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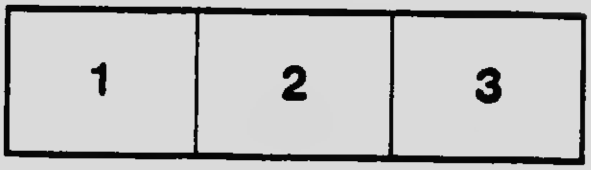
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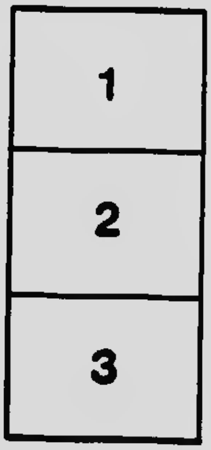
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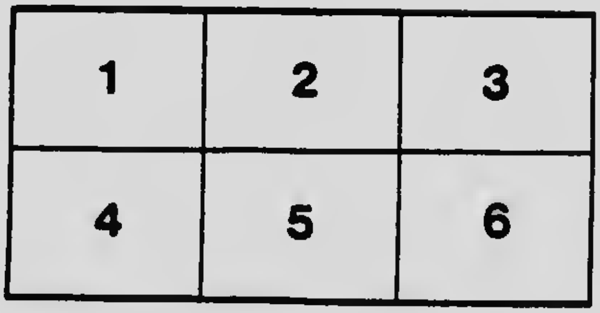
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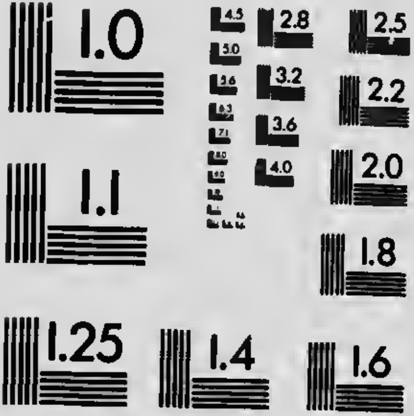

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# SUGGESTIONS
# FOR
# TEACHERS OF SCIENCE

ONTARIO
TEACHERS' MANUALS

# Suggestions for Teachers of Science

IN THE

FIFTH FORMS OF PUBLIC SCHOOLS

AND THE

LOWER SCHOOL CLASSES OF
CONTINUATION AND HIGH SCHOOLS

AUTHORIZED BY THE MINISTER OF EDUCATION

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# PREFACE

The "Suggestions" in the following pages have been prepared mainly in the interests of those teachers in our Continuation and High Schools who, through lack of experience or of proper opportunities, often feel themselves at a loss in dealing with the many details of the Elementary Science work of the Lower School. This Course embraces work in Physics, Chemistry, Botany, and Zoology, and while there are excellent manuals dealing more or less fully with each of these departments, it has been felt that a useful purpose would be served if the beginner in science teaching could have at hand a single reference book containing such hints upon class management, selection of suitable works for extended reading, manipulation of apparatus, and other details, as the experience of some of our teachers of long standing has proved to be of value.

A glance through the pages will show that the "Suggestions" are not in any sense intended to take the place of text-books or to exempt the teacher from the pursuit of information through the channels of the standard literature, but rather by hints and references to stimulate him to personal efforts in various directions. In the part relating to Physics, for example, instead of details of certain experiments which are described in standard text-books, reference is made to those text-books, and the teacher is expected to have them on the library shelves. In Botany and Zoology, in like manner, frequent reference is made to desirable publications in which the suggestions of this Manual are amplified and supplemented, and which the teacher must consult for the best results.

The question of supplies is one which gives a good deal of trouble, not only to the inexperienced, but often to the teacher of long standing, and accordingly considerable attention is paid to this matter also. Suitable lists of materials for biological and other work are suggested and information given as to how and where they may be obtained. These lists, as well as the lists of reference books and those adapted for supplementary reading, may appear formidable, but they are such that selections may be made in accordance with the circumstances of the school, financial and otherwise, and suggestions are offered which will help in the selection.

Another very important matter dealt with is the method of conducting class work. In general it may be said that this method involves much practical work on the part of the pupils. In recent years there has been a satisfactory advance in this direction in the elementary work in Biology and Chemistry. In Physics the tendency is not so marked. There is, however, a great deal of simple experimental work in Physics, requiring no expensive apparatus, which can and should be done by the pupils, and this idea is constantly kept before the teacher in this Manual. But here again, while suggesting a plan of work upon which teachers generally may agree, it is not intended that there should be a rigid uniformity in carrying out the details of the plan, or that the individuality of the teacher should be obscured by a purely mechanical adherence to the outlines of work presented. Nothing can take the place of the teacher's individuality. Certain results are to be accomplished, a certain course of study is to be pursued under the teacher's direction, but different teachers, while following a general scheme recognized by common consent as a desirable one, will put the stamp of different individualities on the mode of presenting the subject, all in the end arriving at the same goal.

To help the young teacher, then, over some of the obstacles which lie in his path, and to stimulate him to wider reading and to the intelligent consideration of how to make the most of the Elementary Science work for the educational value it possesses, is, in a word, the object of these " Suggestions ".

# COURSE IN ELEMENTARY SCIENCE

## ZOOLOGY

### GENERAL SCOPE OF THE WORK

*Indoor Study of Living Animals*: The teacher's immediate responsibility lies in the laboratory work which embodies simple morphological studies of common forms, representing the chief animal types. These studies must, wherever possible, be supplemented or preceded by observation on living specimens. For this purpose, provision will be needed for suitable aquaria and vivaria, where the moving, breathing, and feeding of the living animals may be within ready view of the pupils. Moreover, these morphological studies are not to end in the study of form; behind the observation of the form there must be a constant effort to interpret the meaning of the form, to show the relation of form and function.

Charts and models are not to be substituted for actual specimens.

*Outdoor work*: This will of necessity vary with the locality and must be carried on to a very large extent without the teacher's direct supervision. But the teacher should encourage and direct the pupils, devoting a fair portion of the time of the class to discussions and reports on their independent work. Arrangements should be made for field excursions on suitable occasions.

*School Museum*: For progress in the natural history side of the subject, the equipment detailed on pages 26-32, 71, etc., should be provided. The school museum should be a thing of gradual growth, and great care should be taken in the selection of the material.

## FIRST YEAR

### *September and October*

*Invertebrates.*—Class study of a grasshopper, a spide a centipede.

Comparison of a grasshopper with a cricket or cockroach, leading to the recognition of the order *Orthoptera*

Study of a butterfly and a house-fly with observation on their habits and habitats; feeding and development of butterfly.

*Vertebrates.*—Birds: Study of the external characteristics of a domestic fowl, pigeon, or other common bird; instructions regarding the protection of birds by law. Comparison of the bills and feet of different types of the birds of Ontario.

For Winter: Observation of the winter birds, their feeding habits, their dangers, and modes of protection.

### *April, May, and June*

*Invertebrates.*—Class study of the fresh-water clam and the earthworm.

Observations on the mosquito, the prevalence of its larvæ in wet places and their destruction by kerosene.

*Vertebrates.*—Fishes: Study of the external characteristics of a common fish. Structure of the gills and the manner of breathing.

Amphibians: Study of the external characters of a common frog; of its development from the egg. Economic importance of frogs and toads. Feeding habits of a common fish, frog, or toad.

Migration of birds: Identification of twelve common birds; sufficient description for this purpose to be recorded.

A collection of insects to be made in the first year.

## SECOND YEAR

### *September and October*

*Invertebrates.*—Study of the life history, habits, and methods of feeding of six beneficial or injurious insects (some of each); methods of combating the attacks of the injurious forms.

*Vertebrates.*—Mammals: Study of the external characteristics of a cat, dog, or rabbit; chief characters of the skeleton of a mammal, such as a cat. Recognition of the common wild mammals of the locality, and observations on their habits, including winter habits.

### *April, May, and June*

*Invertebrates.*—Class study of the external characters of a crayfish and a wood louse (*Oniscus*).

*Vertebrates.*—Reptiles: Study of the external characters of a snake and a turtle, and observations on the habits and feeding of these animals.

Continuation of the observations on the life and habits of birds and other animals studied.

General review of the whole Course, including an outline of classification as shown by the animals studied.

## BOTANY

Remarks similar to those introducing the Course in Zoology will apply also to the work in Botany. In particular, it is urged upon the instructor that he should constantly stimulate the effort to interpret the meaning of the forms under observation—to discover where possible the relation between form and function.

## FIRST YEAR

### *September and October*

*The Plant as a whole*: A detailed study of some common plant such as a petunia or a buttercup, taking up the structure of all the parts in succession; the study of additional plants as a basis for the classification of roots, stems, foliage leaves, and inflorescence; the study to be such as can be carried on with the aid of an ordinary lens.

*Roots*: Varieties of form.

*Stems*: Varieties of form; erect, prostrate, climbing, twining, subterranean, aquatic. Stem structure in dicotyledons and monocotyledons.

*Foliage leaves*: General structure, veining, margin, form, and arrangement in relation to sunlight and shedding of rain.

*Inflorescence*: Varieties of axial and terminal types.

*Fruits*: Structure and classification of the simpler fruits, such as a pea or bean, shepherd's purse, poppy, apple, tomato, grape, plum, corn, and maple; adaptation for the dispersal of seeds.

*Preparation for Winter*: Storage of reserve food in root, stem, leaf, and seed; study of winter buds, their arrangement, structure, and means of protection; the fall of the leaf and fruit; interpretation of leaf and scale scars on trees and shrubs.

### *April, May, and June*

*Seeds*: Practical study of some of the common seeds, such as the pea, bean, morning glory, representing dicotyledons; corn, wheat, representing monocotyledons; pine or spruce, representing gymnosperms; form, markings, parts and their functions, position of stored food.

*Germination of Seeds*: Simple experiments to illustrate the more important phenomena and requirements of germination and growth, for example, need of air, warmth, and moisture; evolution of carbon dioxide; how and to what extent water is absorbed; root hairs; root cap; region of growth in root.

*Spring Flowering Plants*: Plant description and identification by means of a flora begun; relation of flower structure to mode of pollination; meaning and significance of cross pollination; structure and expanding of winter buds; adaptation of stem form to habit; spines, prickles, tendrils, their forms and uses; foliage leaves, as in the autumn work of the first year.

## SECOND YEAR

### *September and October*

*Composites*: Study of the inflorescence and flower structure of typical composites, such as dandelion, burdock, and ox-eye daisy.

*Weeds*: Recognition of common forms; how they spread, and how they may be controlled.

*Fungi*: Recognition and mode of life of mushroom, puff-ball, polypore, as saprophytic forms; and apple scab, lilac mildew, wheat rust, black knot, or other common type, as a parasitic form.

*Physiological Experiments*: *Roots*: Simple experiments to illustrate root functions, for example, absorption by osmosis, growth toward moisture.

*Soils*: The presence of soluble and insoluble materials in soils; simple experiments in illustration.

*Stems*: Simple experiments to illustrate stem function, for example, conduction of cell sap, heliotropism, rotation of the end of the stem in twiners and climbers.

*Foliage leaves*: Simple experiments to illustrate leaf functions, for example, transpiration, manufacture of starch in sunlight, disappearance of starch in darkness, exhalation of a gas by green water-plants, exhalation of carbon dioxide.

*April, May, and June*

*Trees*: Mode of branching and identification by leaves, bark, and wood of maple, willow, or oak, a conifer, apple, and plum, or cherry.

Description and identification of twelve different species of flowering plants, representing at least six different orders and including both monocotyledons and dicotyledons.

*Ferns*: General structure and habits of a common fern.

*Review*: General review and comparison of the characteristics of the larger groups of plants taken up in the Course, summarizing and classifying.

A collection of plants to be made in the second year; also a collection of ten economic woods

The collection of plants shall include carefully selected and prepared specimens of the species chosen for identification as required above.

## PHYSICS

### FIRST YEAR

*November to April*

*Introductory*: Measurement in Metrical and English units of length, area, volume, and mass; structure and use of the Balance; The Three States of Matter, defined and explained.

*Mechanics*: The principle of the mechanical powers; some of their more important simple applications.

*Hydrostatics*: Pascal's Law, statement and verification, some of its more important applications; pressure of liquids in its relation to direction, depth, density of liquid, area pressed, and the shape of containing vessel; Archimedes' principle; specific gravity; common methods of finding specific gravities of solids and liquids.

*Pneumatics*: Study of the properties of a gas as exhibited in air as a type; proof that air has weight, occupies space, and exerts pressure; construction of the barometer; the relation between the volume and pressure of a gas; proof of Boyle's Law; practical application of air pressure; air pump, common pump, siphon, the principle of air brakes, air tools.

### SECOND YEAR

### *November to April*

*Heat*: Nature and source of heat; experiments to illustrate the expansion of solids, liquids, and gases by heat; some practical applications of the principle of expansion; the anomalous expansion of water, its significance; meaning of temperature as compared with quantity of heat; graduation of the mercury thermometer in the Centigrade and the Fahrenheit scale; meaning of latent heat, applications; experimental demonstration of the transmutation of heat into mechanical energy.

*Sound*. Nature and propagation of sound: pitch of sound; consonance and resonance; reflection of sound echoes.

*Light*: Nature and propagation of light; simple experiments illustrating the reflection and refraction of light; dispersion of light; colour of bodies.

*Magnetism and Electricity*: Magnets; laws of magnetic attraction and repulsion; polarity; magnetic induction; terrestrial magnetism; construction of simple voltaic cell; decomposition of water by electricity; electro-magnet; electric bell; telegraph; heating and lighting effects of the current.

NOTE.—In both Physics and Chemistry, practice in the proparation and manipulation of apparatus should form part of the Course. Where practicable, the Course should also include simple operations in glass-blowing and lathe work, and in hard and soft soldering.

## CHEMISTRY

### SECOND YEAR

### *March*

*Air*: Its constituents; combustion in air, and resulting changes; detection of carbon dioxide and water vapour in air; rusting of a metal such as iron in the air, and how it affects the air.

*Water*: Decomposition of, into its elements; the obtaining of pure water, and how it differs from ordinary water.

*Carbon*: Its presence in plant and animal substances; combustion of carbon, and lime-water test for carbon dioxide.

# BIOLOGY

**Scope of Biology.** Biology, dealing with plants and animals, has, like most of the other Natural Sciences, developed in different directions. In its many-sidedness, it embraces several more or less distinct sub-sciences. These include *Morphology,* dealing with the structural characters (*Anatomy* with the grosser structures, and *Histology* with the minute microscopic structure); *Ecology,* dealing with the relation of the plant or animal to its environment; *Palæontology,* treating of fossil forms; *Physiology,* dealing with the functions of parts; *Embryology,* dealing with the changes undergone in the development from an egg to the adult form; and *Classification,* or *Systematic Biology,* dealing with the grouping of related forms. Aside from the studies of the actual plant and animal form and life, the science has developed its own *History* also, and a somewhat distinct branch of *Philosophy.* Its *History* is the story of the work of many noted naturalists. Its *Philosophy* seeks to explain the general facts of the science through theories of heredity, evolution, and variation. In a strict sense, all these are embraced in the modern science of Biology.

