultant of reactions to external forces and influences, lie also involved the important pedagogical questions of child interest and self-activity.

The Social Theory of Development. The interaction theory naturally leads to a consideration of social phenomena and their relation to human development. It is claimed that man is primarily a social being; and that, in all matters concerning the developing mind, its relation to human society must be duly considered. The aim of education, it is claimed, is good citizenship; and it is only in human society, under the influence of social forces, that social development can proceed.

This view emphasizes motor activity as being essential to a useful membership in society. The ability to do the practical things of life is supposed to be of greater importance than to know the impractical. It is thought, too, that the mind develops naturally with the development of the bodily functions; that physical development reacts on mental development, manual dexterity of all kinds being of necessity closely dependent on acuteness of the senses and on the practical powers of the mind. The pupil is taught to make things, to do things, and that in the order in which these things have been invented by man in the course of history. Pupils are expected to prepare their own food from the raw materials which nature under their cultivation is made to yield; to make their own garments from fabrics manufactured by them from the unwashed fleece; to repeat, in other words, the economic activities of the race.

There is much reason to suspect that this view of development is a superficial view of the social philosopher trying to be scientific. It penetrates no farther than human activities. Yet so far as it goes, it is in accord with scientific principles. It has the appearance of a return to nature, but is in reality only a return to primitive society. It does not rest its claims on biological laws, but rather on primitive social laws. That such activity is natural to the child is evident from its games.

Yet this theory has the disadvantage of suggesting low ideals; of being the outgrowth of the practical spirit of our age; of being in league with that spirit which places the successful business man above the inspired poet, and a popular foot-ball player above the man of science. There is about it some of the atmosphere of the kitchen and machine-shop and a spirit of the "over-man" that does not impress one as ideal. Notwithstanding its practical appearance, it is essentially artificial, inasmuch as that law of necessity, which operated in primitive society, is wanting. Take away that necessity which compels the hungry savage to hunt his food, and a little pretence at original cooking is hardly better than riding a broomstick instead of a real horse. It is play.

The Humanistic Standpoint. The social theory may be regarded as the outgrowth of those new conceptions of life which the evolution theory, in its broader sense, has developed. With the acceptance of that theory as an explanation of human social life, there necessarily follow new ethical conceptions and new ideals. The purely social conception of the individual tends to minimize his value as an individual. He is supposed to belong to the race, owing all to others but nothing to himself. This is making the individual so social as to rob him of his birthright to individuality and character. No room is left for that solitude with nature in which talent unfolds itself.

The humanistic standpoint is diametrically the opposite of this. It lays all stress on the ideal, but leaves no room for the practical. Instead of useful activity, it emphasizes knowledge and art. These are assumed to be social products; and language, the sole means of human intercourse, is taken to be the only means by which knowledge can be acquired. All knowledge, except that of tradition, which has stood the test of centuries, is regarded with suspicion. Nature, the senses, and the body, are considered vulgar. The child is thought to be at bottom bad, and needs to be regenerated by that idealism which man, in his social capacity, has developed by the exercise of the higher spiritual faculties. Ethical ideas must be inculcated; and the great fundamental truths, forming the basis of all sound philosophy and the surest guarantee of the permanency of civilized institutions, must early be impressed on the plastic mind through the medium of language. Memory, that faculty of the human soul, must be stored with the best spiritual fruits of human culture, and a passive obedience to authority assured.

The fundamental assumptions in this conception of development, if it can be called development, are these: (1) That man is extranatural; (2) that society is a purely human or superhuman invention; (3) that art has no relation to nature; (4) that social knowledge can be transmitted directly from individual to individual by means of language; (5) the total depravity of the child, and the possibility of total regeneration by spiritual forces; (6) that ethical ideas can be effective when passively received; (7) that the greatest generalizations of which the adult human mind is capable can be transmitted directly; (8) that memory is a faculty of a soul, having no connection with the body, yet capable of retaining verbal forms and comprehending their meaning; (9) that humble submission to authority is a state to be desired.

This can hardly be called a theory, but rather a program. No induction or experience is appealed to in substantiation of its feasibility. Indeed, it repudiates evolution and experience alike, and stands on purely *a priori* and transcendental foundations. It is the program of the old education. It certainly has a history. That history is an interesting chapter, too, in the annals of European education. But it cannot be related here. It is impossible not to admire the lofty motives, while at the same time wondering at the *naïeveté* of the scheme. It is certainly free from any contamination of that modern science which it professes to abhor. Yet it is not even now entirely obsolete.

It has the advantage of faith in things that can be imagined, but neither seen nor demonstrated; of stating aims and ideals with no laborious attempts to show the probability of their realization. It also presumes to appeal to the history of the past, and cannot be accused of anything but conservatism. It is the old humanism, the program of that culture which has nothing to admire so much as its own self. It is the natural program of all those teachers who jump at conclusions, with no effort to establish those conclusions by laborious research; who, with an unsophisticated *naïveté*, do not realize that they themselves have had a history, and were not always as they now are.

The humanistic standpoint is at bottom human pride. It has an element of contempt for everything outside itself. There is a suggestive connection between humanism in this form and a Chinese wall. So far as that human pride is based on high ideals, it may spur the race onward; but certainly not before the gates in the wall (eyes) have been opened. Humanism is apt to lack that intellectual honesty which alone can give permanent value to the products of the human mind; for it merely asserts dogmatically, with no honest effort to guard against possible error or even to justify its standpoint. The history of Oriental peoples as well as the history of Europe during the Middle Ages, when humanism held sway, shows how far its professed ideals fail of realization. Craft, cunning, deceit, fraud, like concealed weapons, were everywhere associated with even the ermine and gold embroidery of the highest respectability.

The Recapitulation Theory. Biologists, in studying different forms of animal life, find that their form and structure bear certain resemblances to one another, especially within certain groups or types. A gradual transition from one of these types to another is also noticeable. Such similarity of structure is interesting to the scientific student, because it points to a possible relationship between different groups.

Arranging such organisms according to their similarity and differences, a series presents itself, showing a gradual differentiation from the simpler to the more complex. The distinguished embryologist, von Baer, 1828, in studying the development of the chick from the egg up, found, on comparing it at different periods of embryonic development with forms in the series above referred to, that a striking similarity exists between the different phases of development in the chick and the grades of organization in that series. Thus he found that, (1) the chick at first resembled a protozoon in that it was a single cell; (2) as development progressed it assumed the two-layered condition of the hydra or cœlenterate stage; (3) later it became more or less bilaterally symmetrical, but soft-bodied like an oyster; (4) then transverse divisions made their appearance, suggesting the segmentation of worms and arthropods; (5) and, finally, it bore some resemblance to a fish, an amphibian, a reptile, etc. From these observations it has been concluded that, during embryonic development, higher animals pass through more or less completely all the lower stages,—that, in other words, the history of the individual is a repetition or recapitulation of the history of the race of organisms to which it belongs.

Students of human development were not slow to recognize in the activities of a developing youth some tendencies which recall the various culture epochs of the race. Thus, (1) the infant at first walks on "all fours," and is apt to take his nourishment wherever he finds it; (2) he often betrays special fondness for straying about idly among natural objects; (3) he is fond of fishing and hunting; (4) he is often fond of pet animals, likes to ride on horseback, and to hitch his dog to a cart; (5) he is often passionately fond of feeling mother earth with bare feet, likes to dig in the soil, plant trees, and drive a team to market; (6) later, he often has a passionate desire to leave these early haunts for the busy life of the large city, etc., precisely as we have seen the race develop from its primitive beginning to the highly complex social life of large social centers.

The psychologist, too, finds many points of similarity between the development of intellectual life in the individual and in the race. Thus, the youth is (1) fickle-minded, easily moved by feelings, and apparently guided more by instinct than by reason; (2) children are often untruthful as savages are; (3) they may steal as savages do; (4) they do not know how to value property or how to take care of it; (5) they are apt to be vulgar, disobedient, and pugnacious as savages are; (6) they pass through a dreamy period of mental evolution corresponding to that of the Arab tending his herds and brooding vaguely over the causes of things; (7) they have a period of awakening when they show strong resemblances to those emotional religious states of primitive people; (8) they seem to have, (*a*) their age of faith, (*b*) their age of scepticism, (*c*) their metaphysical stage, when even the ultimate problems of existence do not escape their retiring and introspective minds; (9) and, finally, they have their age of reason and exact observation of phenomena. It has often been remarked, also, that just as nations and races have their period of maximum intellectual life, followed by senile degeneration and decay, so, too, does the individual pass into his second childhood.

This recapitulation theory has been adopted by the new pedagogy as one of its most fundamental postulates. It certainly explains many things about the developing individual which could be comprehended in no other way. It is not necessary to suppose that the recapitulation is absolutely complete. It is not so in embryological development, and need not be so in these culture periods of the individual's history.

VI. Intellectual Development.

Stages in the Development of Thought. Man's economic development is very closely associated with his intellectual development; and the economic stages enumerated in Part I, Section II, are a fair index of corresponding intellectual stages. For man's activities are determined by natural conditions on the one hand, and by his mental life on the other. This is what we should expect from that universal law of action and reaction, the interaction of mind and body, and the interaction of man and the external world. Man thinks the thoughts of nature; and by so doing is able to modify nature. But this is true chiefly in the higher stages, when man has learned to know nature.

Even in the earliest culture epochs that we know anything about, there is evidence of a consciousness, on the part of man, that he is in the midst of forces which he cannot control; and hence a certain reverence for nature can be discovered, which reveals itself in the worship of objects and elements. Besides, primitive language is figurative, showing how nature is personified. Primitive man often seems to project his own inner feelings into external nature, and to endow it with various imaginary attributes which it does not possess. In this respect he is much like the timid girl in the dark night, who imagines she hears voices, sees faces, and feels the breath of ghosts and phantoms.

These early relations to nature contain the germs of future philosophic and religious systems. Philosophy and religion, both dealing with the problems of the non-ego, are at first intimately associated, but are later separated into distinct systems, *knowing* and *feeling* being more distinctly differentiated.

1. The earliest philosophy seems to center in the problem of existence in general. Such problems as that of the essence of matter and force, their relations to space and time, and, finally, the relation of all existence to the absolute and infinite, are the problems of primitive speculation of the race, no less than of the juvenile philosopher.

It must not be forgotten that much real experience with nature had been active in producing these abstract general speculations. Otherwise one might be forced to believe that the general appeals to the human mind earlier than does the particular. The experience, which really lay at the bottom of this abstract speculation, had been unconscious, in so far as no conscious attempt at systematic study of nature had been made.

2. Wearied by these futile attempts to solve the ultimate problems of existence, a few vigorous thinkers, like Bacon, Hobbs, Locke, began to call for a return to nature even in matters of thought; very much as a highly artificial social system had called forth the same general appeal.

The result was a shifting of philosophical inquiry, from the purely metaphysical questions of existence, in general, to the problems of knowledge. How much can a mind, constituted as the finite human mind is, positively know concerning those ultimate problems? Can a complex system of logic, whereby the mind builds up a world of subjective reality, definitely solve the problem of external reality? Attention was thus turned to the human mind itself.

3. As could be expected, the method of psychological study was that of introspection alone. Consciousness was considered; and, under the influence of the notion of free will, was thought to be something other and higher than any attribute of matter, and capable of an independent development. A subjective idealism was thus developed which not only regarded ideas as inborn or innate, but which even refused to acknowledge the value of sense impressions.

4. A reaction to the intuitive, metaphysical, and idealistic psychology made its appearance simultaneously with important advances in biological science. The study of development of organic beings not only showed that the existence of inborn ideas was an absurdity, but that a considerable period of development precedes the appearance of those general ideas thought to be inborn. It was Locke who first sug-

gested the idea that the human mind is originally a *tabula rasa*, i.e., a tablet on which anything can be written, through the influence of the external world acting on the sense-organs. With the further development of scientific methods, the new psychology made its appearance.

THE OLD PSYCHOLOGY was the product of humanism. As studied in schools fifteen or twenty years ago, it consisted in committing to memory some one'so pinions about things in general, so far as those opinions could be gathered from a book. In fact, nothing was worth the while which had not been incorporated into a book. Bookishness was a necessary concomitant of slavish reliance on authority. The authority might have had some just claims to recognition, as such, if the conclusions reached had been based on a systematic study of even human history; but that was not, then, the method of psychological study. Mere introspection, an examination of an individual consciousness, could give, at best, the candid personal conviction of any individual who had the courage to assert his opinions as ultimate truths. Thus we had this man's psychology and that man's psychology, not *a* psychology as we have *a* science.

The idea of growth and development in mind or in nature was not a part of the old scheme. Things were taken for granted as having always been as they now are. The psychologist, finding certain general conceptions already in his mind, did not stop to inquire how those ideas had originated, or whether they had originated; but assumed, without further inquiry or comparison with other living beings, that they have always been present and are, in fact, innate or inborn. These ideas were supposed to belong to certain faculties of the mind. Thus, *reason* was considered one separate department of the mind, and was supposed to supply the general notions of time, space, cause, right, truth, beauty, existence, number, resemblance, spontaneity, and the infinite. The brain and nervous system were given little or no attention in these discussions. It is perhaps safe to say that not a few of the authors who thus laid claim to authority in these metaphysical speculations had never seen a nerve; nor would they have been able to distinguish, visually, between the pineal gland and the vermiform appendix.

The general idea being given at birth, particular ideas, arising later in experience, were thought to be only special manifestations of the general. Thus *a* horse was thought to be recognized before *the* horse; the genus before the species. In many cases this was carried so far as to assert that only the general idea, as existing in the mind, was real, all external phenomena being mere illusions.

The distinguishing characteristic of the old psychology was neither modesty nor common sense. Indeed, the audacity of the intuitive psychologist in dogmatically affirming direct knowledge of the ultimate elements of existence by a mind professing no material connection with that existence, and independently of any external experience through the senses, suggests that arrested development which isolation invariably produces. A professor in one of our foremost universities has somewhat caustically characterized it as the "arm-chair psychology." The laboratory, and the labor involved in sifting truth from falsehood, are both equally conspicuous for their absence. It eschews alike the efforts of the practical world, the common sense of humanity, and the accumulated experience of the race, as embodied in organic changes, social evolution, and systematized knowledge or science.

Although the old psychology did not distinctly recognize the evolution principle, it is logically the counterpart of that view of development which regards things as performed—evolution, in its restricted form of Neo-Darwinism. It is interesting to note that Wallace, the chief exponent of Neo-Darwinism, does not include man in his scheme of evolution.

THE NEW PSYCHOLOGY differs from the old, in (*a*) its conclusions; (*b*) in the method pursued in reaching those conclusions; and (*c*) in its universality. The new psychology has the characteristics of science, in so far as it is not a one man's psychology, but a psychology of all men. Its method is that of science; namely, observation and experiment. The psychological laboratory, with its apparatus for testing sense-organs, nerve stimuli, and the effects of nervous fatigue on the various mental manifestations of different individuals, are characteristic of its method.

It seeks the material for its conclusions in all departments of knowledge, especially the biological sciences, physiology, neurology, and uses the methods of these sciences in the investigation of mental phenomena. Thus the psychologist is not now entirely ignorant of the laws of life as manifested in lower organisms. Animal instincts are recognized and studied with a view to their possible connection with mental manifestations in the child. Development, both in the individual and in the race, as shown in history and literature, is recognized as an important factor in mental evolution, and used as an aid in interpreting mental phenomena and in discovering the origin and activity of mind.

The fundamental fact which the new psychology has emphasized is the elementary character of sensation as arising from nervous action. Stimuli, acting on the end organs, the senses, or other stimuli arising from physiological changes in the tissues of the body, are transmitted to the central nervous system, where, by the activity of the cortical centers of the gray matter of the brain, these sensations are associated by simultaneous or successive nervous discharges of cortical cells into perceptions and associated ideas. Thus it is found that sensation gives rise to perceptions; these in turn blend in consciousness into simple ideas of particular things. Simple or particular ideas blend, by association, into more complex or general ideas, which may be abstracted from the original sensations after the brain centers have acquired that power of nervous discharge which seems to come through repetition of external impressions. Hence general ideas, instead of being inborn or innate, are supposed to originate from the simpler particular ideas.

This entire process may take place very rapidly during the first years or even weeks of life, so that the process is largely an unconscious one at first. Subconscious mental states are thought to exist; the organic life, it is believed, ministers to the whole conscious life of the mind. The lower ganglia of the brain may be concerned in purely reflex or automatic acts without being accompanied by consciousness; or, on other occasions, they may serve as relays of nerve energy, by which the cortical cells may be aroused to activity. Thus the higher proceeds from the lower, just as the simple ganglia of the jellyfish may be a step in the evolution of the nervous system of higher animals. The complex brain arises from the union of many simple nerve-cells or neurons, just as the general idea is supposed to arise from the union of simple ones, the original elements of those simple ideas being sensations.

Now, the nervous system and sense-organs are parts of the body, subject to the same laws of health and disease as are other bodily organs. The nervous system, with which the mind is associated, is particularly susceptible to changes of all kinds; and is, therefore, well adapted to receive impressions of all those changes, both in the body and in the external world, which occasion mental states. Variations in the blood supply and in the amount and character of other elements of the blood supplying the brain quickly influence not only the character but the rapidity of thought. Acuteness of sensation, involving not only perfect sense-organs, but a healthy central nervous system, is, therefore, an essential condition to mental development, inasmuch as it furnishes the material of thought.

To avoid metaphysical difficulties, many psychologists assume a parallelism between mental and physical states, without affirming any causal connection between them. It is found, for instance, that the mind may influence the body, as in voluntary acts of all kinds. A reciprocal action thus exists which may, perhaps, mean the interaction of the nervous system and organs, as the muscles. This is no less true of other organs of the body, for the stomach may influence the body, and may, in turn, be influenced by it. Such interaction between parts of an organized body is a biological fact which nobody disputes.

This view of psychology must lead to a recognition of the physical and vital factors in mental processes. Evidently introspection, or the exclusive study of consciousness, as it appears in the adult, can afford no absolute criterion of truth in all intellectual matters. It must be supplemented by objective reality, for that is the condition and occasion of mental processes.

On the other hand, it is not assumed that the external factor alone can account for the content of consciousness. There is in the central nervous system a capacity to react to external impressions; and this capacity must be sought in protoplasmic organization of a primitive type, in which reside the forces of heredity.

Mind, having its beginning in comparatively simple reactions to stimuli of all kinds, is found to grow and develop as the body and especially the nervous system grows and develops; and, just as the body requires nourishment and exercise, so does the mind. This development is a continuous one, though the rate of development may proceed more or less rapidly at different times.

The equal development of mind and body is normal. The unusual development of either, especially a precocious development of the mind, is now looked upon as abnormal and as unfavorable to the attainment of the highest results. A healthy mind presupposes a healthy body; and, just as the body is strengthened by being exercised in moving external objects and taking in food, so the mind is strengthened by that activity which the response to a varied external world involves.

Manifestly, this view of the mind, as being the result of slow growth from those primitive beginnings of simple reactions to sense stimuli, is a repudiation of the fundamental assumptions of the old psychology. But the old psychology was a part of the humanistic system. The new psychology reverses, therefore, the conclusions on which humanism as an educational influence was based. It assumes: (1) Man develops according to natural law; (2) society cannot be wholly a purely human invention; (3) art must have its origin and foundation in nature; (4) social knowledge cannot be transmitted directly by means of language; (5) the child is totally depraved only in the sense that it is devoid of artifice, or is natural; it can be regenerated, acquire this art, only by a process of slow growth, in which, by a laborious process of self-activity, it attains to that freedom by which spiritual forces become operative; (6) ethical ideas can be effective only when they have been operative in shaping his being according to high ideals; when, in other words, ethics has become constitutional, so to speak; (7) the greatest generalizations, such, for instance, as the idea of evolution, cannot be transmitted directly, but must be achieved by a process of slow growth and laborious mental effort; (8) that memory is largely organic, and the result of experience in modifying the reactions of protoplasm; (9) that a gradual emancipation from authority, the sure even though slow winning of freedom, is a consummation to be desired.

Original and Borrowed Ideas. The old psychology was primarily an attempt to vindicate the humanistic standpoint. One conspicuous feature of it was its bookishness. Bookishness means authority.

The man who aspired to authority was usually he who could borrow most from others. Hence the whole system became one of borrowed ideas. New books were only old books rewritten. The test of a good book was that it pay due respect to tradition. Herein lay the danger; for it closed the avenues to progress, as it closed the mind to new truths. He who ventured to utter ideas not conforming to this test was declared a heretic; hence additional inducement was extended to the borrower, and considerable prestige was thus secured by the very ones who least deserved it, with due allowance for conservatism in even the original thinker. The struggle for existence thus resulted in the survival of the weakest, the dependents, rather than the strongest, those capable of self-help. Thus again was the law of nature reversed. The original thinker, the one who had knowledge at first hand, was often made the victim of persecutions; and the parasite, who merely conformed to the authorities of the past, was made his master and his mentor. Herein lay the secret of that inevitable decay which such artificial systems engender.

But what are original and what are borrowed ideas? The German poet, Schiller, has uttered these words: "Dost thou aspire to the highest and the noblest, the plant can teach it thee. What it is, involuntarily, be thou, voluntarily; that's it!" You say, I do not understand Mr. Schiller; but, as he was a great man, it must be true. You therefore commit those words to memory, with or without understanding them. That is a borrowed thought. Now, on the other hand, you may say that Mr. Schiller is either right or wrong in this matter, because it conforms or does not conform to your own experience. In either case it is an original idea, because the result of your own reflection on the elements of personal experience. What Schiller probably meant, in this case, was, that the highest wisdom is gained from contact with nature, as in the observation and study of a plant.

Ideas gained thus, from personal contact with the thing itself, are of necessity our ideas, because developed in the natural way from the primitive elements of sensation. Such ideas are a part of our own being; and, as such, are important factors in our mental life; while those merely borrowed and retained in memory, as verbal symbols, may be of no value to us, since they vanish from memory at the time when they are most needed. The words right and wrong may fail to come to us when in that agitated state of mind resulting from injury by a fellow being, and when ethical considerations are especially desirable.

Origin of Language. Written languages are the traces of motor activity. Articulate speech results from co-ordinated contractions of such muscles as those of the diaphragm, intercostals, throat, tongue, cheeks, and lips. These muscular contractions, like those of the limbs, are due to nervous impulses arising in the brain, or reflected by it from other internal organs.

In the infant, vital processes are very active in all the organs, and this activity involves active nutrition. Hunger is felt as a natural consequence of growth and waste of the body. Consciously or unconsciously, this hunger gives rise to movements of the body, the vague unco-ordinated attempts to appease the hunger and restore the equilibrium of the body. The natural desire for food, the primitive want seeking satisfaction, may result in movements of limbs or in movements of the vocal organs.

It is perhaps true that those organs whose activity involves least expenditure of energy, are least fatiguing in other words, will be the ones that naturally become active. This selection of the least fatiguing is not necessarily a conscious or a deliberate choice, any more than the natural selection of the fittest is a conscious act on the part of environment. Thus it comes to pass that the first movements of the limbs are abandoned, and the less fatiguing activity of the vocal organs adopted.

At first the unco-ordinated action of those muscles of the vocal organs results in that discordant noise, the infant's cry. The cry is the expression of physical states, possibly wants affecting consciousness. If such a cry serves its purpose—the removal of uneasiness, the satisfaction of its wants—the cry will be selected as the fittest means of satisfying wants.

The original movements, resembling gestures and later the cry, are the first indications of dawning consciousness, the first sign of ideas. So far as these simple signs of ideas serve to satisfy the want which gave rise to them, they may be called a medium of communication, the first beginnings of language. Such primitive modes of expression of ideas or feelings for the satisfaction of wants are common to the lower animals, to primitive man in the lowest savage state, and to the infant of the most highly civilized races.

It is important to notice that the want, or the idea of a desire, is present in consciousness before the sign of that idea appears; also, that the sign may vary according to convenience or ease in making the sign, as well as according to what is necessary to have the sign understood and the want satisfied.

We have here an important explanation of the perplexing question as to how teleological adaptations arise. Manifestly, if there is a consciousness back of this useful adaptation to a purpose, it is a consciousness governed by the same natural law as that leading to the same results in lower forms.

Articulate speech is a further differentiation and specialization of the original cry. Variety of feelings, variety of sensations, variety of wants, and variety of ideas, require greater variety in the vocal utterance; and, consequently, increased modification of the vocal organs, giving rise to a succession of vocal impulses or sound complexes. Hence we find, both in the individual and in the race, that language becomes more and more complex and specialized.

Sounds are first combined into monosyllables, as in the word ma and pa. How do these arise? In the first place, they result from the simplest combination of the vocal organs, and are, therefore, least fatiguing. If the infant finds all his wants attended to by a mere cry, the chances are he will continue to express his wants in that way, as is usually the case with the spoiled baby. If, however, he finds that this does not bring about the desired end, he may adopt other means; in fact, a variety of ways of expressing himself until he hits upon some combination of sounds that is effective. If the child finds that the sound ma has the effect of bringing its mother to attend to its wants, that particular signal will continue to be given whenever "ma" is wanted. The word "ma" is therefore equivalent to a whole sentence; and has not been learned by imitation, as is usually supposed. The ease of utterance, and its effectiveness in bringing about the desired results, is the sole reason for its retention. It would not be effective, however, unless the mother knew what "ma" means. It is useful, therefore it is selected; very much as the co-ordinated contractions of certain muscles of the arm are useful in bringing food to the mouth; and, consequently, selected, while other muscular combinations, not producing useful results, are eliminated. It is essentially in the same way that the child learns to walk.