**Relation of Biology to Natural History.** The term Natural History, as applied to plants and animals, does not lend itself to definition so readily as does the term Biology. It was used to designate that general study which preceded the more exact, comparative, and systematized study which characterizes the modern science of Biology. It concerned itself with out-of-door inquiries into habits, life histories, external characters, and economic relationships to man. It resulted in the accumulation of museum collections and a body of fact, focussed often about the concerns of classification. However, on the facts and material gathered in this field, the generalizations which distinguish the modern science have been based. So it has been the forerunner and the foundation of Biology. At the present time, the term is employed in much the same general sense; that is, the general accumulation of facts about plants and animals by observation and collecting out-of-doors. But the strong emphasis placed a few years ago by the schools on elaborate laboratory work for the sciences has obscured its position and use to some extent. It is only quite recently that it has been, as it were, rediscovered as a proper interest and factor in an education which includes an acquaintanceship with Biology.

**Place of Natural History in an Elementary Course in Biology.** A school course in Biology should be properly related with the Natural History side of the subject. The education of the pupil in and through the subject should accord with the development of the subject. There must be a recognition of the natural and historical relationship existing between the old-fashioned and informal study of plants and animals out-of-doors and the modern and formal studies in the laboratory. The out-of-door work should bring an interest and meaning to the laboratory work, while the laboratory practice should explain the out-of-door and incite to further and deeper observation. The two sides of the study are interdependent and inseparable. The pedagogical need for their mutual use is well expressed in the preface to Parker and Haswell's *Text-book of Zoology*:

> There can be little doubt that the study of Zoology is most profitably as well as most pleasantly begun in the field and by the seashore, in the Zoological Garden and the Aquarium. In a very real sense, it is true that the best zoologist is he who knows the most animals, and there can certainly be no better foundation for a strict and scientific study of the subject than a familiarity with the general appearance and habits of the common members of the principal animal classes. But Zoology as a branch of academic study can hardly be pursued on the broad lines of general natural history and must be content to lose a little in breadth of view—at least in its earlier stages—while insisting upon accurate observation, comparison, and induction within the limited field of Laboratory and Museum work.

These remarks apply equally well to Botany. A well-balanced course in Biology, then, will be one having a proper adjustment between the two phases of the subject and embodying those principles of each which make for the educational wellbeing of the pupil.

**Special Value of Biology in a Scheme of Education.** The reader is referred to Chapter I of *The Teaching of Biology,* by Lloyd and Bigelow, for an admirable exposition of the culture value of Biology. A few extracts from the Summary are given here to indicate the line of argument:

> The special value of biology in education must be indicated chiefly by the nature of the material with which it deals. . . . The study of biology, because it is a study of objective realities, tends to develop the disinterested judgment, to teach the individual how to adjust himself to his surroundings, and to raise the ideals of life.
>
> Biology has a special value in its usefulness in multiplying the interests of the mind, thus furnishing sources of pleasure which are deep and lasting and which produce no bad effects. They are such as are within the reach of all.
>
> Biology calls for a large degree of caution in its method of thought. In this it resembles real life more nearly than the

other natural sciences and has an educational value indicated by its similarity thereto.

Biology has a humanistic value, measured by the amount and value of the information it brings. . . . The knowledge of the nature of many diseases, the field of agriculture and labour, the profoundly important matter of the relation of the sexes are matters concerning which biology brings most valuable information, and so makes for a saner and more normal view of life.

## SCOPE AND LIMITATIONS OF THE LOWER SCHOOL WORK IN BIOLOGY

The inexperienced teacher will undoubtedly meet with difficulties in determining the degree of minuteness with which he will deal with the prescribed work in Botany and Zoology. On the one hand, it might be argued that the work outlined for the two years' Course is such that a whole lifetime might be spent upon it, and on the other, there is the necessary limitation of the time which can be fairly allotted to it in the school time-table. The conditions will have to be reconciled by compromises. The teacher will have accomplished his work fairly, not by covering a complete course in Biology—there never could be a *complete* course in Biology for any person—but by giving his pupils (1) a broad view of the plant and animal world at large, (2) a habit of looking at and thinking about common plants and animals, and (3) an appetite for further inquiry by observation and reading. The work is not to be undertaken as a foundation for advanced work in higher classes or in college. It is complete in itself. Only a small proportion of the pupils taking it will have the opportunity of studying it further in school. It may be hoped, however, that many will have an abiding interest in it through life.

**General Plan of the Work.** The work in Zoology may be summarized as follows:

| First Year | | Second Year | |
|---|---|---|---|
| Autumn Term | Spring Term | Autumn Term | Spring Term |
| *Invertebrates*—<br>Typical Insects<br>Spider<br>Centipede | Mosquito<br>Clam<br>Earthworm | Economic Insects | Crayfish<br>Wood-louse<br>Pond Life |
| *Vertebrates*—<br>Birds | Fish Frog | Mammals | Reptiles<br>Review |

This shows an interrupted and disarranged series of type studies for the laboratory. This work is largely of a morphological character and interpretive of the outdoor Natural History which accompanies it, and for which the individual pupil must become personally responsible. The teacher's responsibility will be to arouse such interest in the laboratory that the outdoor work may be done largely through his directions. In the nature of things, it would be impossible—even if it were desirable—for a teacher to be always at the pupil's side. In the Natural History side of the subject, the pupil must soon learn to work independently—looking to the teacher only for leadership and sympathy.

The work is arranged, broadly speaking, according to seasons, as it naturally should be. It commences in the first autumn with insects and birds—in many respects the most interesting forms of animal life and consequently the best for arousing the pupil's interest. Along with the laboratory work there are, of course, some preliminary outdoor observations. But the chief outdoor work will be done by the pupil the next year, and the year after, and all the rest of his life. It is generally agreed that "the best preparation for the appreciation of study of any animal in the field is a preliminary examination of external structure and activities as far as these can be determined by living and preserved materials in the laboratory. Such preparation will add greatly to the scientific significance of a study of animals in their native haunts; and there is evidence that it intensifies rather than lessens interest".—BIGELOW, *The Teaching of Zoology.*

The Course in Botany may be summarized as follows:

| First Year | | Second Year | |
|---|---|---|---|
| Autumn | Spring | Autumn | Spring |
| Study of a common flowering plant, including an outline of the structure and function of all the parts.<br>Fruits and seed dispersal<br>Study of seed structure<br>Preparation for winter | Germination<br>Artificial propagation<br>Study of spring flowers<br>Continued study of roots, stems, and leaves | Composites<br>Weeds<br>Fungi<br>Physiology | Trees—Special study of conifers<br>Continued study of flowering plants<br>A grass<br>A fern<br>Economic products<br>Review |

This gives a fairly well-rounded course, and the pupil who has covered it should have a good general idea of the morphology and life processes of typical representatives of the great divisions of the plant world. Here, again, the laboratory work and the pupil's independent outdoor work should progress side by side, the scope of the latter to be indicated by the teacher and, as a rule, to be supplementary to whatever may be engaging the attention of the class at any particular time. For example, if seed dispersal be under consideration, the outdoor work would very properly be directed toward collecting evidences of contrivances designed to help dispersal.

## GENERAL PLANS FOR CONDUCTING LABORATORY LESSONS

There are two general plans for conducting laboratory work. The teacher may direct all the observations or investigations of his pupils orally. This method allows the full personality and teaching power of the teacher to come into play and has the further advantage of enabling one to cover much ground rapidly. It is a very satisfactory plan for a small class where teacher and pupils may work together at a few tables. The teacher may pause in his questioning to help those pupils who are noticeably slow in getting answers. On the other hand, it is not so satisfactory where the class is large. The pupils who do not work rapidly through inability, and those who do not work well through carelessness, are overlooked. Their work in consequence is incomplete and unsatisfactory to themselves and their teachers.

The second plan is to direct the pupil's work with written or printed instructions. It is this method which is employed largely in the laboratories of colleges and the large secondary schools. The pupil, with printed or typewritten guide before him, follows step by step the instructions set and records his answers in word or drawing. The teacher's time then is given up to helping individual pupils over difficulties and overseeing the general work of the laboratory. This method suits very well where large classes are engaged in the study of a fixed and formal course. If it lacks in the enthusiasm and inspiration that may come from the viva voce exchange of ideas on the part of teacher and pupil, it gains possibly in the discipline that comes from following explicit directions, answering clearly stated questions, or solving definite problems.

To offset the disadvantages of these two general methods, and to fulfil the intentions and requirements of our own prescribed Course, a plan embodying the two methods is urged. It is on such a scheme that these "Suggestions" have been prepared. For every study in the laboratory the pupil should be given a well-arranged series of short exercises. Each exercise should define the problem or line of observation in a clear and methodical manner; it may be dictated to the class, written on the black-board, or presented in mimeographed or typewritten copies. Where the size of the class and the arrangement of the laboratory will permit, the exercises may be written on large sheets of paper and displayed as wall charts; these have the advantage of being available from year to year and may be extended so as to include many useful phases of the work. Besides these charts outlining laboratory work, others may be made by the pupils, recording their observations on bird migrations, the occurrence of insects, the first appearance of animals and flowers in the spring, etc., so that in a short time each school may have a series of home-made display charts which will help materially in defining and directing the subsequent outdoor work. Sheets of strong manilla paper, about twenty-four inches by thirty-six inches, will answer well; by pasting small pieces of linen at the corners of the sheets they may be hung on nails without tearing. The printing should be done with some such checking crayon as the Falcon or with India ink crayons. Instead of manilla paper the cloth material used for window blinds will be found satisfactory.

## GENERAL METHOD OF DEALING WITH MORPHOLOGICAL STUDIES

The teacher is urged to keep in mind the proper intent of the morphological studies. Form and structure are not to be studied for their own sake; the end does not lie in the observing and recording of these. Behind these always there must be such questions as: Why is this? Why should this be so? Has Nature provided wisely here? Does this suit the environment? As the syllabus states it: " Behind the observation of the form there must be a constant effort to interpret the *meaning* of the form, to show the relation of form and function ".

In the instruction given in the outlines for the different topics, this side of the teacher's work is not directly indicated. Questions to cover the matter would take up unnecessary space, as they would contain many repetitions. The method may be indicated more clearly by a direct reference to a few of the first observations suggested in the study of the grasshopper. These are:

1. *Note the shape, coloration, size, and dimensions (comparative length, width, and depth) of the body.*

*2. Note the nature of the animal's outer body wall (the exoskeleton), the substance of it (chitin), its hardness, smoothness, and hairiness.*

*3. Note the main divisions of the body—head, thorax, and abdomen.*

*Shape.*—Finding the body of the grasshopper to be of a certain shape (and having knowledge besides of the activities of the living animals) the question is, does this suit the animal's activities, for example, in crawling among the grass, leaping, or flying through the air?

*Colour.*—Observing the grasshopper to have a certain general coloration, the question is, does this suit its needs, for example, as a protection; and the young grasshoppers being a brighter green than the older ones, why so, or for what possible purpose?

*Size.*—Noticing that the animals have a certain range of size, would there be disadvantages (providing its conditions of living were the same) in being larger?

*Dimensions.*—What is the advantage (if there is any) in the animal's body having a greater diameter in the depth than it has in the width?

*Body Wall.*—What good purpose is served the animal in its having a hard, chitinous exoskeleton? If it is smooth, what advantage is there in this? If there are hairs, what purpose may they serve?

*Body Divisions.*—What is the significance of the fact that the body has three very well distinguished regions—a head, a thorax, and an abdomen? It must mean that the different regions have distinct functions to perform.

And so, throughout the study, seek to find nature's meanings and purposes.

It is not expected that throughout all the work the teacher will propound a problem as an exercise in inductive reasoning on every single observation. The study does not permit such, even if time did. In the first studies, however, such questionings should be frequent. The pupil having acquired a habit of searching out reasons for himself or herself, the teacher's chief work in this regard is finished. His place will then be to find answers, if possible, for the problems that the pupils will propound for him; or better, to help the pupils to answer them themselves.

A word of warning should be given regarding the too common practice of interrupting pupils in the quiet working out of their answers to the problems set. Quizzing or questioning is highly desirable, but it should not be in the nature of a disturbance to quiet observing and thinking. Questions should not be asked for the mere sake of questioning. When they are necessary, ask them deliberately and allow time for them to be answered; if time cannot be allowed, do not ask them.

**Pupils' Records.** The teacher does not need to be reminded that a very important part of the work lies in the recording of it. It is true that much knowledge may be and is properly acquired and assimilated by pupils without their being required to make formal records of it. But, in the science studies of the schools, there are other considerations than the acquiring of knowledge. One of the chief reasons for their being included in the school programme of studies is that they offer exceptional opportunity for training in habits of accurate observation and expression, the same being the foundation of clear thinking. At its best, the making of a drawing or the statement of a fact in Natural History involves a moral responsibility. They are exercises in truth-telling. The necessity for making a record thus provides incentive for the accurate observation and the correct thinking. These purposes place the teacher under the responsibility of seeing that pupils are not debarred from this wholesome training; under these circumstances, dictating notes becomes a distinct evil; it is not only not doing right, it is doing wrong; it is suppressing individuality and originality where these should be encouraged; it makes for weakness when the proper aim is for strength; it is producing creditable (?) note-books at too great a cost.

Neatness, system, and persistency are essential for the making of a creditable book of science records.

**Drawings.** In this connection the teacher of Biology may take it for a sound working principle that "no one has seen an object aright until he has made a drawing of it". They are quite indispensable. Therefore, encourage records in drawings as far as time and circumstances permit. For the attainment of good results in this, care and patience will be required. To most pupils representation by drawing is very difficult; the hand and the eye have not been attuned to a co-operation in this direction. Because of this very lack, the pupil should be encouraged to persevere in efforts to acquire a manual dexterity that is fundamentally important in all industrial effort and which may be of great service to himself and others.

The following suggestions may be found helpful. Make the conditions for drawing favourable. Be sure that the preliminary *seeing* has been accurate and complete. Before the work is commenced, discuss the size, proportions, and position of the parts of the object that is to be represented; also the scale to be used and the selection of the most suitable position on the sheet of paper. Insist on the mapping out of the whole drawing before any part is finished; encourage the repeated use of the eraser; if the foundation is right, a good superstructure is easily built. In some cases it may be advisable at first to allow the partial use of book drawings as copies. The best exercises should be exhibited on the bulletin board and some of them retained in a school portfolio for showing to subsequent classes.

The drawings must tell the truth or show an effort to tell the truth; a nicely executed and neat representation that is *untrue* must not be accepted as more desirable than a clumsy but *honest* expression of an observation. They should be labelled so as to make clear, as far as possible, the terms used to designate the parts described, and such terms will not need to be set forth again in written records.