Speech is a form of co-ordinated muscular contractions, adopted because of its utility to the organism. But how does this speech become adapted to the environment? Precisely as other adaptations have arisen. In America, the child, wanting its thirst satisfied, finds that certain combinations of sounds, *water*, suffice; in Germany, on the other hand, a different combination produces the same effect, namely, *Wasser*. So far as the child is concerned, it makes no difference which word is used. It adopts that combination of sounds which is effective in bringing about desired results; and, consequently, comes to use the language of those with whom it associates.

Now this explains the origin of language as a whole. Language is not borrowed; it is invented at first. It is invented, too, because of the existence of an idea in the mind, not for the purpose of gaining ideas. A boat is invented because of a desire to cross a body of water dry shod. So language is invented to satisfy wants; and, just as the boat is adapted to the medium, so the language invented will be English in England and German in Germany. An Italian, calling on Patrick Murphy for work on the railroad, makes all those signs which he thinks necessary to make Patrick comprehend. If Patrick calls on the Italian the process will be reversed; for Patrick now has the wants that are to be communicated, the result being broken Italian instead of broken Irish. Thus an amalgamation or agglomeration of the two languages may result by a process similar to that which has formed our modern English.

Language must, therefore, necessarily grow in proportion as the environment becomes more and more complex. The environment of each of us becomes complex in proportion as we fix attention upon all the phases of this environment, and our ideas increase in number according as we come in contact with more and more things. Seeing the "centrosome" in the egg of *Ascaris megalocephala*, made necessary the invention of the new word *centrosome* to designate the new idea gained. The idea came first; and created a need for a name, which was promptly invented. Special experiences with different phases of nature cause special needs to arise for means of labeling, classifying, identifying, and communicating those experiences, and this results in technical or scientific language. Our ideas must correspond to our experiences; and hence our language must acquire that special characteristic also. Thus a sailor has his language; a railroad man his; no less technical than that of the man of science. If we assume species to arise from experience, then we should not be surprised to find among human beings different species, having their own specific language; and, as there are varieties of living things, so there must be varieties (dialects) also in language. We may say, therefore, that language grows, changes, but only because the living being whose product it is, grows and changes. Now this growth and change is due to a more varied and complex experience. It is this, consequently, which leads to that specialization and differentiation, suggesting species and varieties, on the one hand, and specialized human characteristics and human activities on the other. Language is not something floating around in the air, freighted with ideas that can be had by gathering words. The word *centrosome* can give no idea of what the centrosome really is. A word means nothing to us unless we are able to put an idea into it. To the biological investigator, the following combination of articulate sounds or symbols means a great deal, because he has gained through experience the ideas for which the words stand: "The equal splitting of the chromosomes in caryokinesis, and the position of the centrosome of the aster at the end of the spindle, in the maturation of the ovum of *Ascaris megalocephala*, point to the latter as dynamic centers whereby the hereditary qualities are equally distributed." To a child, this means nothing. Ideas do not come from language, but language grows out of ideas. Hence *the idea before the word.*

The Use of Language. In using language, as in conversation or as in reading a book, do we actually gain new ideas or do we merely put into language the thoughts derived from our own experience? The popular conception is that, by reading a book or repeating the words and committing them to memory, the idea for which the word stands, and hence the thought of the book, must be ours also. The common politician, who wishes to really reach his audience so as to influence them in his behalf, does not proceed on that assumption. He deals with images, figures, ideas, and language that are common to the experience of all. To tell people what they know already is to be popular. To express new ideas in new terms is to be unpopular. Ruskin once lamented before his audience that instead of receiving what the speaker had to say, his audience were only trying to discover in what respects he was right and in what wrong. He should have known that it was not only a proper but the natural thing to do; for they were merely reading into his words the ideas they already had, and judging his remarks by the standards of their life experience. Most teachers expect a child to get child's ideas out of Shakespeare; and, consequently, adapt their books and their language to the age and experience of their pupils.

Language is not, primarily, a means of instruction, as is so often assumed, but rather a means or device for the interchange of familiar ideas. Men have language because they have brains. They do not have brains because they have language.

CHAPTER III

Systematic Arrangement of Plant and Animal Forms

VII. Introductory.

Plants and animals are grouped according to their resemblances and affinities into: (1) Kingdom, (2) subkingdom, (3) series, (4) classes, (5) subclasses, (6) orders, (7) suborders, or families, (8) genera, (9) species, and (10) varieties.

The name of the genus and the species taken together constitute the scientific name of the plant or the animal; as, *Caltha palustris* (marsh-marigold) or *Canis familiaris* (the dog). In the case of the plant, *Caltha* is the genus and *palustris* is the species. So in the case of the dog, *Canis* is the genus, *familiaris* the species.

Notice that the genus is written first and begins with a capital initial, while the species occupies second place and is written with a small initial. When the species is named after the discoverer or some other person, as is frequently the case, the species is written with a capital letter.

Comparing these scientific names with that of a man, as, for instance, John Smith, you will notice that they would be similar if the man's name were written Smith John, as is sometimes convenient to do.

But little attention if any need be given in nature study to the determination of species. That is a work for specialists. There is no important reason, however, why the generic name of the genus should not be given the pupil when convenient. He may be encouraged to find the name if analytical keys are available, or if it can be found in the dictionary by the aid of the common name.

It is an advantage to know the common and the scientific name of things. The teacher should at least know how to find the name of the most common things with which nature study deals. This can be done to a limited extent from the following outlines by referring to the index.

The name of the genus is sufficient for all practical purposes in the grades, but even that is not so important as the more essential facts of life.

VIII. Classification of Structures, Functions and Adaptations of Plants.

GENERAL ANALYSIS OF FLOWERS.

- 1. Parts
  - 1. Essential Organs
    - 1. Present
      - 1. Stamens
        - 1. Present
          - 1. Anthers
            - 1. Introrse
            - 2. Extrorse
            - 3. Versatile
          - 2. Filament
            - 1. Present
              - 1. Free
              - 2. Connate
              - 3. Adnate
            - 2. Absent
        - 2. Absent—Pistilate or female
      - 2. Pistil
        - 1. Present
          - 1. Simple
          - 2. Compound
            - 1. Ovary
              - 1. Simple
              - 2. Compound
            - 2. Style
              - 1. Simple
              - 2. Divided
        - 2. Absent—Staminate or male
    - 2. Absent—Sterile
  - 2. Floral Envelopes
    - 1. Present
      - 3. Calyx
        - 1. Present
          - 1. Foliaceous
          - 2. Petaloid
          - 3. Deciduous
        - 2. Absent—Asepalous
      - 4. Corolla
        - 1. Present
          - 1. Polypetalous
          - 2. Gamopetalous
        - 2. Absent—Apetalous
    - 2. Absent—Naked

PLANTS—THE FLOWER.

- 2. Kinds
  - 1. Simple
    - 1. Regular
      - 1. Perfect or imperfect
      - 2. Complete or incomplete
      - 3. Symmetrical or unsymmetrical
      - 4. Double
    - 2. Irregular
      - 1. Papilionaceous
        - 1. Standard
        - 2. Wings
        - 3. Keel
      - 2. Labiate
        - 1. Gaping
        - 2. Masked
  - 2. Compound
    - 1. Ray flowers and disk flowers
    - 2. Disk flowers only
- 3. Plan
  - 1. As regards organs
    - 1. Perfect
      - 1. Stamens
      - 2. Pistils
      - } Hermaphrodite or bisexual
    - 2. Imperfect
      - 1. Staminate or male
      - 2. Pistilate or female
      - } 1. Unisexual or 2. Separate
  - 2. As regards whorls
    - 1. Complete
      - 1. Calyx
      - 2. Corolla
      - } Present
    - 2. Incomplete
      - 1. Calyx
      - 2. Corolla
      - } Absent (naked)
  - 3. As regards form
    - 1. Regular
      - 1. Petals (similar in shape)
      - 2. Sepals (similar in shape)
    - 2. Irregular
      - 1. Petals (dissimilar in shape)
      - 2. Sepals (dissimilar in shape)
  - 4. As regards number
    - 1. Symmetrical
      - 1. Sepals
      - 2. Petals
      - 3. Stamens
      - 4. Pistils
      - } of same number
    - 2. Unsymmetrical
      - 1. Sepals
      - 2. Pistils
      - 3. Petals
      - 4. Stamens
      - } differing in number

- 4. Union of Parts
  - 1. Coalescence (*similar*)
    - 1. Sepals
      - 1. Distinct (polysepalous) not united
      - 2. United (gamosepalous)
    - 2. Petals
      - 1. Distinct (polypetalous)
      - 2. United (gamopetalous)
        - 1. Wheel-shaped
        - 2. Bell-shaped
        - 3. Funnel-shaped
        - 4. Tubular
        - 5. Papilionaceous
        - 6. Labiate
    - 3. Stamens
      - 1. Distinct
      - 2. United (monodelphous, dia, tri, etc.)
      - 3. Syngenesious (anthers united)
    - 4. Pistils
      - 1. Distinct
      - 2. United (monogynous, di, tri, etc.)
  - 2. Adnation (*dissimilar union*)
    - 1. Free
      - 1. Calyx
      - 2. Corolla
      - 3. Stamens
        - 1. Hypogenous (under pistil)
        - 2. Perigenous (around pistil)
        - 3. Epigenous (above pistil)
    - 2. Adnate
      - 1. Calyx adnate to ovary (ovary inferior)
      - 2. Petals adnate to sepals (episepalous)
      - 3. Stamens adnate to petals (epipetalous)
      - 4. Pistil or ovary
        - 1. Superior (free)
        - 2. Inferior (adnate)
- 5. Inflorescence
  - 1. Indeterminate
    - 1. Raceme
    - 2. Corymb
    - 3. Umbel
    - 4. Spike
      - 1. Simple
      - 2. Compound
    - 5. Head
    - 6. Spadix
    - 7. Catkin
  - 2. Determinate
    - 1. Cyme
    - 2. Fasicle
    - 3. Glomerule
      - 1. Simple
      - 2. Compound
  - 3. Mixed
    - 1. Thyrsus
    - 2. Panicle

Adaptations of Flowers.

- 6. Adaptations of Flowers, to
  - 1. Other plants
    - 1. Protandry (anthers first mature)
    - 2. Protogyny (pistil first mature)
    - 3. Cleistogamy (self-fertilized inclosed flower)
  - 2. Animals
    - 1. Nectar
    - 2. Color
    - 3. Odor
    - 4. Union of irregular petals
    - 5. Hairs
    - 6. Wax
  - 3. Functions
    - 1. Production of fruit
    - 2 Self-fertilization (cleistogamy)
    - 3. Cross-fertilization
      - 1. Protandry
      - 2. Protogany
    - 4. Insect fertilization
      - 1. Color
      - 2. Odor
      - 3. Nectar
      - 4. Long stamens and short pistils
      - 5. Long pistil and short stamens
      - 6. Monœcious
      - 7 Diœcious
    - 5. Fertilization by
      - 1. Wind
      - 2. Water
        - 1. Obscure color
        - 2. Light pollen

Fertilization of Flowers.

- 7. Fertilization
  - 1. Self-pollination
    - 1. Close fertilization (same stamen and pistil)
    - 2. Cleistogamy (closed flower)
  - 2. Cross-pollination
    - 1. Insects (entomophilous)
    - 2. Birds
    - 3. Wind (anemophilous)
    - 4. Water

Uses of Flowers.

- 8. Uses to Man
  - 1. Ornament
  - 2. Fragrance
  - 3. Production of fruit
  - 4. Manufacture of perfumery
  - 5. Production of useful seeds
    - 1. Oats
    - 2. Barley
    - 3. Wheat
    - 4. Corn
  - 6. Medicinal
  - 7. Nectar for honey

ORIGIN OF FLOWERS.

- 9. Origin of Flower
  - 1. From bud
  - 2. Modified stem
    - 1. Branch (torus)
    - 2. Leaves
      - 1. Sepals
      - 2. Petals
        - 1. Claw
        - 2. Lamina
      - 3. Stamens
        - 1. Filament
        - 2. Anther
      - 4. Pistil
        - 1. Simple (one leaf or carpel)
        - 2. Compound (two leaves or carpels)

FRUIT.

- 1. Kinds of Fruit (*origin*)
  - 1. Simple
    - 1. Berry
    - 2. Pepo
    - 3. Pome
    - 4. Drupe
    - 5. Akene
    - 6. Cremocarp
    - 7. Utricle
    - 8. Caryopsis
    - 9. Nut
    - 10. Samara
    - 11. Follicle
    - 12. Legume
    - 13. Capsule
    - 14. Silique
    - 15. Silicle
    - 16. Pyxis
  - 2. Aggregate
    - 1. Raspberry
    - 2. Dewberry
  - 3. Accessory
    - 1. Strawberry
    - 2. Blackberry
  - 4. Multiple
    - 1. Syconium
    - 2. Strobile
- 2. Kinds of Fruit (*consistency*)
  - 1. Fleshy
  - 2. Stone
  - 3. Dry
    - 1. Indehiscent
    - 2. Dehiscent
      - 1. Loculicidal
      - 2. Septicidal

- 3. Origin
  - 1. Mature ovary
    - 1. Simple
    - 2. Compound
  - 2. Ovary and calyx
  - 3. Ovary, calyx, and torus
  - (1–3: of one flower.)
  - 4. Ovary, calyx, torus, and rachis of several flowers
- 4. Uses
  - 1. Distribution of seeds
  - 2. Reproduction of the plant
  - 3. Food for
    - 1. Animals
    - 2. Plants
      - 1. Bacteria
      - 2. Yeast
      - 3. Fungi
    - 3. Man
- 5. Useful Properties
  - 1. Hard
  - 2. Soft
  - 3. Juicy
  - 4. Mellow
  - 5. Colored
  - 6. Fragrant
  - 7. Sweet
  - 8. Sour
  - 9. Bitter
  - 10. Starchy
  - 11. Oily
  - 12. Medicinal
- 6. Adaptive Structures
  - 1. Rind
  - 2. Husk
  - 3. Chaff
  - 4. Bristles
  - 5. Pappus
  - 6. Hairs
  - 7. Spines
  - 8. Hooks

Leaves, their Form and Structure.

- 1. Parts of Leaves
  - 1. Blade
    - 1. Epidermis
    - 2. Pulp (parenchyma)
    - 3. Ribs
    - 4. Veins
    - 5. Veinlets
  - 2. Petiole
  - 3. Stipules
    - 1. Persistent
    - 2. Deciduous
    - 3. Dry or scarious
    - 4. Free
    - 5. Adnate
    - 6. Spiny
    - 7. Foliaceous or leaf-like
- 2. Venation of Leaves
  - 1. Parallel-veined
    - 1. From base
    - 2. From midrib
  - 2. Netted-veined (or reticulated)
    - 1. Pinnately or feather-veined
    - 2. Palmately or digitately veined
- 3. Form of Leaves
  - 1. Linear
  - 2. Lanceolate
  - 3. Oblong
  - 4. Elliptical
  - 5. Oval
  - 6. Ovate
  - 7. Orbicular or rotund
  - 8. Oblanceolate
  - 9. Spatulate
  - 10. Obovate
  - 11. Cuneate
- 4. The Base of Leaves
  - 1. Cordate
  - 2. Reniform
  - 3. Auriculate
  - 4. Sagittate
  - 5. Hastate
  - 6. Peltate
  - 7. Obtuse
  - 8. Acute
  - 9. Rounded

5. The Apex of Leaves
    1. Accuminate
    2. Acute
    3. Obtuse
    4. Truncate
    5. Retuse
    6. Emarginate
    (1–6 also applied to petals)
    7. Obcordate
    8. Cuspidate
    9. Mucronate
    10. Aristate

6. The Margin of Leaves
    1. Entire
    2. Serrate
    3. Dentate
    4. Crenate
    5. Wavy
    6. Cut or incised
    7. Lobed
    8. Cleft
    9. Parted
    10. Divided
    (7–10:)
        1. Pinnately
            1. Three
            2. Four
            3. Five
            4. Many
        2. Palmately
            1. Three
            2. Four
            3. Five
            4. Many

7. Kinds of Leaves
    1. Simple
    2. Compound
        1. Pinnately — 1. Pinnules
        2. Palmately — 2. Leaflets
    3. Perfoliate
    4. Equitant
    5. Needle-shaped
    6. Scale-shaped
    7. Seed leaves
    8. Fleshy leaves
    (3–8 Special forms)

8. Arrangement of Leaves
    1. Alternate
        1. Two-ranked (one-half)
        2. Three-ranked (one-third)
        3. Five-ranked (two-fifths)
        4. Eight-ranked (three-eighths)
    2. Opposite
    3. Whorled
    4. Clustered

9. Position of Leaves in the Bud
    1. Straight
    2. Folded
    3. Inflexed
    4. Conduplicate
    5. Plicate
    6. Circinate
    7. Convolute
    8. Involute
    9. Revolute

10. Structures of Leaves
    1. Epidermis
    2. Network of veins
    3. Green mesophyl

ADAPTATIONS OF LEAVES.

1. Adaptations of Leaves to Light
    1. Flat and expanded surface
    2. Cut, divided, or cleft to let in light
    3. Separated on the stem
    4. Petiole lengthened or shortened
    5. Rolled up so as to expose little surface
    6. Turning flat surface or edge to light
    7. Placed uppermost on the stem
    8. Bending towards the light
    9. Green color chlorophyl
    10. Palisade arrangement of cells on exposed surface

2. Adaptations of Leaves to Water
    1. Hairy
    2. Waxy
    3. Covered with cuticle
    4. Large and broad for floating
    5. Drooping
    6. Pitcher-shaped
    7. Prostrate position on the ground
    8. Upright position on stem

3. Adaptation of Leaves for Protection from Other Plants
    1. Prickly
    2. Hairy
    3. Changed into tendrils
    4. Thick, spherical, and fleshy
    5. Converted into spines

- 4. Adaptations to Function
  - 1. Transpiration
    - 1. Stomata
    - 2. Expanded surface
    - 3. Differentiation of two surfaces
    - 4. Hairs
    - 5. Rosin
    - 6. Cuticle
    - 7. Porous mesophyl
    - 8. Spherical or fleshy form
  - 2. Photosynthesis
    - 1. Flat and expanded surface
    - 2. Cut or divided
    - 3. Separated on the stem
    - 4. Petiole lengthened
    - 5. Drooping in sleep
    - 6. Heliotropism
    - 7. Chlorophyl
    - 8. Stomata
  - 3. Respiration
    - 1. Expanded surface
    - 2. Stomata
    - 3. Spongy mesophyl
  - 4. Nutrition
    - 1. Forming roots
    - 2. Trap-shaped
    - 3. Pitcher-shaped
    - 4. Thick and fleshy for storage
- 5. Adaptations to Animals
  - 1. Hairy to prevent injury
  - 2. Spiny for protection
  - 3. Bitter
  - 4. Sticky
  - 5. Smooth
  - 6. Powdery
  - 7. Trap-shaped
  - 8. Pitcher-shaped
  - 9. Nutritious for food
  - 10. Broad for shelter
- 6. Adaptations of Leaves to Man's Uses
  - 1. Nutritious for food
    - 1. Starchy
    - 2. Flavored
  - 2. Chemical elements for
    - 1. Tea
    - 2. Drugs
  - 3. Manufactures
    - 1. Tough
    - 2. Leathery
  - 4. Shelter
    - 1. Large
    - 2. Durable
  - 5. Ornaments

Roots of Plants.

1. Kinds of Roots as to Origin
   1. Primary
   2. Secondary
   3. Tertiary
   4. Adventitious
2. Roots as Regards Distribution
   1. Soil-roots
   2. Water-roots
   3. Aerial roots
   4. Parasitic roots
3. Forms of Roots
   1. Fibrous
   2. Fascicled
   3. Fleshy
      - Tap-roots
        1. Napeform
        2. Conical
        3. Fusiform
4. Roots as Regards Duration
   1. Annual
   2. Biennial
   3. Perennial
5. Structure of Roots
   1. Hair-like
   2. Woody
      1. Outer bark—epidermis
      2. Central wood
         1. Medullary rays
         2. Ducts
      3. Cambium
   3. Soft and juicy
6. Adaptations of Roots to
   1. Absorption
      1. Thin walls of root-hairs
      2. Increase of surface by division
      3. Thickening of epidermis prevents evaporation
   2. Storage
      1. Underground position prevents freezing
      2. Thickened epidermis prevents loss of water
   3. Support—Hard tap-root and tough secondary roots
   4. Holdfasts
      1. Ramification of rootlets
      2. Large descending tap-root
      3. Twisting of aerial roots

7. Uses of Roots to
- 1. Man
  - 1. Food
  - 2. Basket-work
  - 3. Medicine
- 2. Animals
  - 1. Food
  - 2. Shelter
  - 3. Support
- 3. Plants
  - 1. Absorption
  - 2. Food-storage
  - 3. Holdfasts
  - 4. Protection

STEMS OF PLANTS.

1. Distribution of Stems
- 1. Above ground
- 2. In water
- 3. In air
- 4. Under ground

2. Kinds of Stems
- 1. Above ground
  - 1. Culm (straw stem of grass
  - 2. Shrubby
  - 3. Bushy
  - 4. Tree-trunks
- 2. Under ground
  - 1. Rhizome (root-stock)
  - 2. Tuber (potato)
  - 3. Corn (solid bulb)
  - 4. Bulb (scaly)

3. Stems as Regards Direction of Growth
- 1. Leaning
- 2. Reclining
- 3. Rising
- 4. Prostrate
- 5. Creeping
  - 1. Stolon
  - 2. Offset
  - 3. Runner
- 6. Climbing
- 7. Twining

Anomalous Stems and Branches
- 1. Sucker
- 2. Tendril
- 3. Spines

5. Forms oi Stems
- 1. As regards branching
  - 1. Deliquescent (divided)
  - 2. Excurrent (central shaft)
- 2. Jointed
- 3. Square
- 4. Cylindrical
- 5. Flat or leaf-like
- 6. Spherical

6. Structure of Stems
    1. Woody (exogenous)
    2. Pithy (endogenous)
    3. Herbaceous
    4. Hollow or porous
    5. Fleshy
    6. Scaly

7. Duration of Stems
    1. Annual
    2. Biennial
    3. Perennial

8. Growth of Stems
    1. Exogenous
    2. Endogenous
    3. Definite annual growth
    4. Indefinite annual growth

USES OF THE STEM.

9. Uses of Stems to
    1. Plants
        1. Conduction of sap
        2. Storage of food
        3. Support of leaves
        4. Protection
        5. Support of other plants
        6. Reproduction
    2. Animals
        1. Homes of
            1. Larvæ
            2. Ants
            3. Birds
            4. Toads
            5. Snakes
            6. Monkeys
        2. Food
        3. Protection and shelter
    3. Man
        1. Food
        2. Medicines
        3. Building material
        4. Fodder
        5. Manufacture of
            1. Lumber
            2. Furniture
            3. Tools
            4. Sugar
            5. Starch
            6. Paper
            7. Rubber
            8. Dyes
            9. Linen goods
        6. Fibers for manufactures
        7. Bark for tanning
        8. Bark for Indian canoes, etc.

ADAPTATIONS OF STEMS.

10. Adaptations of Stems to

- 1. Light
  - 1. Heliotropism (bending to light)
  - 2. Erect position
  - 3. Branching
  - 4. Elongated or climbing
  - 5. Branching only at extreme top
  - 6. Underground stems
- 2. Heat
  - 1. Bark and hardened cuticle
  - 2. Underground below frost
  - 3. Periodic diminution
  - 4. Flow of sap
  - 5. Hairs
- 3. Moisture
  - 1. Cuticle prevents evaporation
  - 2. Rosin
  - 3. Hairs
  - 4. Powder
  - 5. Creeping and floating posture
- 4. Wind
  - 1. Hard heart wood
  - 2. Hollow
  - 3. Firmly rooted
  - 4. Low and prostrate
  - 5. Flexibility
  - 6. Drying and carrying seeds in wind
- 5. Plants
  - 1. Hollow for strength
  - 2. Firm and woody for support
  - 3. Long and slender for twining
  - 4. Divided and slender for floating in water
  - 5. Underground for protection and propagation
  - 6. Branched for leaf exposure
  - 7. Covered with bark or cuticle for protection
- 6. Animals
  - 1. Spiny for protection
  - 2. Covered with bark for protection
  - 3. Hairy for protection from insects
  - 4. Sticky for protection
  - 5. Bitter for protection
- 7. Man
  - 1. Hard and woody for use
  - 2. Soft and juicy for use
  - 3. Tall and graceful for beauty
  - 4. Tough and flexible
  - 5. Light and heavy
  - 6. Spicy
  - 7. Sweet and bitter

ADAPTATIONS OF STEMS TO WORK.

- 11. Adaptations of Stems to Work of
  - 1. Climbing
    - 1. Roots at many joints
    - 2. Production of tendrils
    - 3. Twisted petioles or leaf-stalks
    - 4. Slender stems for climbing
  - 2. Storage
    - 1. Underground position
    - 2. Thickened and fleshy
    - 3. Corky bark to prevent evaporation
    - 4. Pithy
  - 3. Circulation
    - 1. Fibrovascular bundles
    - 2. Cambium layer
    - 3. Sieve-tubes and tracheids
    - 4. Thickened walls of wood-cells
    - 5. Medullary rays
  - 4. Support
    - 1. Heart wood of trees
    - 2. Hollow stems of grasses
    - 3. Hard wood and bast-tissue

TISSUES OF STEMS.