Have the pupils provide themselves with a good drawing pencil (about H) and a kneaded eraser; if the pencil drawings are to be traced in with India ink, require the use of a good white ledger paper. Many pupils will like to use this ink with a fine tracing or mapping pen. It makes drawings show up very well. A supply of the ink and pens might be provided in the school.

## THE LABORATORY

The fitness and equipment of the laboratory will determine, to some extent, the success of the work. But an elaborate equipment is not a necessity for good work. A progressive teacher will gradually secure and arrange all the essentials for the work. The first requisites are good light and convenient seats. Where special rooms and fittings are provided, the work tables should be placed with their longer axes at right angles to the windows.

There will have to be provision, too, for exhibiting and storing material. A separate room adjacent to the laboratory, which may grow into a school museum, would answer best perhaps. But in many schools a separate room will not be available; in that case, the laboratory will have to hold the fittings. All of these do not need to be furnished at once. They can be added to as the work grows. There should be a cabinet of drawers for holding mounted plants, seeds and fruits, birds' skins, birds' eggs, insect collections, shells, fossils, Indian relics, etc. Shelves may be needed for holding collections of specimens preserved in liquids; if there is to be a school museum, these would be better accommodated in glass cupboards placed around the walls. A laboratory cupboard provided with drawers and shelves will be very necessary, to hold the preserved material needed in class work and the general supply of bottles, dishes, spreading boards, cork, etc. There should be a rack on which to suspend charts; this may be made as a light framework and adjusted with pulleys and cords suspended from the ceiling. A table to hold aquaria, vivaria, and breeding cages is needed, but a large shelf so hinged to the wall that it may be set up as a table will answer well and has the advantage that it may be let down out of the way when it is not in use. Last, but not least, there should be a convenient shelf for holding the laboratory reference library.

**Supplies for Insect Work.** The school should possess a good stock of equipment for loaning to the pupils. There should be a number of insect nets, killing bottles, and stretching boards always available. In many cases the pupils will want to make their own. They will find instructions for this in *Agricultural Bulletin No. 8, Nature*

*Collections for Schools,* published by the Ontario Department of Education. Great care should be taken in giving out the potassium cyanide used in making the killing bottles.

Where local dealers do not keep entomological supplies, a stock of insect pins, cork, and larva vials will be needed. In some schools the pupils arrange among themselves for the purchase of these. It is an advantage, however, to have a supply on hand for the use of both the pupil and the school. Sheet cork costs 25 cents a square foot, and japanned insect pins about $1.25 a thousand.

**Collections of Birds' Eggs and Skins.** While it is prohibited by law to collect the nests and eggs, or to kill our wild native birds, other than hawks, crows, blackbirds, and English sparrows, the Chief Game Warden of the province may issue permits to students for these purposes. The permits are good only until the end of the year in which they are issued, but may be renewed. Applications for such should be made to the Chief Game Warden, Toronto, on a special form which may be obtained on request. A recommendation of character must be submitted with the application.

A booklet, entitled *Ontario Game and Fishery Laws, 1908,* and including the *Act respecting Game, Fur-bearing Animals, and Fisheries of Ontario,* as well as the *Act for the Protection of Insectivorous and Other Birds,* is published by the Department of Public Works. It may be secured by addressing the Ontario Game and Fisheries Department, Parliament Buildings, Toronto.

**The Compound Microscope.** While the outline of work does not call for very much use of the microscope, there should be one to which pupils may have ready access.

One kept under a glass bell-jar on a table near a window will answer well. A little instruction in the use and care of it and the method of mounting objects so that they may be examined, will often bring good results in arousing the young naturalist's interest. It will be well to limit its use to the low power. To guard against mishaps to the instrument, it may be put under the charge of a committee of the pupils or of individual pupils for short terms. There are many objects, botanical and zoological, which a young pupil may readily examine under the teacher's direction. If there is a high power objective, this should be kept by the teacher and used only under his direction. The microscope does not need to be an expensive one. No. $BH_1$, made by Messrs. Bausch & Lomb, Rochester, N.Y., and sold through their Canadian agents, Messrs. Ingram & Bell, Toronto, and No. 7503C, made by The Spencer Lens Co., Buffalo, N.Y., will be found very good. Fitted with one eye piece, low and high power objectives, each costs about $24.50. With a double nose piece it will cost $28.50. An observation microscope, fitted with a low power objective and costing about $8.00, will be found useful for passing about the class. It is made by the above firms.

Microscopes may be imported duty free for schools.

**Museum Jars.** A supply of Crown sealers in pint and quart sizes will be found convenient for storing material. They have large tops which make it convenient to put in or take out material. The two-quart sealer known as "The Best" has the same advantage and will be found suitable for frogs and animals of similar size. If collections of the different fishes, snakes, and amphibians of the neighbourhood are made for the school museum, it will be well to fix on some such bottle as a standard clear glass pickle bottle. It adds much to the appearance of museum specimens to have them exhibited in uniform bottles.

## HOW TO GET SUPPLIES

The following list comprises the best known dealers in such supplies as may be required in biological work. Teachers should send for catalogues, and in purchasing, ask for quotations and terms. Imported for educational purposes, most articles required will be duty free. In some cases, purchase from foreign firms may be made on as good terms through local School Supply Houses as one can secure by dealing directly. If purchasing supplies prepared in France or Germany, through United States firms, it is advisable to give them an import order, so that the United States duty may be saved. It usually requires a long time to fill such an order, and due allowance should be made for this if the supplies are wanted for any particular part of the year's work.

## ZOOLOGICAL SUPPLIES

### MUSEUM SPECIMENS

The Kny-Scheerer Company, 404 West 27th St., New York

Les Fils D'Emile Deyrolle, 46 rue du Bac, Paris, France

The Geo. M. Hendry Co., Limited, 215-219 Victoria St., Toronto

Ward's Natural Science Establishment, 76 College Ave., Rochester, N.Y.

The Rochester firm advertises the following Zoological sets, specially selected, to meet the requirements of the Ontario Course of Study in science:

I. Collection of larger sized mounted skeletons of the Perch, Frog, Snake, Turtle, Crow, and Cat—$50.00 (case $10.00 extra)

II. Collection of smaller sized skeletons, including the Perch, Frog, Turtle, Robin, and Rat—$35.00 (case $5.00 extra)

III. Collection of mounted skulls of Pig, Horse, Sheep, Rabbit, Dog, Mole, and Bat—$25.00

IV. Collection of mounted bones of feet of the animals listed in III—$15.00

V. Collections of specimens, mounted in spirits, illustrating the stages of development of the Frog, Snake, and Fish—$15.00 ($5.00 each)

VI. Collection of skins of twenty representative birds—$15.00

They offer other collections as well.

The Kny-Scheerer Company, besides furnishing supplies similar to those specified in the Ward's sets, carries many series of wall charts dealing with natural history and zoological studies, as well as microscopical slides, such as the mouth parts, spiracles, and wings of insects, etc.

The Paris firm offers very large selections in all kinds of supplies.

The Geo. M. Hendry Co. offers zoological specimens, aquaria, models, wall charts, etc.

### LANTERN SLIDES

Mrs. M. V. Slingerland, Ithaca, New York
C. H. Stoelting & Co., 12 South Green St., Chicago

### MICROSCOPES

The Bausch & Lomb Optical Co., Rochester, N.Y.
(Messrs. Ingram & Bell, Toronto, Canadian agents)
The Spencer Lens Company, Buffalo, N.Y.
The Geo. M. Hendry Co., Toronto

### BIRD SKINS

N. O. Lawson, Geneva, Ill., U.S.A., supplies unmounted skins of our commoner and smaller birds at 25 cents each. Mounted, the cost is 50 cents each.

Teachers desiring to purchase mounted museum specimens or to arrange for the mounting of their own material, should communicate with the following taxidermists. Some of these will undertake to supply sets of skins also: John Maughan, Jr., 498 Wellington St. West, Toronto; John A. Morden, Hyde Park Corners, Ont.; W. A. Brodie, Unionville, Ont.; T. W. Campion, 175 Dundas St., Toronto; E. Elcome, Peterborough, Ont.

### COLOURED BIRD PICTURES

A. W. Mumford, 63 East Washington St., Chicago, U.S.A.
The Perry Pictures Company, Malden, Mass., U.S.A.

### COLOURED BIRD CHARTS

*The Audubon Charts,* Prang Educational Co., New York
*Canadian Birds in Relation to Agriculture,* William Briggs, Toronto

### ENTOMOLOGICAL SUPPLIES

The Kny-Scheerer Co., 404 West 27th St., New York
American Entomological Co., 55 Stuyvesant Ave., Brooklyn, N.Y.
Messrs. Watters Bros., Guelph, Ont.

Cork and insect pins may be purchased from The Entomological Society of Ontario, Guelph.

### BOTANICAL SUPPLIES

The Kny-Scheerer Company, 404 West 27th Street, New York, and

The Cambridge Botanical Supply Company, 1286 Massachusetts Ave., Cambridge, Mass.,

issue comprehensive catalogues of botanical supplies, embracing material of every description, both dry and in preservative fluids, together with wall charts, microscopical mounts, etc., etc. As a rule, however, the teacher will find it to his interest and that of his classes to encourage the pupils to collect their own supplies for botanical work. The difficulties are obviously less than in the case of Zoology.

### SUGGESTIONS FOR AROUSING INTEREST IN THE WORK

**A Class Observation Book.** The keeping of a class observation book may help to arouse and sustain an interest in the work. It should be a well bound book, with good paper and good covers; large enough to last a number of years, but of a size that would permit it to be kept among the other books in the library after it is filled up.

While in use, it should be kept on the teacher's desk or the observation table, so that it may be available for inspection or perusal at any time. Special matters of interest concerning local animals, plants, etc., should be recorded in it by the pupils, in some cases under the teacher's direction, or in other cases independently. All records should be written in ink, dated, and signed. Cuttings from newspapers and magazines might be given space in it, too, but, if these were numerous, it would be better to insert them in a separate class scrap-book. Such a book will be found to be of value, not only as a reference, but also as a personal link with old pupils of the school.

**A Class Portfolio of Science Records.** For reasons similar to those given for the Observation Book, a class portfolio, containing representative exercises from all the pupils, would be of value in the work. These should be on loose sheets of uniform size so that they may be put together neatly in strong covers. If the exercise selected should represent some independent work of the pupils, it would be so much the more valuable as an incentive to the pupils of the following years. While the work of all the pupils should be represented, it should be understood that nothing unworthy of the class as a whole could be allowed a place. The portfolio should be given a place in the school library as a reference work.

**A Naturalists' Club.** At any schools where there are a number of enthusiastic pupils, the organization of a *Naturalists' Club* should be considered. Through this the Outdoor Work outlined in the Courses of Study could be carried on very well, and more of the school time thus devoted to systematic morphological studies. By means of it, too, teachers could arrange for timely supplies of class material, as well as specimens for the school museum. There would, moreover, be great personal advantage to the pupils in the training received in conducting meetings, in giving point and purpose to their desultory (and often harmful) contacts with nature, and in creating the enthusiasm that comes from working with others at home and in other places. It can be imagined that in such bodies of youthful naturalists, the scientific societies of the country would find many recruits.

It is not to be expected that a club of this kind will lessen the teacher's work or responsibility. Indeed, these may be increased; it will probably require his constant supervision as a matter apart from his school work. It should not, therefore, be lightly undertaken.

Different ways of carrying out the work will suggest themselves. It may be considered advisable to make it a part of the proceedings of the school's Literary and Scientific Society, and to use either part of the time of each meeting or to devote the whole time of alternate Friday afternoon meetings to scientific interests. It may be thought best to restrict its meetings to the spring and autumn, when outdoor nature studies can best be carried on. By this plan, there would be no interference with the literary interests of the winter meetings. Pupils in the senior classes should be included in the membership, as well as ex-pupils and other persons in the locality who are interested in natural history. If the club were made an affair of the whole community, it would be necessary perhaps to hold evening meetings in the public library or some other central public place. By affiliating with some of the older organized scientific societies, such as The Entomological Society of Ontario, the club could have the advantage of its publications, support, and experience. From a number of clubs thus affiliating, a strong representative provincial Naturalists' Society might be organized in time, with our High School Science Departments as its local centres. The Audubon Society and Agassiz Associations of the United States are also open to Canadian branches.

To facilitate the work of organization of such a club, the following outline of a constitution may be found useful; it may be modified to suit local needs:

### CONSTITUTION SUGGESTED FOR A NATURALISTS' CLUB

*Article I—Name*

The name of this organization shall be the Naturalists' Club of.....................................

*Article II—Object*

The object of this club is to increase and diffuse the knowledge of Natural History and to assist in the intelligent protection of our native plant and animal life.

*Article III—Members*

All persons interested in the study of Natural History shall be eligible for membership. Members shall be elected by a two-thirds vote of the members present at any meeting.

*Article IV—Meetings*

Section 1.—Regular meetings of the Society shall be held on alternate Fridays during April, May, June, September, and October.

Section 2.—Special meetings may be called by the President.

Section 3.—The annual meeting shall be held on the last Friday of March.

Section 4.—The regular meeting shall be open to all.

*Article V—Dues*

The annual membership fee shall be ......................

*Article VI—Officers*

Section 1.—The officers of this Club shall be a President, a Vice-president, and a Secretary-treasurer, elected at the annual meeting to serve one year.

Section 2.—The duties of the officers shall be as follows:

The President shall preside at the meetings of the Society.

The Vice-president shall preside in the absence of the President.

The Secretary-treasurer shall record the proceedings of all meetings, conduct correspondence, announce the meetings of the Club, collect all dues, and pay all bills authorized by the Club; he shall make an annual report, and his accounts shall be audited by a Committee of the Club, previous to the annual meeting.

Section 3.—All officers elected shall assume office at the first meeting after the annual meeting.

### *Article VII—Committees*

Section 1.—The Executive Committee of this Club shall consist of the President, Vice-president, and Secretary-treasurer.

Section 2.—The Executive Committee shall constitute a standing committee on programmes, publications and library, admission to membership and finance, arranging for special lectures by outside naturalists, Club field excursions, and the acquiring of a library of nature books, lantern slides, etc.

Section 3.—The Executive Committee shall, as it sees fit, appoint sub-committees or officers to take charge of special lines of work such as: (1) To act as curator of the Club museum; (2) to act as Club librarian or arrange for the selection and purchase of suitable books and periodicals for the school or public library; (3) to prepare articles on local natural history for the local press; (4) to correspond with Naturalists' Clubs in other Canadian High Schools or through The League of the Empire (Caxton Hall, Westminster, London, England) with schools in Australia, South Africa, etc.; (5) to represent the Club at meetings of other Naturalists' or Scientific organizations; (6) to report on bird migration; (7) to make lists of the trees, flowering plants, etc., of the locality; (8) to report violations of the bird laws and take measures to protect birds and attract them about the school, homes, or parks; (9) to encourage the protection of our wild flowers and the planting of these, as well as shrubs and trees, in our school grounds and parks.