- 12. Tissues of
  - 1. Exogens
    - 1. Epidermal tissue
    - 2. Fundamental system
      - 1. Fundamental parenchyma
      - 2. Sclerotic parenchyma
      - 3. Sclerotic prosenchyma
    - 3. Fibro-vascular system
      - 1. Bundle sheath
      - 2. Phlœm sheath
      - 3. Bast-fibers
      - 4. Sieve-tubes
      - 5. Phlœm parenchyma
      - 6. Tracheids
      - 7. Scalariform vessels
      - 8. Spiral and pitted ducts
  - 2. Endogens
    - Systems as above, but differently arranged.

CELLS OF PLANT TISSUES.

- 13. Forms of Plant-cells
  - 1. Spherical
  - 2. Cylindrical
  - 3. Flat
  - 4. Spindle-shaped
  - 5. Hexagonal
  - 6. Elongated
  - 7. Irregular

14. Kinds of Tissue-cells
   1. Cork cells or epidermal cells
   2. Bast cells
   3. Green-bark cells
   4. Cambium cells
   5. Primary meristem cells
   6. Wood cells
   7. Tracheids or pitted cells
   8. Pith cells

SEEDS.

1. Reproductive Bodies in Plants
   1. Spores of cryptogams (cells)
   2. Seeds of phænogams (containing embryo)

2. Structure of Seeds
   1. Seed-coats
      1. Testa
         1. Markings
            1. Hilum (scar)
            2. Raphe (ridge)
            3. Chalaza
            4. Micropyle
         2. Shape
         3. Color
         4. Appendages
            1. Wings
            2. Fibers (coma)
            3. Wool (cotton)
            4. Aril (bladders)
            5. Strophiole
      2. Inner coat (thin membrane)
   2. Kernel
      1. Embryo
         1. Cotyledons
            1. One or monocotyledonous
            2. Two or dicotyledonous
            3. Many or polycotyledonous
         2. Plumule
         3. Hypocotyl (radicle or caulicle)
            1. Superior
            2. Inferior
      2. Albumen
         1. Present (albuminous)
         2. Absent (exalbuminous)

USES OF SEEDS.

- 3. Uses of Seeds to
  - 1. Wild animals
    - 1. Food
    - 2. Nest
  - 2. Man
    - 1. Food for
      - 1. Domestic animals
        - 1. Poultry
        - 2. Horses
        - 3. Cows
        - 4. Pigs
        - 5. Sheep
      - 2. Man
        - 1. Corn meal
        - 2. Oat meal
        - 3. Flour
        - 4. Starch
        - 5. Rice
    - 2. Drugs
      - 1. Coffee
      - 2. Cocoa
    - 3. Spices
      - 1. Nutmegs
      - 2. Juniper
      - 3. Extracts
    - 4. Manufactures
      - 1. Fermented spirits
      - 2. Cotton goods
      - 3. Linseed-oil
      - 4. Ornaments
      - 5. Ointments
    - 5. Agriculture
      - 1. Timothy
      - 2. Clover
      - 3. Red-top
      - 4. Blue grass
      - 5. Buckwheat
      - 6. Corn
      - 7. Oats
      - 8. Wheat
      - 9. Barley
      - 10. Flax
      - 11. Sugar-corn
      - 12. Broom-corn
      - 13. Garden vegetables
      - 14. Cultivated flowers
      - 15. Trees
        - 1. Maple
        - 2. Cherry
        - 3. Apple
        - 4. Peach
        - 5. Orange
        - 6. Cott'nwood
        - 7. Osage
  - 3. The Plants
    - 1. Dissemination
    - 2. Reproduction

ADAPTATIONS OF SEEDS.

- 4. Adaptations of Seeds to
  - 1. Resting period
    - 1. Drouth
      - 1. Small surface
      - 2. Impervious outer coat
    - 2. Moisture
      - 1. Dry albumen
      - 2. Hard impervious outer coat
    - 3. Mechanical injury
      - 1. Small size
      - 2. Spherical form
      - 3. Spines and prickles
  - 2. Protection
    - 1. Hardness
    - 2. Compactness
    - 3. Thick and hard outer coat
    - 4. Spherical or arched surfaces
    - 5. Protective coloring
  - 3. Dissemination
    - 1. Color
    - 2. Loose bladder appendages
    - 3. Wings
    - 4. Spines
    - 5. Hooks
    - 6. Hairs
    - 7. Lightness
  - 4. Germination
    - 1. Albumen
    - 2. Embryo
- 5. Means of Dissemination
  - 1. Wind
    - 1. Seeds blown by the wind
    - 2. Fruit carried by the wind
    - 3. Entire plant carried by the wind
  - 2. Water
    - 1. Floating seeds
    - 2. Floating fruit
    - 3. Floating plants
  - 3. Animals
    - 1. Birds
      - 1. In beak
      - 2. On feet
      - 3. In crop
    - 2. Hairy animals
      - 1. In wool
      - 2. In hair
      - 3. Alimentary canal
    - 3. Burrowing animals
      - 1. In mouth
      - 2. Stored food
  - 4. Man
    - 1. Clothing
    - 2. Wagons
    - 3. Cars
    - 4. Ships
    - 5. Mud on boots
    - 6. Sowing by hand or machine

Soils and Germination of Seeds.

- 6. Properties of Soils
  - 1. Sand
  - 2. Clay
  - 3. Loam
  - 4. Moisture
    - 1. Carbon compounds
    - 2. Carbon dioxide
    - 3. Proteids
    - 4. Ammonia
  - 5. Organic substances
  - 6. Various salts

- 7. Conditions for Germination
  - 1. Resting period of some seeds
  - 2. Moisture
  - 3. Heat
  - 4. Oxygen or air

- 8. Effects of Germination
  - 1. Absorption of albumen from
    - 1. Seed leaves
    - 2. Endosperm
  - 2. Unfolding of embryo
  - 3. Lengthening of the hypocotyl
  - 4. Formation of roots
  - 5. Connection with the soil

Buds.

- 1. Classification of Buds
  - 1. Position
    - 1. Terminal
    - 2. Lateral
      - 1. Axillary
      - 2 Extra-axillary
  - 2. Number
    - 1. Solitary
    - 2. Supernumerary
      - 1. Collateral
      - 2. Superposed
  - 3. Kinds
    - 1. Accessory
    - 2. Naked
    - 3. Scaly
    - 4. Leaf-buds
    - 5. Flower-buds
    - 6. Mixed
    - 7. Dormant

- 2. Homology of Buds
  - 1. Leaf-buds, stems in miniature
  - 2. Flower-buds, homologous to leaf-buds, as the flower is a modified stem

- 3. Adaptations of Buds to
  - 1. Light
    - 1. Arrangement on stem
    - 2. Underground
    - 3. Under the bark
  - 2. Temperature
    - 1. Hairs
    - 2. Scales
    - 3. Position under ground
    - 4. Position under the petiole
    - 5. Position under the bark
  - 3. Moisture
    - 1. Waxy
    - 2. Hairs
    - 3. Scales
    - 4. Location under petiole
    - 5. Location under bark
- 4. Uses of Buds to
  - 1 Plants
    - 1. Reproduction
    - 2. Condensation of exposed parts
    - 3. Saving of time in early spring
    - 4. Provision for accidents
  - 2. Animals
    - 1. Food (insects, mammals, etc.)
    - 2. Shelter (insect eggs)
  - 3. Man
    - 1. Food
    - 2. Medicine
    - 3. Seed
- 5. Protective Adaptations
  - 1. Scales
  - 2. Wax
  - 3. Bitter taste
  - 4. Obscure color
  - 5. Hairs
  - 6. Position under bark
  - 7. Position under petiole

CLASSIFICATION OF PLANTS.

Flowering Plants.

- 1. Series Spermatophyta
  - 1. Class Angiospermæ
    - 1. Dicotyledons
      - 1. Order *Cupuliferæ*
        - 1. Oak, *Quercus*
        - 2. Hazel-nut, *Corylus*
        - 3. Birch, *Betula*
        - 4. Alder, *Alnus*
      - 2. *Salicineæ*
        - 1. Willow, *Salix*
        - 2. Poplar, *Populus*
        - 3. Cottonwood, *Populus*
      - 3. *Urticaceæ*
        - 1. Elm, *Ulmus*
        - 2. Hop, *Humulus*
      - 4. *Compositæ*
        - 1. Aster, *Aster*
        - 2. Dandelion, *Taraxacum*
      - 5. *Labiatæ*
        - 1. Sage, *Salvia*
        - 2. Monkey-flower, *Mimulus*
      - 6. *Umbeliferæ*
        - 1. Parsnip, *Thaspium*
        - 2. Carrot, *Daucus*
      - 7. *Leguminosæ*
        - 1. Locust, *Robinia*
        - 2. Bean, *Phaseolus*
        - 3. Lupine, *Lurpinus*
      - 8. *Rosaceæ*
        - 1. Rose, *Rosa*
        - 2. Apple, *Pyrus*
        - 3. Cherry, *Prunus*
        - 4. Strawberry, *Fragaria*
        - 5. Raspberry, *Rubus*
        - 6. Plumb, *Prunus*
      - 9. *Ranunculaceæ*
        - 1. Buttercup, *Ranunculus*
        - 2. Marsh-marigold, *Caltha*
        - 3. Larkspur, *Delphinum*
        - 4. Virgin's-bower, *Clematis*
    - 2. Monocotyledons
      - 1. *Orchidaceæ*—Lady's-slipper, *Cypripedium*
      - 2. *Iridaceæ*—Flag, *Iris*
      - 3. *Liliaceæ*
        - 1. Onion, *Allium*
        - 2. Camass, *Camassia*
        - 3. Lily, *Lilium*
      - 4. *Graminæ* (grasses)
        - 1. Timothy, *Phleum*
        - 2. Barley, *Hordeum*
        - 3. Wheat, *Triticum*
        - 4. Corn, *Zea*
        - 5. Bluegrass, *Poa*
      - 5. *Juncaceæ* (rushes)
        - 1. Bog-rush, *Juncus*
        - 2. Wood-rush, *Luzuala*
      - 6. *Typhaceæ*—Cat-tail, *Typha*
  - 2. Class Gymnospermæ *Conifers*
    - 1. Pine, *Pinus*
    - 2. Spruce, *Picea*
    - 3. Fir, *Abies*
    - 4. Juniper, *Juniperus*
    - 5. Arbor-vitæ, *Thuja*
    - 6. Redwood, *Sequoia*
    - 7. Larch, *Larix*

FLOWERLESS PLANTS (Cryptogams).

Mosses and Ferns.

2. Pteridophyta
   1. Club moss, *Lycopodium*
   2. Scouring rushes (horestails) *Equisetum*
   3. Ferns, *Filicales*
      1. Spleenwort, *Asplenium*
      2. Christmas fern, *Aspidium*
      3. Bracken fern, *Pteris*
      4. Maidenhair, *Adiantum*

3. Bryophyta
   1. Mosses, *Musci*
      1. *Polytrichium*
      2. *Hypnum*
      3. *Dicranum*
   2. Liverworts, *Hepaticæ*
      1. *Jungermania*
      2. *Marchantia*

Algi and Fungi.

- 4. Thallophyta
  - 1. Algi
    - 1. Higher algi, *Characeæ*, stoneworts
      - 1. *Chara*
      - 2. *Nitella*
    - 2. Brown algi, *Phæophyceæ*, brown seaweeds
      - 1. *Laminaria*
      - 2. *Fucus*
    - 3. Red algi, *Rhodophyceæ*, red seaweeds
      - 1. *Dasya*
      - 2. *Ptilota*
    - 4. Green algi, *Chlorophyceæ*, pond-scum
      - 1. *Desmids*
      - 2. *Pleurococcus*
      - 3. *Spirogyra*
    - 5. Blue algi, *Cyanophyceæ*, jelly colonies
      - 1. *Oscillaria*
      - 2. *Nostoc*
  - 2. Lichens, *Lichenes*
    - 1. Crusted and scaly, *Collema*
    - 2. Filiform and branched, *Usnea*
  - 3. Fungi
    - 1. Basidia fungi, *Basidiomycetes*
      - 1. Toadstools, *Polyporus*
      - 2. Mushroom, *Boletus*
      - 3. Puffballs, *Crucibulum*
    - 2. Polymorphic fungi, *Æcydiomycetes*
      - 1. Smuts, *Phragmidium*
      - 2. Rust, *Puccinia*
    - 3. Sac-fungi, *Ascomycetes*
      - 1. Mildews, *Microsphæra*
      - 2. Blue Mold, *Penicillium*
    - 4. Alga-fungi, *Phycomycetes*
      - 1. Bread Mold, *Mucor*
      - 2. Water Mold, *Saprolegnia*
    - 5. Yeast, *Bread yeast—Saccharomyces cerevisiæ*
    - 6. Bacteria, *Schizomycetes*
      - 1. *Spirillum*
      - 2. *Vibrio*
      - 3. *Bacillus*
      - 4. *Micrococcus*
    - 7. Slime Molds, *Myxomycetes*

IX. Classification of Animals.

METAZOA.

SUBKINGDOMS AND CLASSES OF ANIMALS.

Animal Kingdom
1. Series Metazoa (many-celled)
2. Series Protozoa (one-celled)

Subkingdoms
1. Vertebrata (animals with back-bone)
2. Arthropoda (animals with segmented body and jointed legs)
3. Mollusca (soft body covered with mantle)
4. Vermes (bilateral, with no legs)
5. Echinodermata (radiate, with leathery or spiny covering
6. Cœlenterata (radiate, with tentacles and nettling cells
7. Porifera (sponge-like animals)
8. Protozoa (no true tissues, single cells)

Classes of Vertebrates
1. Mammals (suckle the young)
2. Birds (feathered, wings, lungs)
3. Reptiles (lungs and scales)
4. Amphibians (gills and lungs)
5. Fishes (permanent gills, fins)

Classes of Arthropods
1. Insecta (six legs, distinct head, thorax, and abdomen)
2. Arachnida (eight legs, head and thorax united)
3. Myriapoda (many legs, body of distinct segments)
4. Crustacea (more than eight legs, gills)

Classes of Mollusks
1. Cephalopoda (head with arms around the mouth)
2. Gasteropoda (shell of one valve, tentacles)
3 Lamellibranchiata (shell of two valves)

Classes of Worms
1. Annelides (worms with soft body of similar segments)
2. Brachiopoda (worms with shells)
3. Polyzoa (minute, composite worms)
4. Rotifera (minute ciliated worms)
5. Nematelminthes (thread-like, not jointed)
6. Platyhelminthes (flatworms)

Classes of Echinoderms
1. Holothuroidea (cylindrical and soft body)
2. Echinoidea (covered with spinous shell)
3. Asteroidea (body star-shaped)
4. Crinoidea (cup-shaped body, stalked)

Classes of Cœlenterates
1. Ctenophora (transparent body with eight rows of paddles)
2. Anthozoa (soft body with radiating septa)
3. Hydrozoa (simple bag-like body)

Classes of Porifera
1. Spongida (collection of cells held together by a fibrous skeleton

Classes of Protozoa
1. Infusoria (covered with cuticle and cilia)
2. Gregarinida (a single worm-like cell)
3. Rhizopoda (having root-like feet)
4. Monera (homogeneous protoplasmic body)

ORDERS OF MAMMALS AND SOME COMMON GENERA.

1. Primates, *great toe*
   1. Man, *Homo*
   2. Gorilla, *Troglodytes*
   3. Orang-outang, *Simia*
   4. Gibbon, *Hylobates*
   5. Monkey, *Ateles*

2. Prosimii, *arboreal, clawed*—Lemur, *Lemur*

3. Carnivora, *flesh-eaters*
   - pinnigrade:
     1. Seal, *Phoca*
     2. Walrus, *Trichecus*
     3. Sea-lions, *Zalophus*
   - plantigrade:
     4. Bear, *Ursus*
     5. Badger, *Taxidea*
     6. Raccoons, *Procyon*
   - digitigrade:
     7. Lion, *Felis*
     8. Tiger, *Felis*
     9. Leopard, *Felis*
     10. Panther, *Felis*
     11. Cat, *Felis*
     12. Dog, *Canis*
     13. Wolf, *Canis*
     14. Fox, *Vulpes*
     15. Coyote, *Canis*
     16. Otter, *Lutra*
     17. Weasel, *Putorius*
     18. Mink, *Lutreola*
     19. Skunk, *Mephites*

4. Ungulata, *hoofed*
- 1. Ox, *Bos* (ruminants)
- 2. Camel, *Camelus* (ruminants)
- 3. Deer, *Cervus* (ruminants)
- 4. Elk, *Alces* (ruminants)
- 5. Sheep, *Ovis* (ruminants)
- 6. Goat, *Capra* (ruminants)
- 7. Pig, *Sus*
- 8. Hippopotamus, *Hippopotamus*
- 9. Rhinoceros, *Rhinoceros*
- 10. Tapir, *Tapirus*
- 11. Horse, *Equus*

5. Proboscidia, *with proboscis*
- 1. Mastodon, *Mastodon*
- 2. Elephant, *Elephas*

6. Sirenia, *herbivorous*
- 1. Manatee, *Manatus*
- 2. Dugong, *Halicore*

7. Cetaceæ *carnivorous*
- 1. Whale, *Physeter*
- 2. Porpoise, *Phocæna*
- 3. Dolphin, *Delphinus*

8. Cheiroptera, *winged*—Bats, *Lasiurus*

9. Insectivora, *insect-feeders*
- 1. Mole, *Scalops*
- 2. Shrew, *Sorex*
- 3. Hedgehog, *Erinaceus*

10. Rodentia, *gnawers*
- 1. Guinea-pig, *Cavia*
- 2. Beaver, *Castor*
- 3. Rabbit, *Lepus*
- 4. Mice, *Mus*
- 5. Rats, *Mus*
- 6. Muskrat, *Fiber*
- 7. Squirrel, *Sciurus*

11. Edentata, *toothless*
- 1. Armadillo, *Dasypus*
- 2. Sloths, *Bradypus*
- 3. Ant-eaters, *Myrmecophaga*

12. Marsupalia, *pouched* (didelphia)
- 1. Kangaroo, *Macropus*
- 2. Opossum, *Didelphus*

13. Monotremata (ornithodelphia)
- 1. Duckbill, *Platypus*
- 2. Spiny-anteater, *Echidna*

ORDERS OF BIRDS AND SOME COMMON GENERA.

1. Insessores, *singing birds, three toes in front, perchers*	1. Raven, *Corvus*
	2. Magpie, *Pica*
	3. Crow, *Corvus*
	4. Blackbirds, *Agelaius*
	5. Lark, *Sturnella*
	6. Starling, *Sturnus*
	7. Vireos, *Vireo*
	8. Waxwings, *Ampelis*
	9. Swallows, *Hirundo*
	10. Wrens, *Campylorhynchus*
	11. Thrush, *Turdus*
	12. Blue-birds, *Sialia*
	13. Robin, *Erythacus*
	14. Mockingbird, *Mimus*
	15. Kinglet, *Reglus*
	16. Chickadee, *Parus*
	17. Jays, *Cyanura*
	18. Finch, *Carpodacus*
	19. Grosbeak, *Hedymeles*
	20. Song-sparrow, *Melospiza*
	21. Oriole, *Icterus*
	22. Sparrow, *Passer*
	23. Bobolink, *Dolichonyx*
	24. Pewees, *Sayornis*
	25. Starling, *Sturnus*
	26. King-bird, *Tyrannus.*
	27. Vireo, *Vireo*
	28. Nightingale, *Daulias*
	29. Linnet, *Linaria*
	30. Snow-finch, *Montifringilla*
	31. Canary, *Serinus*
2. Psittaci, *fleshy tongue, stout curved beak, arboreal*	1. Cockatoos, *Plictolopleus*
	2. Lory, *Trichoglossus*
	3. Parrots, *Psittacus*
	4. Love-birds, *Agapornis*
3. Picariæ, *paired toes, ærial*	1. Swifts, *Chætura*
	2. Humming-birds, *Trochilus*
	3. Woodpeckers, *Melanerpes*
	4. Cuckoos, *Coccyzus*
	5. Trogons, *Tmetotrogon*
4. Raptores, *strongly hooked bill and talons, preying*	1. Eagle, *Aquila*
	2. Hawks, *Aocipiter*
	3. Owls, *Nyctea*
	4. Vulture, *Cathartes*
	5. Condor, *Carcorhampus*
	6. Buzzard, *Buteo*

5. Columbæ, *long wings, slender legs, perching feet*	1. Pigeon, *Ectopistes* 2. Rock-dove, *Columba* 3. Mourning dove, *Zneaida* 4. Dodo, *Didus*
6. Rasores, *stout beak, legs and claws, scratchers*	1. Fowl, *Gallus* 2. Prairie-hen, *Tympanuchus* 3. Sage-cock, *Centrocercus* 4. Quail, *Colinus* 5. Golden pheasant, *Thaumalia* 6. Peacock, *Pavo* 7. Guinea-hen, *Numida* 8. Turkey, *Meleagris*
7. Grallatores, *long bill neck and legs, waders*	1. Cranes, *Grus* 2. Snipes, *Scolopax* 3. Storks, *Ciconia* 4. Bittern, *Botaurus* 5. Plovers, *Ægialites*
8. Lamellirostres, *long, flat soft bill, webbed feet*	1. Flamingo, *Phœnicopterus* 2. Coot, *Fulica* 3. Water-hen, *Galinula* 4. Ducks, *Anos* 5. Geese, *Anser* 6. Swans, *Cygnus*
9. Totipalmates, *long, curved beaks, webbed feet, carnivorous*	1. Cormorants, *Graculus* 2. Pelicans, *Pelicanus* 3. Gannet, *Sula*
10. Longipennes, *long, pointed wings, flyers, carnivorous*	1. Gulls, *Larus* 2. Terns, *Sterna* 3. Albatross. *Diomedea* 4. Petrels, *Ossifraga*
11. Pygopodes, *legs far back, short wings, divers*	1. Penguins, *Aptenodytes* 2. Auks, *Alca* 3. Loons, *Colymbus* 4. Grebes, *Podicipes*
12. Cursores, *rudimentary wings, stout legs, runners*	1. Ostrich, *Rhea* 2. Cassowary, *Casuarius* 3. Emu, *Dromæus* 4. Kiwi, *Apteryx*

ORDERS OF REPTILES AND SOME COMMON GENERA.

1. Crocodilia
1. Crocodile, *Crocodilus*
2. Gavial, *Gavialis*
3. Alligator, *Alligator*

2. Chelonia
1. Green turtles, *Chelonia*
2. Snapping turtle, *Chelydra*
3. Mud-turtle, *Pseudemys*
4. Painted turtle, *Chrysemys*
5. Terrapins, *Terrapene*
6. Land-tortoise, *Clemmys*
7. Chicken-tortoise, *Emys*

3. Lacertilia
1. Horned toad, *Phrynosoma*
2. Land lizard, *Lacerta*
3. Common lizard, *Sceloporus*
4. Geckos, *Gecko*
5. Dragons, *Draco*
6. Chameleon, *Anolis*
7. Gila monster, *Heloderma*

4. Ophidia
1. Boas, *Boa*
2. Viper, *Heterodon*
3. Rattlesnake, *Crotalus*
4. Green-grass snake, *Liopeltes*
5. Striped garter-snake, *Thamnophis*
6. Spotted adder, *Lampropeltes*
7. Blacksnake, *Bascanion*
8. Water-snake, *Natrix*

ORDERS OF AMPHIBIA AND SOME COMMON GENERA.

1. Anura
1. Toads, *Bufo*
2. Bullfrog, *Rana*
3. Tree-frog, *Hyla*
4. Flying frog, *Rhacophorus*

2. Apoda, *blind and worm-like—Cœcilia*

3. Urodela, *tailed*
1. Newt, *Molge*
2. Salamander, *Amblystoma*
3. Hellbender, *Cryptobranchus*

4. Proteida, *embryonic*
1. Axolotl, *Siredon*
2. Furrowed salamander, *Necturus*

Some Orders and Common Genera of Fishes.

1. Dipnoi, *Eel-like, with gills and bladder-like lungs*
   1. Australian lungfish, *Ceratodus*
   2. S. American mudfish, *Lepidosiren*
   3. African mudfish, *Protopterus*

2. Teleostei, *bony fishes*
   1. Cod, *Gadus*
   2. Herring, *Clupea*
   3. Bluefish, *Pomatomus*
   4. Bullhead, *Ameiurus*
   5. Toadfish, *Batrachus*
   6. Searobin, *Prionotus*
   7. Rockfish, *Roccus*
   8. Perch, *Perca*
   9. Bass, *Micropterus*
   10. Salmon, *Salmo*
   11. Flounder, *Paralichthys*
   12. Flying fish, *Exocœtus*
   13. Dogfish, *Amia*
   14. Pickerel, *Esox*
   15. Trout, *Salvelinus*
   16. Whitefish, *Coregonus*
   17. Snakefish, *Synodus*
   18. Anchovies, *Stolephorus*
   19. Shad, *Dorosoma*
   20. Ladyfish, *Albula*
   21. Minnows, *Notropis*
   22. Suckers, *Catostomus*
   23. Catfish, *Ameirus*
   24. Smelts, *Mallotus*
   25. Eels, *Echelus*
   26. Swordfish, *Remora*
   27. Mackerel, *Scomber*
   28. Halibut, *Hippoglossus*

3. Ganoids, *heterocercel tail, skeleton incomptetely ossified*
   1. Spoonbill, *Polyodon*
   2. Sturgeon, *Acipencer*
   3. Gar-pike, *Lepisosteus*
   4. Mudfish, *Amia*

4. Elasmobranchs, *uncovered gills, cartilaginous*
   1. Dogfish, *Squalus*
   2. Shark, *Carcharhinus*
   3. Ray, *Torpedo*
   4. Skate, *Raja*
   5. Sea-devils, *Manta*
   6. Chimæra

ORDERS OF ARACHNIDA AND SOME COMMON GENERA.