These committees or officers shall report on their work at the regular meetings.

### *Article VIII—Amendments*

Any amendments to this constitution may be adopted by a two-thirds vote of the members present at any regular meeting, provided that notice of such amendment was read at the last previous regular meeting of the Club.

*Article IX—Order of Business at Regular Meetings*

The order of business to be followed at regular meetings shall be as follows:

1. Reading of minutes of previous meetings
2. Business arising out of the minutes
3. Reading of correspondence by the Secretary
4. Reports of special committees or officers
5. Miscellaneous business
6. Natural objects or occurrences of interest to be presented or reported upon by members
7. Paper, lecture, demonstration with microscope, or debate
8. Discussion.

## THE LIBRARY

No text-books have been prescribed by the Department of Education for the use of pupils in the Elementary Science Course, and none will be used by them in their daily work in the class-room, but it is of the highest importance that the best available works in both Botany and Zoology should be on the library shelves for supplementary reading by the pupils and for constant reference by the teacher.

**Books Recommended in Connection with the Work in Biology.** The selection of books for a biological library is not an easy matter. As the field covered in the science is so extensive and varied, there is a multiplicity of works to be considered. There is, besides, a great diversity of demands and uses to be made of them; some are wanted for the teacher and some for the pupil; some are for guides in the field and some for manuals in the laboratory; some are for references for the teacher and some are for supplementary reading for the pupil.

In the list given below an effort has been made to select the fewest, most approved, and most modern works necessary for the proper covering of the field of study. It must be remembered that it will take time to build up a complete library; but systematic additions should be arranged for in all purchases of books. The order of listing the books may be taken as a guide in purchasing; the best books are listed first.

Where there is a public library in the town co-operating with the school in furnishing books recommended for the pupils' supplementary reading, the school may be relieved of purchasing many of the general works. The school should endeavour to have a representative on the library board who can arrange for plans for bringing the library and school into close association in the cause of good reading and education generally.

## SPECIAL BOOKS FOR THE TEACHER

### ZOOLOGY

*Text-book of Zoology,* 2 vols. Parker and Haswell. Macmillans, Toronto. $9.00.

*Manual of Zoology.* (An American abridgment of above) Parker and Haswell. Macmillans, Toronto. $1.60.

*The Teaching of Biology.* Lloyd & Bigelow. Longmans, Green & Co. $1.50.

*Teacher's Manual.* (Accompanying *Zoology, Descriptive and Practical*) Colton. Heath & Co., Boston.

*Book of Suggestions to Teachers.* (Accompanying *Studies of Animal Life*) Walter, Whitney, & Lucas. Heath & Co.

Parker and Haswell's *Text-book of Zoology* is almost indispensable as a comprehensive and standard work of reference.

Lloyd & Bigelow's *The Teaching of Biology* discusses the whole problem of Biology teaching. It is full of suggestions and information regarding methods, books, and laboratory equipment for both Botany and Zoology.

### BOTANY

*The Teaching of Biology.* Lloyd & Bigelow.

*The Teaching Botanist.* Ganong. Macmillans, Toronto. $1.10.

A thoroughly modern work, full of useful hints for teachers.

*The Teacher's Handbook.* Bergen. Ginn & Co., Boston. 30c.

*Elementary Botany.* Atkinson. Holt & Co., Boston. $1.25.

*Field, Forest, and Garden Botany.* Grey. American Book Company, New York. $1.80.

*New Manual of Botany.* Gray. American Book Company. $1.62.

These last two manuals are the best for identification of plants, as supplementary to the High School Flora, Part II.

**Laboratory Manuals.** These books have been prepared as guides for practical laboratory work. They are a link in the development of the teaching of Biology, connecting the formal method of instruction of the University laboratory through the work done in the modified laboratory of the secondary school with our present semi-Nature Study methods. In Ontario schools, good use may be made of them in Upper School classes; for Lower School Elementary Science their chief value to the teacher will be in suggesting ecological or morphological observations or exercises. They should be available on the laboratory book shelf, as there may be occasions when they can be put into a pupil's hands with advantage.

### ZOOLOGY

*Studies of Animal Life.* Walter, Whitney, & Lucas. Heath & Co. 50c.

*Studies in Zoology.* Merrill. American Book Co. 50c.

*Practical Zoology.* Colton. Heath & Co. 60c.

*Elementary Biology.* Boyer. Heath & Co. 80c.

### BOTANY

*Plant Biology.* Cavers. W. B. Clive, London, England. 3s. 6d.

*Laboratory Practice for Beginners in Botany.* Setchell. Macmillans, Toronto. 90c.

**General Texts for Pupils' Reference and Supplementary Reading, as well as for Teachers' Use.** These books should be kept on the laboratory book shelf, where pupils can have such ready access to them that they may form a habit of using them.

### ZOOLOGY

*First Course in Biology.* Bailey and Coleman. Macmillans, Toronto. $1.25.

*Modern Nature Study.* Silcox and Stevenson. Macmillans, Toronto. 75c.

*Nature Study and Life.* Hodge. Ginn & Co. $1.50.

*First Lessons in Zoology.* Kellogg. Holt & Co. $1.12.

*Introduction to Zoology.* Davenport. Macmillans, Toronto. $1.10.

*Animal Forms.* Jordan and Heath. Appleton & Co., New York. $1.10.

*Animal Life.* Jordan and Kellogg. Appleton & Co. $1.20.

*Animals* (combining the two above). Jordan, Heath, and Kellogg. Appleton & Co. $1.80.

*The Study of Animal Life.* Thomson. John Murray, London, 5s.

*Descriptive Zoology.* Colton. Heath & Co. $1.50.

*Elementary Lessons in Zoology.* Needham. American Book Co. 90c.

*Elementary and Comparative Zoology.* Kingsley. Holt & Co. $1.20.

*Animal Activities.* French. Longmans, Green & Co., New York. $1.20.

The first five books listed will be found most useful. The others are useful books, too, but will be found suitable for reference and reading rather than for guides in the practical work. Bailey and Coleman's book especially is recommended to teachers. It is the latest High School text in Biology and comes nearest to supplying the requirements of our Courses of Study in purpose, matter, and method.

### BOTANY

*The Essentials of Botany.* Bergen. Ginn & Co. $1.50.

*Botany All the Year Round.* Andrews. American Book Company. $1.00.

*Lessons with Plants.* L. H. Bailey. Macmillans, Toronto. $1.10.

*Plant Studies.* Coulter. Appleton & Co. $1.80.

*Elements of Botany.* Kellerman. Hinds, Hayden & Eldredge, New York. 90c.

(Useful for information as to economic plant-products)

*First Book of Forestry.* Roth. Ginn & Co. 75c.

*Our Native Trees.* Keeler. $2.00.

*Our Native Ferns and Their Allies.* Underwood. Holt & Co. $1.00.

The *Bulletins* of the Ontario Department of Agriculture. Free on application.

## SPECIAL ZOOLOGICAL WORKS

### BIRDS

*Bird Guide, Part I. Water and Game Birds East of Rockies.* Reed. Musson Book Co., Toronto. 75c.

*Bird Guide, Part II. Land Birds East of Rockies.* Reed. Musson Book Co., Toronto. 75c.

*Wild Birds in City Parks.* Walter. Mumford, Chicago. 40c.

*Check List of the Birds of Ontario.* Nash. Department of Education. Free.

*Birds of Ontario in Relation to Agriculture, Bulletin 218.* Nash. Department of Agriculture. Free.

*Catalogue of Canadian Birds* (new edition, 1909). Macoun. Geological Survey of Canada, Ottawa. Free to High Schools.

*The Birds of Ontario.* McIlwraith. Briggs, Toronto. $2.00.

*Handbook of Birds of Eastern North America.* Chapman. Appleton & Co. $2.25.

*Bird Life.* Chapman. Appleton & Co. $2.00.

*Colour Key to North American Birds.* Chapman. Doubleday, Page & Co., Garden City, New York. $2.75.

*North American Birds' Eggs.* Reed. Doubleday, Page & Co. $2.50.

*Birds of the United States and Canada.* Nuttall. Little, Brown Co., Boston. $3.00.

*Birds of Village and Field.* Merriam. Houghton, Mifflin, Boston, Mass. $2.50.
*Bird Neighbours.* Blanchan. Doubleday, Page & Co. $2.50.

Reed's *Bird Guide. Parts I and II,* and Walter's *Wild Birds in City Parks* are suitable for pupils' use in the field. *Part II Bird Guide* is particularly usable in having coloured pictures of all our land birds. Nash's *Check List* is suggestive. Chapman's *Handbook of Birds of Eastern North America* is generally accepted as our standard bird book.

The other books have their chief use as references. Macoun's *Catalogue of Canadian Birds* (1909) contains a very comprehensive account of the distribution of all birds found in Canada.

### INSECTS

*Common Insects Affecting Fruit-trees*—Bethune, and *Fungus Diseases Affecting Fruit-trees*—Jarvis. Department of Agriculture, Toronto. Free.
*Insects Affecting Vegetables* (Bulletin 171). Bethune. Department of Agriculture, Toronto. Free.
*Annual Reports of the Ontario Entomological Society.* Department of Agriculture, Toronto. Free.
*Insect Life.* Comstock. Appleton & Co. $1.75.
*How to Know the Butterflies.* Comstock. Appleton & Co. $2.50.
*Manual for the Study of Insects.* Comstock. Comstock Pub. Co., Ithaca, N.Y. $3.75.
*Insects Injurious to Fruits.* Saunders. Lippincott & Co., Philadelphia. $2.00.
*Insects Injurious to Vegetables.* Chittenden. Orange, Judd & Co., Fourth Ave., New York. $1.50.

*Insects Injurious to Staple Crops.* Sanderson. Wiley & Sons, New York. (Renouf, Montreal) $1.50.

*Economic Entomology.* Smith. Lippincott & Co. $2.50.

*Outdoor Studies.* Needham. American Book Co. 40c.

*Moths and Butterflies.* Dickerson. Ginn & Co., 1901. $1.50.

From the large number of books dealing with insects there is some difficulty in selecting a list; on the whole, the books given above will be found to cover all the ground on which references might be required by teacher or pupil. *The Insect Book, The Moth Book,* and *The Butterfly Book,* of the Nature Library, published by Doubleday, Page & Co., might have been included. Comstock's *Manual* is the standard College text on this continent. For any pupil making a special study of butterflies Comstock's *How to Know the Butterflies* is recommended.

Dr. Bethune's *Bulletins* and the *Reports of the Entomological Society* will be found very useful in making an acquaintance with the economic insects occurring in Ontario.

### MISCELLANEOUS

#### VERTEBRATES

*Taxidermy and Zoological Collecting.* Hornaday. Scribners, New York. $2.50.

*Monual of Vertebrotes of the Northern U.S.* Jordan. McClurg & Co. $2.50.

*American Food and Game Fishes.* Jordan and Evermann. Doubleday, Page & Co. (Briggs, Toronto) $4.00.

*The Reptile Book.* Detmar. Doubleday, Page & Co. (Briggs) $4.00.

*American Animals.* Stone and Cram. Doubleday, Page & Co. (Briggs) $3.00.

*Four-footed Americans.* Wright. Macmillans, Toronto. $1.50.

### INVERTEBRATES

*Everyday Butterflies.* Scudder. Houghton, Mifflin. $2.50.

*The Butterfly Book.* Holland. Doubleday, Page & Co. $4.00.

*The Insect Book.* Howard. Doubleday, Page & Co. $3.00.

*The Moth Book.* Holland. Doubleday, Page & Co. $4.00.

*Common Spiders of the United States.* Emerton. Ginn & Co. $1.50.

*Injurious and Useful Insects.* Miall. Macmillans. $1.00.

*Insect Stories.* Kellogg. Holt & Co. $1.50.

*Our Insect Friends and Foes.* Smith. Lippincott Co. $1.50.

Address the Superintendent of Public Documents, Washington, D.C., for lists of publications issued by the United States Department of Agriculture. Many of them deal directly with topics included in the programme of science studies. They are furnished at a nominal cost. There are farmers' bulletins also distributed free in the United States.

### SCIENTIFIC PUBLICATIONS

*The American Naturalist.* Ginn & Co. Monthly. $4.00 per annum.

*Popular Science Monthly.* The Science Press, Lancaster, Pa. Monthly. $5.00 per annum.

School Science and Mathematics. Chicago, $2.00.

**Special Works on Natural History for Supplementary Reading.** A very long list of books might be made here, including such books as those of Burroughs, Gibson, Long, Thompson-Seton, and Ingersoll. A selected list only is inserted, however. It comprises a number of those which stand out prominently in biological literature as great books, being the works of famous scientists or travellers:

*Natural History of Selborne.* Gilbert White. Dent (Everyman). 35c.

*Vegetable Mould and Earthworms.* Darwin.

*Voyage of the Beagle.* Darwin. Appleton & Co., 1899. $4.00.

*Animal Intelligence.* Romanes. Intrl. Science Series, 1886. Appleton & Co. $1.75.

*Island Life.* Wallace. Macmillans, 1895. $1.75.

*Ants, Bees, and Wasps.* Lubbock. Appleton & Co. $2.00.

*The Naturalist on the River Amazon.* Bates. Dent (Everyman). 35c.

*Naturalist in Nicaragua.* Belt. Dent (Everyman). 35c.

## SCIENTIFIC SOCIETIES

Some of the best known organizations concerned in scientific interests related to the work are listed below. Teachers will find it an advantage to become acquainted with the work of these. The official publications of some of them may be secured for the school library or reading-room, and some pupils thereby be given a stimulus to advance in the study.

| Name | Headquarters | Publication | Subscription |
|---|---|---|---|
| The Royal Society of Canada | Ottawa | *Transactions* | |
| The Entomological Society of Ontario | Guelph | *The Canadian Entomologist and Annual Report* | Monthly, $1.00 per annum |
| The Royal Canadian Institute | Toronto | ................ | |
| The Ottawa Field Naturalists' Club | Ottawa | *The Ottawa Naturalist* | Monthly, $1.00 per annum |
| The Wellington Field Naturalists' Club | Guelph | *The Ontario Natural Science Bulletin* | Yearly, 25 cents |
| The British Association for the Advancement of Science | Great Britain | *Nature*, published by The Mecmillan Co. | Weekly, $5.00 per annum |
| The American Association for the Advancement of Science | United States | *Science*, published by the Science Press, Lancaster, Pa. | Weekly, $5.00 per annum |
| The National Association of Audubon Societies | 141 Broadway, New York | *Bird Lore*, published by The Macmillan Co. | Bi-monthly, $1 per annum |
| The Agassiz Association | Sound Beach, Conn., U.S.A. | *The Guide to Nature* | Monthly, $1.50 per annum |
| American Nature Study Society | Urbana, Ill. | *The Nature Study Review* | $1.50 per annum |
| The American Ornithological Union | ........... | *The Auk* | Quarterly $3.00 per annum |

## REFERENCES

Teachers who desire information on matters pertaining to the work may feel free to consult the following gentlemen:

Concerning insects in general, Dr. Hewitt, Dominion Entomologist, Department of Agriculture, Ottawa, and Dr. Bethune, Department of Entomology, Ontario Agricultural College, Guelph; concerning Orthoptera, Odonata, Ephemeridae, as well as fishes, amphibians, reptiles, and our smaller mammals, Dr. Walker, Department of Zoology, University of Toronto, Toronto; concerning bees and bee-keeping, Morley Pettit, Esq., Provincial Apiarist, Department of Apiculture, O.A.C., Guelph; concerning birds, W. E. Saunders, Esq., London, and C. W. Nash, Esq., Lecturer in Biology, Department of Agriculture, Toronto; concerning text-books or matters in general relating to the teaching of the subject, George Cornish, Esq., Faculty of Education, University of Toronto, or Dr. Dandeno, Department of Education, Toronto.