1. Araneina, *spiders with cephalothorax, eight legs*
    1. Garden-spider, *Epeira*
    2. House-spider, *Theridium*
    3. Crab-spider, *Myale*
    4. Running spider, *Lycosa*
    5. Jumping spider, *Attus*
    6. Grass-spider, *Agalena*
    7. Trap-door spider, *Cteniza*
    8. Wheelweb-spider, *Argiope*
    9. Water-spider, *Argyronetra*
2. Arthrogastra, *jointed abdomen, clawed palpi*
    1. Scorpion, *Centrurus*
    2. Harvestman, *Phalangium*
3. Acarina, *divisions of the body united*
    1. Mites, *Acarus*
    2. Ticks, *Ixodes*

ORDERS OF INSECTS AND SOME COMMON GENERA.

1. Hymenoptera, *mostly social*
    1. Bees
        1. Hive-bees, *Apis*
        2. Humblebees, *Bombus*
        3. Leaf-cutters, *Megachile*
        4. Mason-bees, *Osmia*
        5. Carpenter-bees, *Xylocopa*
    2. Ants, *Formica*
    3. Wasps, *Vespa*
    4. Ichneumons, *Pimpla*
    5. Gall-flies, *Rhodites*
    6. Saw-flies, *Tremex*
2. Lepidoptera, *scaly, mouth a proboscis*
    1. Butterflies
        1. *Papilio*
        2. *Terias*
        3. *Vanessa*
        4. *Anosia*
    2. Clothes-moth, *Tinea*
    3. Regal moth, *Citheronia*
    4. Sphinx, *Smerinthus*
    5. Codling, *Carpocapsa*
    6. Silkworm, *Bombyx*
    7. American silk, *Polyphemus*
3. Diptera, *one pair membranous wings*
    1. Bot-fly, *Gasterophilus*
    2. House-fly, *Musca*
    3. Mosquito, *Culex*
    4. Flea, *Pulex*
    5. Daddy-long-legs, *Tipula*
    6. Flesh-fly, *Sarcophaga*
    7. Horse-fly, *Tobamis*
    8. Hessian-fly, *Cecidomyia*

4. Coleoptera, *Chitinous Elytra*

1. Tiger-beetle, *Cicindela*
2. Potato-beetle, *Doryphora*
3. Ground-beetles, *Harpalus*
4. Water-beetles, *Dytiscus*
5. Ladybirds, *Coccinella*
6. Weevils, *Balaninus*
7. Bark-borers, *Dendroctonus*
8. Fireflies, *Lampyris*
9. Carrion-beetle, *Silpha*
10. Tumblebugs, *Phanæus*
11. June-bug, *Sachnosterna*
12. Goldsmith-beetle, *Cotalpa*
13. Sexton-beetle, *Necrophorus*

5. Hemiptera, *bugs*

1. Bedbug, *Cimex*
2. Louse, *Pediculus*
3. Squash-bug, *Anasa*
4. Assassin-bug, *Reduvius*
5. Water-boatman *Notonecta*
6. Water-strider, *Hygrotrechus*
7. Plant-louse, *Aphis*
8. Apple-blight insect, *Schizoneura*
9. Scale insect, *Coccidæ*
10. Cochineal insect, *Coccus*

6. Orthoptera, *fore wing straight and narrow*

1. Cricket, *Gryllus*
2. Grasshopper, *Acrydium*
3. Cockroach, *Blatta*
4. Locust, *Locusta*
5. Stick insect, *Daphomera*
6. Leaf insect, *Phyllium*
7. Earwigs, *Forficula*
8. Seventeen-year locust, *Cicada*
9. Book-lice, *Psocus*

7. Neuroptera, *long, lacy, equal wings*

1. Dragon-fly, *Libellula*
2. White ants, *Termes*
3. Caddis-flies, *Phryganea*
4. May-flies, *Ephemera*
5. Lace-wing flies, *Hemerobiu*

ORDERS OF CRUSTACEA AND SOME COMMON GENERA.

1. Decapods, *ten limbs*

1. Lobster, *Homarus*
2. Crab, *Cancer*
3. Crayfish, *Astacus*
4. Shrimp, *Crangon*
5. Prawns, *Pandalus*
6. Hermit-crab, *Pagurus*

- 2. Tetradecapods, *fourteen-footed*
  - 1. Sand-flea, *Gammarus*
  - 2. Wood-louse, *Oniscus*
- 3. Entomostracans, *variable number of legs*
  - 1. Brine-shrimp, *Artemia*
  - 2. Water-flea, *Cyclops*
  - 3. Shell-flea, *Daphnia*
- 4. Cerripedes, *limbs feathery, shelled*
  - 1. Goose-barnacle, *Lepas*
  - 2. Acorn-barnacle, *Balanus*

SOME CLASSES, ORDERS, AND GENERA OF MOLLUSKS.

- 1. Class Lamellibranchs, *bivalved shell*
  - 1. Order Monomya
    - 1. Oyster, *Ostrea*
    - 2. Scallop, *Picten*
  - 2. Heteromya—Sea-mussel, *Mytilus*
  - 3. Isomya
    - 1. Fresh-water mussel, *Unio*
    - 2. Clam, *Mya*
    - 3. Quohog, *Venus*
- 2. Class Gasteropoda, *mollusks with univalve shell*
  - 1. Order Pteropods—Sea-butterflies, *Hyalea*
  - 2. Order Opisthobranchs, *with feathery gills*
    - 1. Sea-lemon, *Doris*
    - 2. Sea-hare, *Aplysia*
  - 3. Order Pulmonates, *air-breathers*
    - 1. Sand-snail, *Helix*
    - 2. Slugs, *Limax*
    - 3. Pond-snails
      - 1. *Limnæa*
      - 2. *Planorbis*
  - 4. Order Prosobranchs, *aquatic gasteropods*
    - 1. Limpet, *Patella*
    - 2. Litorina
    - 3. Paludina
    - 4. Nassa
- 3. Cephalopoda, *large mollusks with distinct head*
  - 1. Order Tetrabranchs
    - 1. Pearly, *Nautilus*
    - 2. Extinct, *Ammonites*
  - 2. Order Dibranchs
    - 1. Paper-nautilus, *Argonauta*
    - 2. Poulpe, *Octopus*
    - 3. Squid, *Loligo*
    - 4. Cuttlefish, *Sepia*

Classes of Worms, Some Orders and Genera.

- 1. Class Platyhelminthes, *flat segmented or unsegmented worms*
  - 1. Order Turbellaria, *planarians*
    - 1. *Planaria*
    - 2. *Dendrocœlum*
  - 2. Order Trematodes, *flukes*
    - 1. *Distomum*
    - 2. *Fasciola*
  - 3. Order Cestodes, *tapeworm*
    - 1. Dog, *Tænia*
    - 2. Human, *Bothriocephalus*
- 2. Class Nematelminthes, *round threadworms*
  - 1. Order Acanthocephali, *parasitic, without alimentary canal*—Pig parasite, *Echinorynchus*
  - 2. Order Nematodes, *true roundworms*
    - 1. Human roundworm, *Ascaris*
    - 2. Pinworm, *Oxyuris*
    - 3. Palisade-worm, *Enstrongylus*
    - 4. Pork parasite, *Trichina*
  - 3. Order Chætognathi, *Sagitta*
- 3. Class Rotifers, *microscopic, ciliated worms, wheel animalcules*
  - 1. Oval, cleft tail, *Squamella*
  - 2. Elongate, worm-like, *Rotifer*
  - 3. *Asplanchna*
- 4. Class Polyzoa, *colonial, moss-like worms*
  - 1. Pedicellina
  - 2. Myriozoum
  - 3. Paludicella
  - 4. Plumatella
- 5. Class Brachiopoda, *worms with dorsal and ventral shell resembling mollusks*
  - 1. *Terebratulina*
  - 2. *Lingula*
  - 3. *Discina*
- 6. Class Nemertina, *soft flattened worms, not distinctly segmented*
  - 1. Anopla, *Mekelia*
  - 2. Enopla, *Nemertes*
- . Class Annulata, *many segments with spines or suckers*
  - 1. Order Hirudinea, *leeches*
    - 1. *Hirudo*
    - 2. *Nephelis*
    - 3. *Clepsine*
  - 2. Order Annelides
    - 1. Oligochœta, *earthworms*
      - 1. *Lumbricus*
      - 2. *Nais*
      - 3. *Allalobophora*
    - 2. Chætopoda, *sea-worms*
      - 1. *Nereis*
      - 2. *Clymenella*
      - 3. *Amphitrite*
      - 4. *Cirratulus*

Some Classes, Orders, and Genera of Echinoderms.

1. Class Crinoidea, *radiate animals with jointed flexible stem*
    1. Order Brachiata, *Pentacrinus*
    2. Order Blastoidea, *Pentremites*
    3. Order Cystidea, *Edriaster*
2. Class Asteroidea, *star-fishes with sucking ambulacral feet*
    1. Order Asteroidea, *true starfishes*
        1. *Asterias*
        2. *Archaster*
        3. *Solaster*
        4. *Cribella*
    2. Order Ophiuroidea, *sand-stars and brittle-stars*
        1. *Astrophyton*
        2. *Amphiura*
        3. *Ophioglypha*
        4. *Ophiocoma*
        5. *Ophiothela*
3. Class Echinoidea, *sea-urchins with spherical or flat, spiny body*
    1. Order Antichinida
        1. *Echinus*
        2. *Arbacia*
        3. *Echinarachinus*
        4. *Clypeaster*
    2. Order Spatangida, *Hemiaster*
4. Class Holothuroidea, *sea-cucumber*
    1. Order Apoda, *without ambulacral feet*
        1. Synaptidæ
            1. *Synapta*
            2. *Chirodota*
        2. Molpadidæ
            1. *Molpadia*
            2. *Caudina*
    2. Order Pedata, *with ambulacral feet*
        1. Dendrochirotæ
            1. *Pentacta*
            2. *Thyone*
        2. Aspidochirotæ, *Holothuria*

CLASSES, ORDERS, AND SOME GENERA OF CŒLENTERATES.

- 1. Class Hydrozoa, *radiate animals with distinct digestive tube*
  - 1. Order Hydroidea
    - 1. *Hydra*
    - 2. *Sertularia*
    - 3. *Campanularia*
    - 4. *Obelia*
    - 5. *Hydractinia*
    - 6. *Cordylophora*
  - 2. Order Discophora, *radial canals divided*
    - 1. Trachymedusæ
      - 1. *Ægina*
      - 2. *Charybdæa*
    - 2. Lucernaræ, *Lucernaria*
    - 3. Acalephæ
      - 1. *Pelagia*
      - 2. *Aurelia*
      - 3. *Cyania*
  - 3. Order Siphonophora, *with polymorphic persons*
    - 1. Physophoræ, *Agalma*
    - 2. Physaliæ, *Physalia*
    - 3. Calycophora, *Diphyes*
    - 4. Discoideæ, *Velella*
- 2. Class Actinozoa, *radiate animals such as corals and sea-anemones*
  - 1. Order Zoantharia
    - 1. Sea-anemone, *Actinia*
    - 2. Coral, *Astrea*
    - 3. Coral, *Madrepora*
    - 4. Coral, *Astrangia*
  - 2. Order Alcyonaria
    - 1. Sea-fan, *Gorgonia*
    - 2. Sea-pens, *Pennatulidæ*
- 3. Class Ctenophora, *transparent walnut-shaped animals*
  - 1. Order Eurystomeæ
    - 1. *Idyia*
    - 2. *Beræ*
  - 2. Order Saccatæ, *Pleurobranchia*
  - 3. Order Tæniata, *Cestum*
  - 4. Order Lobatæ, *Bolina*

ORDERS AND SOME GENERA OF SPONGES.

- 1. Order Carneospongiæ, *with flexible, horny framework of fibers*
  - 1. Fresh-water sponge
    - 1. *Spongilla*
    - 2. *Siphydora*
  - 2. Marine sponge
    - 1. *Chalinula*
    - 2. *Spongia*
    - 3. *Axinella*
  - 3. Venus flower-basket, *Euplectellum*
- 2. Order Calcispongiæ, *with calcareous spicules*—Sycon

PROTOZOA.