Postage is free on letters or parcels to Dr. Hewitt, he being an official of the Dominion Government; to the others, postage must be prepaid. Specimens sent for identification should be carefully and securely packed and have the correspondent's name plainly attached to the parcel.

## MUSEUMS

Teachers of Biology will derive much benefit from the inspection of good museums. Besides suggesting interesting lines of work that may be followed up, it makes one's subsequent reading more effective. In some instances it may be found possible to arrange an excursion for the pupils to some of the following public museums:

The Museum of the Ontario Department of Education, Normal School, Toronto
The Geological Survey Museum, Geological Survey Building, Ottawa
The Biological Museum, University of Toronto, Toronto
The Royal Canadian Institute Museum, College Street, Toronto
Agricultural and Biological Museum, Ontario Agricultural College, Guelph (including the cabinets of the Entomological Society of Ontario).

# ZOOLOGY

## AUTUMN WORK OF FIRST YEAR

### GRASSHOPPER

*References:*

*First Course in Biology.* Bailey and Coleman
*Studies of Animal Life.* Walter, Whitney, & Lucas
*Studies in Zoology.* Merrill

*Drawings suggested:*

1. Entire animal viewed from the side, x 3
2. The mouth parts, x 3
3. A leg, x 3
4. Facets of compound eye, x 50.

### LABORATORY STUDIES—THE LIVING ANIMAL

*With specimens of different ages kept in vivaria or glass jars, which are supplied with grass or other food materials—*

NOTE:

1. Its movements.—(*a*) how it walks and jumps; (*b*) whether it can crawl up glass; (*c*) how it clings to an upright stick or blade of grass; (*d*) how its head, feelers, and mouth parts move; (*e*) what are the nature and rate of the breathing pulsations of the posterior end of the body—the *abdomen.*

2. Its developments.—(*a*) the differences in the amount of wing development in the different ages; (*b*) keep some of the smaller specimens to see how they increase in size through *moulting.*

3. Its feeding.—(*a*) if possible, how it bites a blade of grass and eats it; (*b*) the kind of green food it prefers.

### LABORATORY STUDIES—MORPHOLOGICAL

*Using freshly killed specimens if possible—*

NOTE:

1. The shape, coloration, size, and dimensions (comparative length, width, and depth) of the body.

2. The nature of the animal's outer body wall (the *exoskeleton*).—the substance of it (*chitin*); its hardness, smoothness, and hairiness.

3. The main divisions of the body.—*head, thorax* (chest), *abdomen.* These may be best seen from the under (*ventral*) side.

4. The thorax and appendages.—(*a*) its comparative size and strength; (*b*) the number, places of attachment, and relative size of the wings and legs; (*c*) the three divisions of the thorax, (1) the *prothorax,* (2) the *mesothorax,* (3) the *meta-thorax* (*pro*=front, *meso*= middle, *meta*=last); (*d*) the structure of a leg—starting from the body its parts are named *coxa* (hip), *trochanter* (thigh ring), *femur* (thigh), *tibia* (shin), *tarsus* (foot). (*e*) Compare the size, position, and direction of setting of the *fore, middle,* and *hind* legs. (*f*) Compare the size, colour, shape, thickness, folding, and veins of the *fore* and *hind* wings.

5. The abdomen.—(*a*) How many segments compose it? (*b*) What is the composition of each segment? (*c*) Note that the first and last two segments are incomplete rings. (*d*) How do the rings overlap, and what arrangements allow the abdomen to bend, expand, and stretch? (*e*) Distinguish the male and female animals by the shapes of the ends of their abdomens; the male is blunt and enlarged, the female is elongated and somewhat pointed with a projecting *ovipositor* (egg-placer).

(*f*) Locate the *spiracles* (breathing pores), small openings, one on each side of the first eight segments. (Are there any in the thorax?) (*g*) Identify the pair of glistening membranous oval *ear drums* on the sides of the first abdominal segment.

6. The head and appendages.—(*a*) the size, shape, hardness, and movability of the head; (*b*) the position of the mouth; (*c*) the position, size, structure, and movability of the *antennæ* (feelers); (*d*) the position, shape, and numerous facets of the two large *compound* eyes; (*e*) the three *ocelli* (simple eyes), one in the middle of the forehead and one just behind the base of each antenna; (*f*) the structure of the mouth parts—the *labrum* (upper lip), the *labium* (lower lip) with its jointed *labial palps* (lip-feelers); the *mandibles* (biting jaws), the *maxillæ* (holding jaws) with their jointed *maxillary palps*.

As there is considerable difficulty in making out these mouth parts, it will be advisable to help the pupils by showing them a printed chart or a set of the parts dissected off and glued to a card. The use of the large Carolina locusts makes the work easier.

### STUDIES WITH THE MICROSCOPE

EXAMINE:

1. A piece of the *cornea* of a compound eye, to show the shape and number of the facets.

2. A thin piece of an abdominal segment containing a *spiracle*, to show the slit and its borders.

3. A piece of one of the hind wings, to show the veins, hairs, etc.

4. A piece of the muscle of the thigh teased out, to show the character of muscle *fibres*.

### GENERAL DISCUSSIONS

1. How well the animal's structure and mode of life accords with the conditions surrounding it—its environment

2. The locust in history—famous plagues

3. The economic importance of locusts—the damage that results from them; have they any value as a food supply?

4. The natural and artificial checks on their increase or destructiveness.

### OUTDOOR WORK

**Note:**

1. The time of the year when grasshoppers become noticeably prevalent.

2. The kind of season (wet or dry) in which they appear to be most abundant.

3. (*a*) On what kind of a day and at what time of day they seem to be most active; (*b*) how far and how long they can fly; (*c*) how far they can jump.

4. In what kind of places or localities they are most abundant.

5. The kind of crops they attack and the manner of their attack. Make an estimate of the number infesting an acre, say, of pasture-land.

6. Whether they injure such things as clothing or woollen articles.

7. Their destruction by turkeys, chickens, and ducks.

8. Which of our native wild birds prey on them.

9. That grasshoppers seen in the early part of the season are not fully developed.

10. The two common species—the smaller Red-legged grasshopper and the larger Carolina locust that flies from dusty roads with a crackling noise. Both of these are true locusts, that is, they have short antennæ.

11. The Carolina locust laying its eggs in the sand along railway tracks in September.

12. The effects of the cold weather on the prevalence of grasshoppers.

### CRICKET OR COCKROACH

The outdoor and laboratory studies outlined for the living grasshopper should be followed in general for the cricket also.

With crickets kept in a vivarium and fed on grass, bits of apple, etc., opportunities will arise for seeing how they produce their "chirp".

Observation of the cockroach in its natural haunts may occasionally be made in kitchens and pantries.

#### LABORATORY STUDY—MORPHOLOGICAL

*With the structure of the grasshopper brought clearly to mind by a review, study the structure of the cricket or cockroach, systematically comparing—*

1. The general shape, coloration, size, and dimensions
2. The divisions of the body
3. The *thorax* and its appendages
4. The *abdomen* and its appendages
5. The *head* and its appendages.

Summarize the differences and similarities. Discuss the significance of the close relationships indicated in the structures, and introduce the idea of the order *Orthoptera* (Straight-winged Insects).

It may be considered best to postpone the fuller consideration of this topic until some other insect, such as a butterfly, has been studied and compared with the grasshopper.

## BUTTERFLY

*References:*

*How to Know the Butterflies.* Comstock
*Studies in Zoology.* Merrill

### LABORATORY STUDIES—LIVING ANIMALS

*Using the cabbage-butterfly—*

1. Set specimens free in the school-room, to observe their manner of flight and how they feed at bouquets or saucers containing sweetened water. Notice how the wings are held when the animal is at rest; compare in this respect with a moth.

2. With specimens in glass jars or *terraria*, observe: (*a*) their manner of walking or climbing; (*b*) the movements of the antennæ; (*c*) how they feed on sweetened water, etc.

3. With eggs or larvæ brought from the garden and kept in a terrarium furnished daily with fresh cabbage leaves, trace the whole life history of the animal—the hatching of the *egg*, the growth of the *larva* (caterpillar) by moulting, the change into a *chrysalis*, the emergence of the *imago* (completed butterfly).

### LABORATORY STUDIES—MORPHOLOGICAL

*Keeping in mind the structure of the grasshopper as a basis for comparison, and the pupils having specimens of the butterfly, larva, and chrysalis—*

NOTE:

1. The divisions of the body.—their shape, hairiness, and comparative size.

2. The *head.*—(*a*) its movability and the nature of the neck connecting it with the thorax; (*b*) the position and size of the compound eyes (are there simple eyes?); (*c*) the position, shape, colour, hairiness, and *segmentation* of the antennæ; (*d*) the position, number of coils, length, and tendency to recoil of the *proboscis.*

3. The *wings.*—(*a*) their number, comparative sizes, colour, and attachment; (*b*) their position in the killed insect; (*c*) the arrangement of the scales on them.

4. The *legs.*—their number, attachment, division, hairiness, and presence or absence of claws.

5. The *abdomen.*—the number of segments, the presence or absence of ovipositors.

6. The *caterpillar.*—its colour, hairiness, and shape; the number of segments; the number of pairs of true and false legs.

7. The *chrysalis.*—the appearance of the forthcoming butterfly's wings and proboscis in its case.

### STUDIES WITH THE MICROSCOPE

EXAMINE:

1. Some of the scales from the wings.
2. An antenna to show the segments, hair, and knobs.

### GENERAL DISCUSSIONS

1. The meaning of "complete metamorphosis"

2. The varied beauties of colouring in butterflies (see coloured pictures in *The Butterfly Book* or *How to Know*

*the Butterflies*); the advantages or disadvantages of their striking colours; how Nature "paints" these colours on these animals

3. Distinctions between moths and butterflies.

### OUTDOOR WORK

*Using the cabbage-butterfly as an example—*

NOTE:

1. The time of its first appearance and the condition of garden vegetation at the time.

2. The manner of its flight.—its rate, direction, height; motion of wings; play with mates; manner of alighting; and position of wings when at rest.

3. Its feeding habits.—(*a*) what flowers (and the colour of them) it frequents; (*b*) whether it rests while feeding; (*c*) how it extends and withdraws its tongue.

4. Its manner of reproduction.—(*a*) the plants on which the eggs are deposited (cabbage, turnip, nasturtium); (*b*) how the female quickly lays an egg; (*c*) whether she lays more than one egg at the same place; (*d*) the size, shape, colour, and markings of the egg; (*e*) its development into a larva or caterpillar (the cabbage-worm) and how this eats the leaves and grows; (*f*) its change into a chrysalis (to be found under window-sills, fence rails, etc.); (*g*) its emergence as a butterfly.

5. Its dangers and enemies.—(*a*) the battered condition of the wings of old specimens; (*b*) the appearance of parasites hatched from larvæ kept in terraria or glass jars; (*c*) whether birds chase and eat it.

Collect specimens of butterflies, larvæ, or cocoons for putting in class-room vivaria or for morphological studies in class. See the list given for the Autumn Work of the Second Year.

## CENTIPEDE

*References:*

*Introduction to Zoology.* Davenport
*Studies in Zoology.* Merrill

### LABORATORY STUDIES—LIVING ANIMALS

*Using a glass jar or vivarium provided with a moist "cover" for the animals—*

NOTE:

1. Whether they can climb up glass.
2. Their manner of walking.
3. Their ability to turn themselves over if they are thrown on their backs.
4. Their behaviour toward food such as a dead fly, small piece of meat, or a worm.

### LABORATORY STUDIES—MORPHOLOGICAL

1. Note the general shape, size, proportions, colour, and hardness of the animal.

2. Note the divisions of the body (*head* and *trunk*), and compare them.

3. Count the segments and compare the *dorsal* (upper) side with the *ventral* (lower) in regard to the segmentation or number of plates to be seen; in what directions do the segments allow for movements?

4. Note the head.—(*a*) its colour, shape, comparative size, movability on the neck; (*b*) the mouth parts, the direction of their movement, evident strength and purpose; (*c*) the *antennæ* (feelers)—situation, comparative length, segmentation, movability; (*d*) the eyes—their location, number, and whether single or compound.

5. Note the legs.—their number, similarity or diversity, place of attachment, number of segments, range of movement, presence or absence of claws or hairs.

### GENERAL DISCUSSIONS

1. Distinction between centipedes and millipedes

2. Difference between an insect larva, for example, a so-called wire-worm (the larva of a click-beetle) and a centipede

3. (*a*) How the animal's shape, colour, hardness, etc., suit its environment; (*b*) its enemies, its dangers and means of protection; (*c*) its manner of breathing

4. Its relationship to the so-called centipede (scorpion) of tropical countries.

### OUTDOOR WORK

1. The collection of specimens for putting in school vivaria or preserving. Specimens for collections will need to be kept in liquid preservative in vials or tubes, or glued to a piece of stiff paper and mounted on an insect pin.

2. (*a*) Observation of their habitat—under boards, stones, or rubbish; (*b*) their presence and prevalence under ground as seen when digging gardens; (*c*) the dryness or dampness of the surroundings; (*d*) the other animals found in the same places.

3. Note the difficulties of capturing them.—(*a*) their manner of escape or hiding; (*b*) their attempts to bite (our small centipede, *Lithobius*, can hardly puncture the skin); (*c*) length of time required to kill them in cyanide bottle as compared with insects.

4. Observe their food and feeding habits.—how they capture insects or worms and eat them.

### SPIDER

*References:*

*Modern Nature Study.* Silcox and Stevenson
*First Lessons in Zoology.* Kellogg

*Introduction to Zoology.* Davenport
*Studies in Zoology.* Merrill

### LABORATORY STUDIES—LIVING ANIMALS

*With specimens under a tumbler, in a clean, dry bottle, or in a vivarium—*

NOTE:

1. Whether they can crawl up glass.
2. How they walk.
3. Their treatment of an offered fly.
4. Whether they eat sugar.
5. The length of time they live without feeding.
6. The amount of distress or inconvenience apparent from the loss of a leg.
7. The hatching of the young spiders from the egg sacs or cocoons—and their cannibalistic behaviour.
8. With a specimen isolated on an upright stick and surrounded by water, observe how it builds its web and escapes.—Hodge, *Nature Study and Life,* p. 419.

### LABORATORY STUDIES—MORPHOLOGICAL

1. Note the two distinct regions of the body.—the *cephalothorax* (head-thorax) and the *abdomen;* their shapes, colours, hairiness, and comparative sizes; also the size of the connecting part.

2. Note the legs.—their number, place of attachment, position in death, number of joints, hairiness.

3. Note the mouth parts (the *mandibles* and *maxillæ* with *palps*).—their position, size, directions of movement, apparent uses.

4. Note the eyes (single eyes—*ocelli*).—their number, situation, arrangement, and apparent field of vision.

5. Note the spinning apparatus.—its situation and general structure.

### STUDIES WITH THE MICROSCOPE

EXAMINE:

1. The hooked end of a leg.
2. The spinning apparatus, which may be sliced off a preserved specimen for this purpose.
3. The structure of one strand of a web.

### GENERAL DISCUSSIONS

1. Comparison of structure of insect and spider
2. Economic uses of spiders.—food of birds, destroyers of harmful insects, silk producers
3. The relationship of harvestmen (Daddy-long-legs) with the true spiders
4. The occurrence of the allied mites and ticks.—leaf-gall-mites, water-mites, itch-mites, cheese-mites, cattle-ticks, etc.
5. The misunderstandings about the poisonous character of spider bites and the danger of the tarantula.

### OUTDOOR WORK

1. Collect specimens for putting in school vivaria or for preservation in liquid preservative in vials—(they cannot be mounted on pins like insects).
2. Collect also some of the tough little egg sacs to be found under window-sills, etc., and keep in jars or bottles, to see the little spiders hatch during the winter or spring.
3. Note.—(*a*) the location and building of webs; (*b*) the position taken by the watching spider; (*c*) manner of securing and entangling prey; (*d*) behaviour when

molested or the web disturbed; (*e*) actions when flies or other spiders are put in webs.

4. Note the structure of webs.—(*a*) the cobwebs of the house-spiders (line weavers) to be found in houses and sheds; (*b*) the orb webs of the garden-spiders (orb weavers) to be found in doorways, lattices, etc.; (*c*) the tube webs of the field- or grass-spiders (tube weavers) found in the grass, corners of fences, etc.

5. Count the number of webs of the grass- or field-spiders on the lawn early in the morning when the dew marks them out. Note whether these webs continue more or less permanently.

6. Compare the spider webs with the webs of insects, for example, tent caterpillars and fall web worm.

7. Observe how prey is secured by the jumping spiders (on logs, barks, etc.) and running spiders (under stones and rubbish), which do not spin webs.

8. Watch for the ballooning of gossamer, or flying, spiders.

9. Watch how they get up to ceilings or let themselves down from heights.

10. Account for the occurrence of spiders with legs missing or shorter than the other legs.

## BEE

*References:*

Text: *First Lessons in Zoology.* Kellogg
Manual: *Studies in Zoology.* Merrill

In a locality where the production of honey is an important industry or where conditions warrant a larger interest in the matter, the study of the honey-bee would be very properly selected as one of the insect studies.

### LABORATORY WORK—LIVING ANIMALS

For this work an *observation bee-hive* will be needed. There are different models of these hives on the market. In Hodge's *Nature Study and Life,* Chap. XIV, different models are described and their use and care explained. It may be possible to arrange with a local apiarist to put one in the school for a season and to look after it. Single-frame hives are best; in them one can have every bee, including the queen, under observation, and if it is set up with a queen cell at the beginning of the season, practically all phases of the bee's life history and activities may be seen. Such a hive will probably require to have its bees put back into a larger hive for the winter. It may be attached to a window-sill in the school-room, preferably where it will not be disturbed too much or have the sun shining on it.

These hives may be secured from The A. I. Root Co., Medina, Ohio (E. Grainger & Co., Deer Park, Toronto, Canadian agents), or F. W. Krouse, Esq., Guelph. The price will depend on the style of the hive and whether bees and queen are required. A hive complete with super, frame of bees, and queen cell will cost about five or six dollars.

1. Learn to recognize the different kinds of bees—queen, drone, and workers. Compare them as to size, shape, activities, and functions.

2. Note the work done by the different classes of workers—guarding, fanning, feeding the grubs, gathering honey, attending the queen, etc.

3. Observe the life history—the queen laying eggs; the growth of the larvæ; the emerging of young bees, etc.

### LABORATORY STUDIES—MORPHOLOGICAL

*The pupils having freshly killed specimens before them and keeping the structure of the grasshopper in mind for frequent comparisons, proceed as outlined for the cabbage-butterfly.*

STUDY:

1. The general form, divisions, etc., of the whole animal.
2. The head and its appendages, noting especially the simple eyes, the mouth parts adapted for biting as well as sucking, the antennæ with their characteristic joint.
3. The wings—noting their differences from the grasshopper's and butterfly's.
4. The legs—noting the flattened *pollen baskets* on one pair of them.
5. The abdomen—noting the *sting* that may be made to protrude by pressure and may then be pulled out.

### STUDIES WITH THE MICROSCOPE

EXAMINE WITH THE LOW POWER:

1. The mouth parts of a honey-bee.
2. The sting of a worker bee drawn from a freshly killed specimen.

### GENERAL DISCUSSIONS

1. The extent of the honey-producing industry in Ontario; the suitability of our climate and vegetation (See the *Annual Reports of the Ontario Beekeepers' Association,* which may be procured from the Department of Agriculture, Toronto.)
2. The extent of the use of bees to the fruit grower
3. The kinds of honey sold in the shops; prices, etc.

4. The different varieties of bees and the history of their origin (See Hodge's *Nature Study and Life.*)

5. Whether it is *instinct* or *intelligence* that explains the wonders of their work and co-operation.

NOTE: OUTDOOR WORK

1. The time of the first appearance of bees in spring.

2. The flowers they visit.—whether they visit (*a*) early spring flowers, such as crocus, tulip, dandelion, or willows; (*b*) fruit-producing blossoms, such as apples, currants, strawberries, grapes; (*c*) flowers of shade trees or ornamental shrubs, such as maples, horse-chestnut, flowering currant, and lilac; (*d*) flowers of vegetables, such as garden peas, beans; (*e*) flowers of field crops, such as clovers, peas, buckwheat, flax; (*f*) flowers of weeds, such as blueweed, thistles, and mustard.

3. Their manner of feeding.—(*a*) how they work at a flower to get the nectar or pollen; (*b*) how they "load-up" with the pollen; (*c*) whether they visit all nearby flowers of like and unlike kind; (*d*) whether they seem to prefer any particular colour of flower; (*e*) whether they interfere in any way with other bees; (*f*) whether they enter houses to secure food.

4. Their enemies.—whether birds molest them (the king-bird is sometimes called the bee-bird).

NOTE: OBSERVING THE WILD BEES

1. Early in the spring, the large queen bumble-bees, which have survived the winter, flying clumsily about, seeking quarters to establish a colony.

2. In the summer, the circular patches cut out of rose leaves, etc., by the leaf-cutting bees.

## COLORADO POTATO BEETLE

### LABORATORY WORK—LIVING ANIMALS

*With specimens in glass jars or terraria—*

NOTE:

1. Their manner of walking and climbing. Can they climb up glass?

2. Their life history. This may be observed if eggs are brought in and the larvæ fed regularly; notice the manner of feeding, moulting, etc.

3. Their powers of reproduction. Count the number of eggs laid by one female alone.

### LABORATORY WORK—MORPHOLOGICAL

*Keeping in mind the grasshopper or other type studied as a basis of comparison, proceed as outlined for the cabbage-butterfly.*

Note particularly the things that characterize it as a beetle.—(*a*) the *elytra* (shield wings); (*b*) the *mouth parts* adapted for biting and chewing; (*c*) the movable *prothorax,* and (*d*) the complete *metamorphosis.*

### DISCUSSIONS

1. The use of Paris green in controlling the pest; what Paris green is composed of, its manufacture and cost; best methods of application

2. The history of the introduction of the pest—recollections of old settlers regarding it; localities still free from it; its cost to the country.

### OUTDOOR WORK

NOTE:

1. The date of its first appearance; whether it has any relationship to the time of potato planting; whether living beetles are uncovered in spring working of gardens.

2. The nature of its flight.—(*a*) how its outer wings are held; (*b*) how high, how fast, and how far it flies; (*c*) how it adjusts its wings on alighting.

3. Its development and feeding habits.—(*a*) whether the matured beetles eat the potato leaves; (*b*) the location, colour, size, number, markings, and attachment of the eggs; (*c*) the hatching of the eggs into larvæ, their growth and varying sizes; (*d*) how the larvæ eat the foliage; (*e*) the effects of Paris green applications; (*f*) the occurrence of full-grown larvæ or their pupæ in the ground about the potato plants.

4. Its enemies.—whether birds or poultry attack it, either as a full-grown beetle or as the larva.

## HOUSE-FLY

*Reference:*

*Studies in Zoology.* Merrill

### LABORATORY STUDIES—LIVING SPECIMENS

1. With some attractive food on one's hand or finger, study the fly's manner of feeding.

2. Note its manner of flying, walking, crawling on the ceiling.

3. With different substances, for example, sweetened water, milk, meat, salt, and sand, set in dishes in different parts of the room, determine which is most attractive or which is preferred.

4. With a piece of meat or some horse manure (kept from drying out) put into a vivarium together with a definite number of flies, watch the development and determine in some measure the rate of increase of this pest.

### LABORATORY STUDIES—MORPHOLOGICAL

Proceed as with the butterfly and other insects, noting particularly.—(*a*) the number of wings; (*b*) the structure of the feet; (*c*) the structure of the mouth parts; (*d*) its hairiness; (*e*) the size of the eyes.

### STUDIES WITH THE MICROSCOPE

Examine:

1. The detached mouth parts.
2. The fly's foot.
3. Its wings.

### GENERAL DISCUSSIONS

1. The justification for its being called the deadliest animal in the world. How typhoid fever is spread by it.

2. Its toll of death in the South African War. Comparison with the Russo-Japanese War.

3. Best means of combating the pest.

### OUTDOOR WORK

Note:

1. How the approach of the autumn affects the prevalence of flies.

2. How the attacks of a fungus parasite kill them off in the autumn.

3. Where are surviving flies to be found in winter?

4. At what time are they first noticed in numbers in the spring?

5. Does the proximity to horse stables or manure piles seem to affect their numbers?

6. Estimate the number that may be produced from a little pile of horse dung.

7. What kinds of odours or foods seem to attract them most?

8. In what kinds of shops are they seen most frequently?

9. Learn to distinguish other common flies, such as the stable fly, the horsefly, the blue-bottle fly.

10. Observe how some of their natural enemies capture them, for example, the common garden toad, swallows, etc.

## BUGS

*References:*

*Modern Nature Study.* Silcox and Stevenson
*Studies in Zoology.* Merrill

### LABORATORY STUDIES—LIVING ANIMALS

*On a house plant, twig of fruit tree, or cabbage leaf infested with plant-lice (aphids)—*

1. Count the number of insects feeding on one leaf.
2. Note the effect of treating the foliage with an infusion of tobacco leaves or soap-suds.
3. Observe the emergence of winged forms from the larvæ, the presence of the larval skins, etc.

### LABORATORY STUDIES—MORPHOLOGICAL

*Using any of the common forms mentioned below, for example, the squash-bug, proceed as in other insect studies, noting particularly—*

1. The suctorial mouth.
2. The wing structure and arrangement.

### STUDIES WITH THE MICROSCOPE

Examine a plant-louse (aphid), with the low power, noting the eyes, antennæ, honey tubes, etc.

### GENERAL DISCUSSIONS

The wide prevalence of plant-lice on plants, the damage they do, and the remedies to apply.

### OUTDOOR WORK

Learn to recognize some of the common insects of this class, such as the following:

1. (*a*) The many different plants infested by plant-lice or aphids; (*b*) their manner of feeding and the effects on leaves; (*c*) the occurrence of "honey-dew" and ants on some of the plants infested by the aphids—also their enemies, the larvæ of lady-bird beetles.

2. The water-bugs.—the giant water-bug (the large so-called electric light bug) flying about electric street lamps in the spring or summer, and the water-boatman and back swimmers in ponds and quiet pools.

3. The water striders.—(*a*) how they walk on top of the water; (*b*) the depressions in the surface of the water made by their feet; (*c*) the shadows and colour effects made on the bottom of the stream by these depressions.

4. The Cicada.—learn to recognize its shrill trill among the trees during the hot days of July and August; if possible, observe how this noise is made by a series of cymbal-like plates.

5. Other important insects of this class.—the bed-bug infesting houses; the stink bug on berries; the squash-bug on squash vines; the lice infesting man or domestic animals; the leaf-hoppers in the grass or among shrubbery; the scale insects, such as oyster-shell bark louse and San José scale.

## DRAGON-FLY

*References:*

*Insect Stories.* Kellogg
*Studies in Zoology.* Merrill

### LABORATORY STUDY—LIVING ANIMALS

*Gather some of the dragon-fly nymphs from the bottom of a pond or roadside ditch in the early spring and place them in the school aquarium. Feed them well on mosquito wrigglers, tadpoles, etc.*

1. Observe their manner of swimming, walking, fighting, etc.

2. Notice how they seize their food.

3. Note the changes in the sizes of the growing nymph and try to find one moulting.

4. Provide sticks on which they may crawl to the top of the water; cover the aquarium with netting, and try to see the insect emerge from the nymph state into that of the fully developed dragon-fly.

### LABORATORY STUDY—MORPHOLOGICAL

Examine killed nymphs and notice the peculiar projectible under lip; also the appearance of the developing wings.

Study the dragon-fly as the other insects were studied, comparatively and systematically, noting particularly:

1. (*a*) The great strength of thorax and wings; (*b*) the movability of the head; (*c*) the mouth parts specially adapted for securing and crushing mosquitoes; (*d*) the large eyes; (*e*) the netting of the wings.

### STUDIES WITH THE MICROSCOPE

EXAMINE:

1. A piece of one of the compound eyes.
2. One of the wings.

### GENERAL DISCUSSION

The dangers reputed to pertain to these "Devil's Darning Needles".

### OUTDOOR WORK

1. During what months are they found flying? At what times during the day are they most active?

2. Are they ever to be seen far from bodies of water?

3. Study their wonderful flight.—(*a*) their speed; (*b*) their power of suddenly rising, dropping, zigzagging, backing, or standing apparently motionless in the air. (*c*) Can you hear any noise made by their wings? (*d*) Can you see the wings move? (*e*) How and where do they rest? (*f*) Are there any signs of play in their flying? (*g*) Notice their pausing and dipping the tip of the abdomen into the water; this is an egg-laying act.

4. Is there justification for calling them the "hawks" among the insects? What do they feed on? Do they ever try to take any fair-sized insects?