Classes of Protozoa, Some Orders and Species.

1. Class Infusoria, *unicellular, ciliated, with permanent form*
   - 1. Order Ciliata
     - 1. *Paramecium*
     - 2. *Stentor*
     - 3. *Vorticella*
     - 4. *Epistylus*
   - 2. Order Tentaculifera, *Acineta*
   - 3. Order Flagellata
     - 1. *Monas*
     - 2. *Noctiluca*

2. Class Gregarinida, *unicellular, thread- or worm-like, parasiticforms* (*Gregarina*)

3 Class Rhizopoda, *unicellular, with soft body and root-like pseudopodia*
   - 1. Order Foraminifera
     - 1. *Amœba*
     - 2. *Globigerina*
     - 3. *Rotalia*
     - 4. *Polystomella*
   - 2. Order Radiolaria
     - 1. Fresh water, *Actinophrys*
     - 2. Marine, *Collosphæra*

4. Class Monera, *unicellular forms with no distinct nucleus*
   - 1. Order Gymnomonera
     - 1. *Protamœba*
     - 2. *Myxodictyum*
   - 2. Order Lepomonera
     - 1. *Protomonas*
     - 2. *Protomyxa*

CHAPTER IV

Material and Equipment

XIV. Collecting and Preserving Material

Saturday and vacation excursions offer best opportunities for collecting. Each member of the party should be provided with something in which to carry the material collected. Small baskets, bags, tin cans, and bottles will do.

For collecting plants a rubber bag or a tin can, which prevent evaporation and hence the wilting of the specimens, are desirable. A convenient form of collecting can is an oval, elongated one with a hinged lid on one side. Eighteen inches long, with ends 9 inches by 6 inches, is a convenient size. It should be provided with loops for straps, by which it can be suspended from the shoulder. Any tinner will make such a can for about $1 or $1.50. It can also be purchased from dealers (see below).

For preserving plants, they should be pressed while fresh; if possible, the same day as collected or at least early next day. Wrapping them in moist paper or sprinkling them in the can with water will preserve them from withering for some time. In order to preserve its form and color the plant should be placed between blotting-paper (or porous carpet-paper) with pieces of newspaper between. A convenient size of dryers is 18 inches by 12 inches.

All parts of the plant, root, stem, leaf, and fruit should be preserved if possible; and it should be so placed in the dryers as to exhibit the natural appearance when dried. The dryers are then piled up one on top of the other, and are finally placed between two boards of the same size as the dryers. Considerable pressure is then produced, either by a heavy weight, such as a large stone, or better by a stout cord or rope wound around projecting cleats fastened to the boards. Such convenient portable hand-presses can also be purchased for $2 (see below).

The dryers should be changed at first once a day to preserve the natural color. If the dryers are allowed to remain moist, the specimen it apt to turn brown. *For mounting specimens* good stiff white paper should be used. It can be obtained from dealers at a small cost (see below). The specimen, when thoroughly dried and pressed, is placed on the mounting paper and fastened by means of glue, or better, narrow strips of white court-plaster. Some taste should be used in placing the specimen on the sheet and in making the sticking strips as inconspicuous as possible. A label bearing the owner's name, printed at the top, is placed in the right hand-lower corner, the edges coinciding with the edge of the sheet. On this is neatly written, in pen and ink, the date of collection, the locality, kind of soil, the scientific and common name. A convenient size for these labels is 3½ by 1½ inches. Printers usually charge about 15 cts. per hundred for them.

All specimens belonging to the same genus (or order) are then placed into covers of strong Manilla paper with the genus or order written in the right lower corner. Finally, these are placed in portfolios manufactured expressly for that purpose. They can be had from dealers at prices ranging from 35 cts. to $1.

Animals.

For collecting animals, a small leather grip, containing bottles of various sizes partly filled with alcohol, is convenient. A tin pail, with a cover having a hinge in the middle, so that one-half the cover can be opened, is also convenient. Tinsmiths make them to order at a small cost.

Instead of alcohol a 5% aqueous solution of Formaldehyde (Formalin) may be used. This is very much cheaper than alcohol and preserves some delicate organisms like jellyfishes beautifully. Alcohol, however, is better for general use.

On Raising Insects for Study. The life history of insects is exceedingly interesting. To actually observe this life history is worth considerable trouble, even if that were necessary to secure the specimen. Seeing the actual transformation of an insect is a revelation compared with merely reading an account of it. But insects are very easily reared. The simplest and, in many localities, the most convenient insect for study is the "potato-bug." Its eggs are found on the under side of the leaf of the potato, where they can be readily watched while hatching. It requires but little attention to see this beetle actually lay its eggs. Dragonflies often deposit their eggs when held in the hand, and moths kept in confinement lay their conspicuous eggs where they can readily be seen. In the case of the potato-beetle, it is an easy matter to watch the gradual transformation of the egg into the larva, and to observe this transforming itself into the adult beetle. But their history is not so interesting as that of the common fly, butterflies, and moths.

Flies can be reared for study in the following way: (1) Soak some beans for a week or two; (2) place soaked decaying beans, or other decaying substance, in a dish covered with a bell jar (a common saucer covered with a tumbler will do for a moist chamber); in warm weather flies are attracted by the odor, and if carefully watched they can be seen projecting a tube under the cover into the decaying substance. The eggs can actually be seen through this tube as they pass down one by one and are placed regularly in tiers. These eggs then begin to hatch and after a time are converted into worm-like larvæ, usually called maggots. Observe these through the glass. After some days of feeding, they begin to crawl around on the glass and finally come to rest, gradually changing their color from white to a dark brown—the pupa. Observe the actual transformation. After two weeks the real fly can be seen coming out through an opening of one end of the brown shell.

Butterflies. Collect some of the large larvæ walking over leaves or stems or sometimes on the ground. Note the kind of plant they live on, and supply them for a few days with fresh food of the same kind.

They may be kept in paper boxes if nothing better can be had; a very convenient cage can be made from an ordinary sieve into which is fitted, as a cover, an ordinary kitchen fly-screen. This allows circulation of the air, and gives an unobstructed view of the larva at work. The pupation usually takes place in a few days, for when the larva begins to wander about, it is a sign that it is looking for a suitable place to remain during the pupa stage. The final transformation takes place the next spring in May and June after an apparent sleep of six or eight months.

Moths can be secured as larvæ; or the adult moth may be taken and kept for a few days, when it will lay its eggs. From these then the larvæ can be reared. (See pupil's paper in Part I on the "Sage Galls and Their Inhabitants.")

On Killing Insects. Insects and similar organisms should first be put into a cyanide bottle. This can be made without much difficulty as follows: Put a few lumps of Potassium Cyanide (druggists keep it) into a wide-mouthed bottle; or, better, a small museum or preserving jar; cover the cyanide with cotton batting, and place over it all a piece of stiff paper cut to fit the inside of the bottle or jar; fasten the edges of this paper with glue after having punctured a few holes in it for the fumes to pass through. Keep the bottle or jar constantly closed, for the fumes are poisonous. An insect put into such a jar will be put to sleep in a few minutes, but often recovers if removed too soon.

A collecting-net is very essential. It can be made very cheaply from cheese-cloth, a stiff wire, and a broom-handle. The cheese-cloth is made into a bag about 2 feet long. The free edge of this bag is wound around the stout, stiff wire bent into a circle about 1½ feet in diameter, and sewed firmly to it. The ends of the bent wire are crossed and tied firmly to the handle (bamboo may be used), about 4 feet long. This may be done by winding fine wire around the crossed ends of the hoop after making a notch in the end of the handle to receive the crossed hoop wires.

A pair of forceps and a stout knife are also essential. Equipment of all kinds, like those enumerated above, can be purchased from Bausch and Lomb, Rochester, New York, by sending directly to them. They also have branch houses in Chicago and San Francisco. Druggists can frequently supply alcohol, formalin, viols, etc.

The following items, with the price of each, are taken from the Catalog (sixteenth edition) of the Pacific Micro-Materials Company, 432 Montgomery Street, San Francisco:

1. Drying Paper, extra heavy, 33×46 cm., per hundred, $1.00.

2. Genus Covers, 42.5×61.3 cm., extra quality, per hundred, $2.00.

3. Mounting Paper, 29.2×42 cm., purest and strongest stock per ream, $4.50.

4. Portable Plant Press, elastic bands with six dryers, $2.00.

5. Vasculum (collecting-box) enameled, each, $1.50.

6. Hand-lenses of various makes can be had for from 20 cts. to $2.00.

7. Forceps, medium fine, straight points, file-cut edge, each, 40 cts.

8. Scalpels, with ebony handle, best steel, each, 35 cts.

For $5 can be had the following complete set of instruments of the best quality of steel in Morocco-leather two-fold case, with velvet lining and chamois-skin protecting flaps: Catalog No. 1612. It contains:

1	Scalpel, No.	1458;	all steel ,edge	45 mm.
1	" "	1462;	" " "	32 "
1	" "	1464;	" " "	25 "
1	Scissors, "	1550;	fine, straight.	
1	" "	1560;	heavy "	140 mm. long.
1	Forceps, "	1394;	for vertebrate work.	
1	" "	1388;	heavy, straight, 120 mm. long.	

1 Cartilage Knife, No. 1492; all steel, edge 45 mm.
1 Tenaculum, No. 1596.
1 Seeker, No. 1590.
1 Triple Chain and Hooks, No. 1430.
1 Blow-pipe, No. 1370.

XI. Reference Books for the Teacher's Library.

1. Wood's New Illustrated Natural History. George Routledge & Sons, New York.
2. Animal Life, by Jordan and Kellogg. D. Appleton & Co., New York.
3. Introduction to Zoology, by Davenport. The Macmillan Company, New York.
4. Plants, by John M. Coulter. D. Appleton & Co., New York.
5. The Foundations of Botany, by Bergen. Ginn & Co., Boston.
6. The Structure and Habits of Spiders, by J. H. Emerton. B. Whidden, Boston.
7. Manual of the Vertebrates, by David Starr Jordan. A. C. McClurg & Co., Chicago.
8. Flowers and Ferns in their Haunts, by M. O. Wright. The Macmillan Company, New York.

9. Nature Study and Life, by C. F. Hodge. Ginn & Co., Boston.
10. Outlines of Botany, by R. G. Leavitt. American Book Company, Chicago.
11. Johnson's Natural History, by S. G. Goodrich. A. J. Johnson, New York.
12. The Royal Natural History, edited by Richard Lydekker. Frederick Warne & Co., New York. 5 vols.
13. Gray & Coulter's Text-book of Botany. American Book Company, Chicago.
14. The Butterfly Book, by W. J. Holland. Doubleday & McClure Co., New York.
15. Bird Neighbors, by Neltje Blanchau. Doubleday & McClure Co.
16. Comparative Zoology, by James Orton. American Book Company, Chicago.
17. Animals and Plants under Domestication, by Charles Darwin. D. Appleton & Co., New York.
18. Origin of Species, by Charles Darwin. D. Appleton & Co., New York.
19. Lay Sermons, Addresses, and Reviews, by T. H. Huxley. D. Appleton & Co., New York.
20. Apes and Monkeys, by R. L. Garner. Ginn & Co., Boston.
21. Nature Study in Elementary Schools, by Mrs. L. L. Wilson. The Macmillan Company, New York.
22. Nature Study, by Jackman. Henry Holt & Co.
23. One Hundred Lessons in Nature, by Frank O. Payne. E. L. Kellogg Co.
24. Handbook of Nature Study, by D. Lange. The Macmillan Company, New York.
25. How to Know the Wild Flowers, by Mrs. William Starr Dana. Charles Scribner's Sons, New York.
26. Lives of the Hunted, by Ernest Seton-Thompson. Charles Scribner's Sons, New York.
27. Wild Animals I Have Known, by Ernest Seton-Thompson. Charles Scribner's Sons, New York.
28. The Beauties of Nature, by Sir John Lubbock. The Macmillan Company, New York.
29. The Friendship of Nature, by Mabel Osgood Wright. The Macmillan Company, New York.
30. Short Studies in Nature Knowledge, by William Gee. The Macmillan Company, New York.
31. Wake-Robin, by John Burroughs. Houghton, Mifflin & Co., Boston and New York.
32. Fresh Fields, by John Burroughs. Houghton, Mifflin & Co., Boston and New York.
33. Birds and Poets, by John Burroughs. Houghton, Mifflin & Co., Boston and New York.
34. Insect Life, by J. H. Comstock. D. Appleton & Co., 1901, New York.

35. How to Know the Ferns, by Frances Theodora Parsons. Charles Scribner's Sons, New York.
36. A Text-Book of Entomology, by A. S. Packard. The Macmillan Company, New York
37. Jelly-fish, Star fish and Sea-urchins, by G. J. Romanes. D. Appleton & Co , New York.
38. Trees of Northern United States, by Austin C. Apgar. American Book Company, Chicago.
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