5. Note whether any birds prey upon them.

## COLLECTING AND MOUNTING INSECTS

*Reference:*

*Nature Collections for Schools*—Agricultural Bulletin No. 8 (revised edition of *Bulletin 134*), Department of Education, Toronto. Free.

In order to lessen the expense to the pupil of the materials required for making a collecting outfit, wholesale supplies might be kept on hand at the school and sold at cost. If a class committee can be appointed to buy and distribute the material, the teacher will be spared a great deal of trouble. For each pupil there will be required: one wide-mouthed bottle (a quinine bottle suits well) for a killing bottle; thirty inches of strong coppered spring wire, one three-foot basswood stick, half a yard of mosquito netting, some stove-pipe wire and a few window-blind staples for an insect net; fifty insect pins, sizes, 3, 4, and 5; a small cork-lined insect box. The whole outfit should not cost more than seventy-five cents, the school supplying cyanide and plaster of Paris free.

The most expensive item is the cork-lined insect box. A cigar box may be made to answer for a commencement. It is advisable to get cork lining, but corrugated cardboard used for packing bottles will answer fairly well.

Basswood window dowels make good handles for the nets.

The value of an insect collection is not to be measured by its size. A small collection, carefully and neatly prepared, pinned and labelled, is much to be preferred to a much larger collection that is marked by carelessness and untidiness. Each insect in a collection should represent a clear, if slight, advance in a knowledge of nature; this will find expression in a label showing when and where the capture was made. Unlabelled hodge-podges of collections should be discouraged. It is desirable, for the sake of the training in neatness, to insist on the use of proper insect pins.

Pupils showing a special aptitude for the work of collecting should be encouraged to follow up the study of some special class of insects along with their general collecting. They should be directed, too, to make the acquaintance of other collectors through The Entomological Society of Ontario or some of its branches.

## BIRDS

*Reference:*

*First Course in Biology.* Bailey and Coleman

### LABORATORY OBSERVATION—LIVING ANIMALS

*With a canary or other caged bird that may be loaned to the school by a pupil—*

NOTE:

1. The general shape and divisions of the body.
2. The general arrangement of the feathers.
3. The structure of the bill, leg, foot, and toes.
4. The manner of eating, drinking, bathing, preening, singing or chirping, and sleeping.
5. The manner of roosting, hopping, flying, or balancing on the perch.

*Using a pigeon or sparrow set free in the school-room—*

NOTE:

1. The manner of flight.—(*a*) how it commenced; (*b*) how far and in what direction the wings are extended; (*c*) the directions of their movements; (*d*) the position of the legs and feet in flight; (*e*) the manner of turning and alighting.

### LABORATORY STUDIES—MORPHOLOGICAL

*Using a mounted bird, a bird skin, or a freshly killed sparrow, pigeon, or fowl, locate and name the different regions or areas recognized in the description of the topography of a bird—*

1. Along the middle line of the body.—*bill, forehead, crown, nape, back, rump, tail, belly, breast, throat,* and *chin.*

2. The legs.—*tibia, tarsus, toes.*

3. The feather areas.—*contour feathers,* making the general covering; *tail feathers, upper tail coverts, under tail coverts; wing feathers,* comprising *primaries, secondaries,* and *tertials, upper wing coverts,* and *under wing coverts.*

Discuss the differences in the character of the feathers in these different areas and the special purposes served by them.

### THE LEGAL ASPECT OF BIRD STUDIES

Write to E. Tinsley, Esq., Superintendent of the Ontario Game and Fisheries Department, Parliament Buildings, Toronto, for copies of the booklet, entitled *Ontario Game and Fishery Laws, 1908.* With these in the hands of the pupils, discuss the provisions of the *Act for the Protection of Insectivorous and other Birds,* p. 53. Retain the copies for subsequent classes, but keep one copy on the bulletin board for reference.

### COMPARISON OF THE BILLS, WINGS, LEGS, AND FEET OF DIFFERENT TYPES OF BIRDS

1. Direct the pupils to make observations on these structural features of hens, ducks, pigeons, parrots, and canaries, or such common wild birds as gulls, herons, hawks, owls, killdeer, woodpeckers, humming-birds, etc.

2. Discuss the observed similarities or differences and their adaptations to their special uses or functions.

3. With the pupils' knowledge acquired by personal observation as a basis, use mounted specimens, charts, or lantern slides to extend their knowledge.

Mounted collections of these parts of birds suitable for class use may be made by tacking the dried and extended wings, feet, or bills on boards. Being well dried, they will prove serviceable for years.

### SKELETAL CHARACTERS OF BIRDS

*Reference:*

*First Course in Biology.* Bailey and Coleman

From the knowledge already in possession of the pupil regarding the external form of a bird, some deductions may be made regarding the probable internal skeletal structures, for example, the vertebral structure of the movable neck, and the connection of the bones of the wings and those of the legs with an internal framework. These facts may be deduced as an introduction to the examination of a skeleton.

*Using a prepared mounted skeleton—*

NOTE:

(*a*) The bony character of the skeleton with the exception of bill and nails; (*b*) the vertebral axis extending from the head to the tail with distinct regions marked by differently shaped vertebræ; (*c*) the strong breast-bone and its connection with the vertebral axis; (*d*) the manner in which the wings and legs are swung to the rest of the skeleton; (*e*) the likeness of a wing to an arm.

Based on these observations, discuss the suitability of the structure to the purposes of the living animal.—(*a*) its being almost entirely bone; (*b*) its having movable vertebræ in the neck and tail; (*c*) its having united vertebræ in the synsacrum; (*d*) the possession of a strong keel on the breast-bone; (*e*) the necessity for strong supports for the wing and leg attachments, etc.

*With more or less separated bones brought from home or picked up on field excursions*—

Identify the part of the skeleton to which they belong and get their names.

Add some of these bones, correctly labelled, to the school's museum collections, for example, the skulls, breastbones, merry-thoughts, thigh bones, etc., of the common domesticated fowl.

## FEATHERS

*Reference:*

*First Course in Biology.* Bailey and Coleman

*Using samples of tail, wing, and the ordinary contour feathers (these supplied to the pupils or preferably brought to class by them)*—.

NOTE:

1. The general form, substance, weight, and colourings.

2. The divisions.—*quill, vane, rachis, after-shaft,* and *barbs.*

3. The close attachment of the barbs or their loose binding in the different kinds of feathers.

*Using a fowl prepared for market*—

NOTE:

1. The areas that are free of feather bearing.

2. The presence of the small hair-like feathers (*filoplumes*).

3. Whether the quills go through the skin into the flesh beneath.

4. The occurrence of developing feathers (*pin feathers*) on young fowl.

### STUDIES WITH THE MICROSCOPE

**Examine:**

1. A few disturbed barbs of a feather to show how they are interlocked.

2. A barb taken from an ostrich plume or a down feather.

### GENERAL DISCUSSIONS

1. The suitability of feathers to the special needs of birds
2. Their use in comforters, "feather-bone", etc.
3. The "plucking" of geese and the value of goose feathers
4. The kinds of feathers used in millinery
5. The proper uses of feathers in hat decoration
6. The Audubon Societies and their work.

### COLLECTION OF FEATHERS

Characteristic feathers of fowl or wild birds may often be picked up. These may be used for testing the pupil's ability to recognize the birds by odd feathers; they may be used, too, for collections, by fastening them to cardboard or into a portfolio.

### EGGS

*Reference:*

*Manual of Zoology.* Parker and Haswell

*Using perfectly fresh hens' eggs, note:*

1. The shape, colour, and appearance of the surface of the shell.
2. Its buoyancy and axis of floating in a glass of water.
3. The size of the air space found at the larger end when the shell is removed therefrom.

*Breaking away some of the shell, note:*

The colour and toughness of the underlying *shell-membrane.*

*Emptying the contents of the shell into a basin of water, note:*

1. The colour and consistency of the white (*albumen*), tough, rope-like strands in it; the ease or difficulty of separating the white from the yolk, using forceps.
2. The inclosure of the yolk in a membrane and the presence of a white spot (*germinal disc*) on it.

*Using a very hard-boiled fresh egg, note:*

The layered nature of the albumen and the presence of a core in the yolk that does not harden.

### DISCUSSIONS

1. The functions of the different parts of an egg
2. The number of eggs laid by different birds
3. The preservation of eggs (O.A.C. Bulletin) for household uses
4. Methods of testing eggs in the trade
5. The extent of the egg industry.

### EXPERIMENTS

1. To find out how much weight is lost in a week by evaporation from a dozen eggs kept under ordinary household conditions.
2. To compare this with the evaporation from a dozen kept in cold storage, wrapped in paraffined paper, or immersed in water-glass pickle.
3. To find the effect of this evaporation on the size of the air space in the egg and the consequent change in buoyancy.

### COLLECTIONS OF BIRDS' EGGS

While a collection of birds' eggs might serve a useful purpose in connection with school bird studies, great care must be taken not to encourage wholesale egg-collecting by the pupils. The law should be carefully observed in the matter. Let any school collection that is made grow slowly and through legitimate and judicious collecting by some of the older boys or by the teacher.

A collection of typical eggs laid by different breeds of chickens and other domesticated fowl would prove of value and interest in country schools.

For instructions on preparing egg-shells for collections see *Bird Life,* Chapman, p. 29.

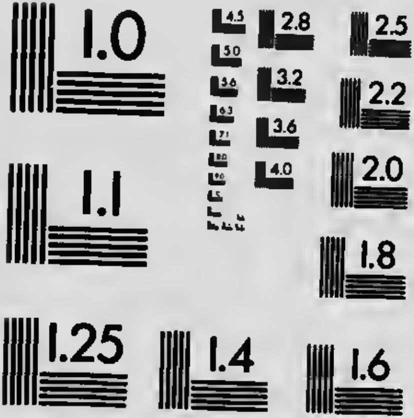
### VISCERA OF A BIRD

As the Course of Study in general lacks in a physiological application, this topic will be of value in directing some attention to such a consideration; so far, at least, as making a practical acquaintance with the vital organs of the body. It may prove worthy of consideration, too, in localities where there are home interests in poultry keeping, or where boys or girls help in preparing fowl for the home table or for the market.

The work may be covered by directing the pupils to study the subject at home, putting such a book as Bailey and Coleman's *First Course in Biology* or Colton's *Descriptive Zoology* into their hands as a guide. If the school is provided with a mounted dissection, such as furnished by Ward or Kny-Scheerer, the subject may be readily covered by the class.

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



*Using a freshly killed and healthy hen or pigeon—*

1. Open the bird's mouth and insert a glass tube or blow-pipe through the glottis into the windpipe. Blow through this to show the large expansion resulting from filling all the air chambers in the visceral cavity.

2. With the bird lying on its back on a sheet of heavy paper, cut through the ventral body wall carefully with scissors and observe the expanded air chambers mentioned above.

3. Remove the flesh of the ventral body wall and with strong scissors cut out the breast-bone as well, so as to expose the entire visceral cavity. Note the organs as they lie naturally, and make a drawing.

4. Respiratory organs.—Trace the windpipe (*trachea*) through its branches (*bronchi*) into the two lungs.

5. Digestive organs.—Trace the alimentary (food) canal from the gullet through the crop, stomach, gizzard, small intestine, large intestine, cæca, and cloaca. Notice the liver, spleen, and pancreas.

6. Reproductive organs.—Note the left ovary, the oviduct, and its connection with the cloaca.

7. Excretory organs.—Note the size and position of the two kidneys.

8. Circulatory organs.—Note the location and size of the heart and the arteries leading from it.

9. Note the membrane lining the body cavity and holding together the folds of the intestine (*peritoneum*).

### GENERAL DISCUSSIONS

1. The functions performed by the different organs
2. The structure of the gizzard and its manner of working
3. Comparison with organs in the human body.

### LABORATORY STUDIES—BIRD RECOGNITION

*To introduce pupils to a few common birds, so that their interest may be aroused and their field work made effective.*

Using the school collection of birds' skins, note the size, colourings, bills, and feet of such birds as pupils may still see in the neighbourhood during the autumn or winter, for example, house-sparrow, junco, goldfinch, snowbird, and redpoll, representing the *finches* and *sparrows;* the meadow-lark and cowbird, representing the *orioles* and *blackbirds;* the flicker, downy woodpecker, and hairy woodpecker, representing the *woodpeckers,* etc.

Arrange to have the skins accessible for further independent study or observation. A class committee might take charge of them. In subsequent lessons, test the pupils' ability to recognize the birds, by giving them short, pithy, practical examinations or quizzes. At the commencement of the spring migrations, continue this exercise with other skins.

Have the pupils commence the keeping of independent records of their observations. Walter's *Wild Birds in City Parks* offers good suggestions in this connection.

### LIST OF ONE HUNDRED OF THE COMMONER BIRDS OF ONTARIO

This list of birds is inserted as a directive suggestion of the attainment in bird recognition that might reasonably be reached. Pupils should be encouraged to use either Walter's *Wild Birds in City Parks* or Reed's *Bird Guide, Part II,* for a field guide; a committee of the class might arrange for their purchase at a reduced clubbing rate.

The dates given in the list have been compiled from Nash's *Check List of the Birds of Ontario* and the migration reports made by the Wellington Field Naturalists' Club in the years 1904 and 1905. They are not to be considered in any sense as fixed times, but merely as suggestions for directing timely observations. In our variable seasons and wide separations in latitudes, there are reasons for great differences in the times of bird migrations.

The birds are listed, so as to allow teachers to keep records for themselves in this Manual.

***Water, Marsh, and Shore Birds***

| | |
|---|---|
| **Horned Grebe** | **Occasional resident** |
| **Pied-billed Grebe** | **April-October** |
| **Loon** | **Occasional resident** |
| **American Herring Gull** | **Resident** |
| **American Merganser** | **Resident** |
| **Red-breasted Merganser** | **Resident** |
| **Mallard** | **Scarce resident** |
| **Black Duck** | **Scarce resident** |
| **Blue-winged Teal** | **Scarce resident** |
| **Canada Goose** | **Migrant** |
| **American Bittern** | **April-October** |
| **Great Blue Heron** | **April-September** |
| **American Coot** | |
| **Spotted Sandpiper** | **May-September** |
| **Killdeer** | **March-October** |

***Grouse and Partridge***

| | |
|---|---|
| **Quail (Bob White)** | **Resident** |
| **Ruffed Grouse** | **Resident** |

***Pigeons***

| | |
|---|---|
| **Mourning Dove** | **Occasional resident** |

***Hawks***

| | |
|---|---|
| **Red-tailed Hawk** | **March-November** |
| **Red-shouldered Hawk** | **March-October** |

| | |
|---|---|
| Marsh Hawk | March-October |
| Sharp-shinned Hawk | April-September |
| Cooper's Hawk | March- |
| Sparrow Hawk | March-September |
| *Owls* | |
| Great Horned Owl | Resident |
| Saw Whet Owl | Occasional resident |
| Screech Owl | Occasional resident |
| *Cuckoos and Kingfishers* | |
| Black-billed Cuckoo | May-September |
| Belted Kingfisher | April-October |
| *Woodpeckers* | |
| Flicker (High Holer) | April-October |
| Yellow-bellied Sapsucker | April-September |
| Red-headed Woodpecker | May-September |
| Downy Woodpecker | Resident |
| Hairy Woodpecker | Resident |
| *Goat-suckers, Swifts, and Humming-birds* | |
| Whip-poor-will | May-October |
| Night Hawk | May-September |
| Chimney Swift | May-August |
| Ruby-throated Humming-bird | May-September |
| *Flycatchers* | |
| Phoebe | April-October |
| King-bird | May-August |
| Crested Flyca | May-August |
| Wood Pewee | May-September |
| Least Flycatcher | May-August |
| *The Larks* | |
| Prairie Horned Lark | February-November |
| *The Crows and Jays* | |
| Blue Jay | Resident |
| Crow | Resident |
| *Orioles and Blackbirds* | |
| Bronzed Grackle | March-October |
| Meadow-lark | March-October |

| | |
|---|---|
| Red-winged Blackbird | March-October |
| Cowbird | April-October |
| Bobolink | May-August |
| Baltimore Oriole | May-August |

*Finches and Sparrows*

| | |
|---|---|
| Purple Finch | Resident |
| Junco | Resident |
| American Goldfinch | Resident |
| House Sparrow | Resident |
| Song Sparrow | March-October |
| Vesper Sparrow | April-October |
| Savannah Sparrow | April-October |
| White-throated Sparrow | April-October |
| Field Sparrow | April-October |
| Chipping Sparrow | April-September |
| Swamp Sparrow | April-November |
| Towhee | April-October |
| Red-breasted Grosbeak | May-August |
| Indigo Bunting | May-August |
| Scarlet Tanager | May-August |
| Fox Sparrow | Migrant |
| White Crowned Sparrow | Migrant |
| Tree Sparrow | Winter visitor |
| Snowbird | Winter visitor |
| Pine Siskin | Winter visitor |
| Redpoll | Winter visitor |

*Swallows*

| | |
|---|---|
| Barn Swallow | April-September |
| Tree Swallow | April-September |
| Purple Martin | April-September |
| Cliff Swallow | May-August |
| Bank Swallow | May-September |

*The Waxwings*

| | |
|---|---|
| Cedar Waxwing | Occasional resident |
| Bohemian Waxwing | Winter visitor |

*The Shrikes*

| | |
|---|---|
| Northern Shrike | Winter visitor |
| Migrant Shrike (Butcher Bird) | April-August |

*The Vireos*

| | |
|---|---|
| Red-eyed Vireo | May-September |
| Warbling Vireo | May-September |

*Kinglets*

| | |
|---|---|
| Golden-crowned Kinglet | Migrant |
| Ruby-crowned Kinglet | Migrant |

*The Warblers*

| | |
|---|---|
| Black and White Warbler | May-September |
| Yellow Warbler | May-August |
| Chestnut-sided Warbler | May-September |
| Black-throated Green Warbler | May-October |
| Oven Bird | May-September |
| Water Thrush | May-September |
| Maryland Yellow-throat | May-September |
| Canadian Warbler | May-August |
| American Redstart | May-September |
| Blackburnian Warbler | May-September |

*Wrens and Thrashers*

| | |
|---|---|
| Catbird | April-October |
| Brown Thrasher | April-October |
| House-wren | May-October |

*Thrushes*

| | |
|---|---|
| Wilson's Thrush (Veery) | May-August |
| Hermit Thrush | May-August |
| Robin | March-November |
| Bluebird | March-October |

### WALL CHART SHOWING BIRD MIGRATIONS

A chart, made by the pupils themselves and showing the times of arrival and departure of a few well-known common birds, will stimulate observation and arouse interest. If it is ruled so as to allow records to be made for a number of years, it will be of so much the greater value. The material used for roller window-blinds answers well, as it takes a good impression from an India ink crayon and wears well; for the sake of economizing wall space and protecting the chart it should be fastened to a spring roller. Care should be taken to have only reliable records tabulated. The following twenty-five birds are suggested for the chart. The records will be made chiefly in April and May, September and October.

| Birds | First and Last Appearances | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1917 | | 1918 | | 1919 | | 1920 | |
| Prairie Horned Lark | | | | | | | | |
| Killdeer | | | | | | | | |
| Bluebird | | | | | | | | |
| Robin | | | | | | | | |
| Song Sparrow | | | | | | | | |
| Meadow-lark | | | | | | | | |
| Red-winged Blackbird | | | | | | | | |
| Phoebe | | | | | | | | |
| Bronzed Grackle | | | | | | | | |
| Flicker | | | | | | | | |
| Kingfisher | | | | | | | | |
| Barn Swallow | | | | | | | | |
| Chipping Sparrow | | | | | | | | |
| Chimney Swift | | | | | | | | |
| Spotted Sandpiper | | | | | | | | |
| Bobolink | | | | | | | | |
| Yellow Warbler | | | | | | | | |
| King-bird | | | | | | | | |
| House-wren | | | | | | | | |
| Catbird | | | | | | | | |
| Brown Thrasher | | | | | | | | |
| Humming-bird | | | | | | | | |
| Wood Pewee | | | | | | | | |
| Cedar Waxwing | | | | | | | | |
| Night Hawk | | | | | | | | |

### BIRD STUDIES AT EXHIBITIONS

In a locality where there is a general interest in poultry raising, a good use may be made of the poultry exhibits at the Fall Fairs, etc., to develop an interest in the study of domesticated birds. Previous to the fair, a live fowl might be used in school to teach the names of the parts and markings, so that any systematic observations made at the fair may be intelligent and to the point. If a local poultry fancier can be secured to give a talk to the pupils on some of the common breeds, using live birds for illustrations, so much the better. Such work may lead to the formation of very wholesome interests and hobbies.

## SPRING WORK OF FIRST YEAR

### MOSQUITO

*References:*

*Nature Study and Life.* Hodge
*First Lessons in Zoology.* Kellogg
*Book of Suggestions to Teachers.* Lucas

### LABORATORY STUDIES—LIVING ANIMALS

*Using packages of the eggs or a supply of the larvæ placed in glass jars, which are kept covered by mosquito netting—*

NOTE:

1. The number of eggs in a package and their hatching into larvæ.
2. The shape, size, colour, and divisions of the body.
3. Their locomotion.—how they reach the top of the water (do they float up?); how they get to the bottom of the water (do they sink down?); their position in respect to the surface of the water; the effect of disturbing the jar or water.

### LABORATORY STUDIES—MORPHOLOGICAL

*Using freshly killed specimens of the insects—*

NOTE:

1. The divisions of the body, number of legs and wings, the antennæ, presence of hairs, the mouth structures.

2. The distinctions between the male and female in their antennæ and mouth parts.

### STUDIES WITH THE MICROSCOPE

Examine the mouth parts, antennæ, wings, and eyes, with the low power; a living larva is also interesting

### DISCUSSIONS

1. Malarial and Yellow Fevers

2. The distinction between the malarial-producing *Anopheles* and the common *Culex* (See *Nature Study and Life,* Hodge.)

### OUTDOOR LIFE

NOTE:

1. Whether active wintering specimens are to be found in warm houses, cellars, greenhouses, etc.

2. The presence of the wrigglers (larvæ) in rain barrels, swamps, ponds, and puddles in the early spring. Collect some and keep them in jars of water.

3. (*a*) The time of year that the mosquitoes become common; (*b*) the relation of their abundance or scarcity to the dampness or dryness of the season; (*c*) the time of the cessation of the pest, and its relation to the dry weather; (*d*) their comparative abundance in high and low parts of the town.

4. Their value as a fish food, by putting some of the larvæ into an aquarium where a fish is kept.

5. The occurrence of little boot-shaped packages of eggs in barrels or pails of water that may be exposed overnight in places where mosquitoes prevail, or in dishes of water set in terraria supplied with specimens.

6. How the humming noise is produced by the insect. Do male mosquitoes hum?

7. How they "draw blood" from their victims. Do the males do this?

8. The effect of treating the irritating wound left by the insect with baking soda or ammonia water.

## FRESHWATER MUSSEL OR CLAM

*References:*

*First Course in Biology.* Bailey and Coleman
*Studies in Zoology.* Merrill

### LABORATORY STUDIES—LIVING ANIMALS

In collecting it is not necessary to carry specimens in pails of water; it is sufficient to keep them moist and cool in damp moss. Clams will live a long time in a jar of water, even without any plants growing in it. When a specimen dies, care should be taken to remove it, as its decomposition causes a horrible odour.

*Using a specimen kept in water in a glass jar or aquarium that has a few inches of clean sand at the bottom—*

NOTE:

1. How long, and by what method, it takes to get "right side up" after being deposited on the sand on its side.

2. How far, and in what position, it buries itself in the sand and how it manages to do it.

3. The rate of its forward movement, measured by the length of the furrow left behind it or by marking its positions with pieces of paper fastened to the glass.

4. Its behaviour when disturbed.—effect of jarring the aquarium, stirring the water, touching the fringe of its valves with a pencil.

5. The water currents entering and leaving the shell through the valves; these may be seen by inserting a few drops of coloured ink near the valves by means of a pipette, or by having the water in the aquarium so shallow that the surface is just above the clam (which should be near the side of the aquarium) and then looking through the glass up under the surface.

### LABORATORY STUDIES—MORPHOLOGICAL

Clams are best killed by immersing in boiling water for a few minutes. If they are to be preserved in alcohol, a hole should be made in the shell, so that the liquid will be readily admitted.

*Using clean, empty shells, a supply of which should be kept on hand—*

NOTE:

1. On the outside.—the colour, shape, proportions, markings, line of dirt deposits, and amount of springiness in the *hinge* joining the two *valves.* How far apart are the valves kept by the hinge?

2. On the inside.—the colours and markings made by the *mantle* and *muscle*; the presence of rough spots in the pearly layer—the *mother-of-pearl* layer.

3. The nature of the substance composing the shell. Scrape the outside of the shell to see if there is anything

like horn in it; in a test-tube, treat a broken piece of the shell with a solution of hydrochloric acid. What kind of substance composes the hinge?

*Lay in water, in a soup plate, a freshly killed specimen from which one valve has been carefully removed, either by cutting through the adductor muscles or breaking it away piecemeal, and—*

NOTE:

1. The absence of any distinct divisions of the body or such organs as eyes, feet, feelers, bones.
2. The two large *muscles* which hold the valves together.
3. The large ploughshare-shaped *foot.*
4. The *mantle* with the band of muscle bordering it and fixing it to the valve.
5. The *siphons* with their fringes at the posterior edge of this.
6. The two *gills* lying under the mantle, and their markings. (If one of these is much swollen it will be due to the presence of young "seed" which the female carries here for a time.)
7. The *mouth* above the forward end of the foot, with a pair of flap-like *palps* at the side of it.
8. The *heart* at the top between the two large muscles.
9. The likeness of the structure to a book with the two valves of the shell making the cover; the two parts of the mantle, the gills and the foot constituting the leaves and body of the book.
10. As a supplementary exercise, identify as far as possible the corresponding parts of an oyster. Both being *bivalves*, account for the differences in structure.

### DISCUSSIONS

1. The manner of formation, composition, and value of pearls

2. The so-called pearl buttons and ornaments.—how they are made; the clam-shell trade of the Mississippi valley; Ontario factories

3. Oysters and the oyster industry. *First Lessons in Zoology.* Kellogg

### OUTDOOR WORK

NOTE:

1. The occurrence of clams in the bottom of rivers or ponds; how their appearance accords with the stones; how they reveal their presence by the slit between the valves.

2. The closing of their valves when disturbed; how they may sometimes be drawn from the water through their closing on a stick or wire that is gently inserted in the slit.

3. The occurrence of small piles of empty clam-shells along the banks, showing evidence of the feeding of musk-rats; also open and empty shells lying out in the river or washed up by the waves on the shores of lakes.

4. The presence of numerous small specimens—from the size of a mustard seed to that of a grain of corn—in the sand or small gravel that is found in the river bottom below ripples or bars.

## COMMON GARDEN SLUG

*References:*

*Modern Nature Study.* Silcox and Stevenson

*Book of Suggestions to Teachers.* Walter, Whitney, and Lucas

*Studies in Zoology.* Merrill

### LABORATORY STUDIES—LIVING ANIMALS

*Using specimens in a glass jar in which some cool, moist "cover" is provided for them—*

NOTE:

Their feeding habits.—how they eat freshly provided cabbage leaves, etc.

*Using specimens moving on a sheet of glass or in a tumbler—*

NOTE:

1. The sliding, undulating movement of the foot observable when one looks through the glass at the under side of the animal.

2. The slimy trail left on the glass. Does the animal's supply of the mucous substance seem to become exhausted in travelling over dry glass? Is the animal's body naturally dry or moist?

3. Whether the animal can crawl up or down, according as the glass is turned one way or the other.

4. The changes in the shape of its body.—(*a*) how long, how flat, or how rounded it becomes; (*b*) how it projects or withdraws its *tentacles* or mouth; (*c*) the effects of disturbing it by touching the tentacles with a pencil.

5. The eyes.—dark spots at the end of the longer pair of tentacles.

6. The mouth.—to be seen through the glass on the under side, beneath the tentacles.

7. The respiratory aperture.—its position on the right side of the body and its opening and closing.

8. The mantle.—the thickened and raised fold on the upper forward part of the body.

### SUPPLEMENTARY LESSONS

If opportunity offers, pupils should be made acquainted with the common land and pond snails also. The pond snails will be found in great abundance in the spring, and can be observed well in glass jars of water. In an aquarium they are very useful in keeping glass sides free of incrustations. Their eggs can be easily found. The land snails will be found under damp leaves in the woods.

### DISCUSSIONS

1. The trade in edible slugs in France
2. Means of combating garden slugs when they become a pest to gardeners.

### OUTDOOR STUDIES

NOTE:

1. (*a*) Their occurrence in the garden under boards or rubbish; (*b*) the attitude assumed when disturbed; their attempts to escape; (*c*) whether they are to be found under dry boards or rubbish.
2. Whether they are to be seen moving about during the day, either when it is dry and sunny, or damp and cool. Where and how do they winter?
3. The silvery tracings to be seen on the sidewalks or ground in the early morning, marking the slimy tracks of the animal's travels during the night.
4. Whether they are found damaging vegetables such as cabbage, lettuce, or tomatoes.
5. Whether birds or toads prey on them.

## EARTHWORM

*References:*

*First Course in Biology.* Bailey and Coleman

*Nature Study and Life.* Hodge

*Book of Suggestions to Teachers.* Walter, Whitney & Lucas

### LABORATORY STUDIES—LIVING ANIMALS

*Using large-sized specimens on sheets of moistened paper or on plates—*

NOTE:

1. (*a*) The colour; (*b*) the length, extended and contracted; (*c*) the *anterior* (head) and *posterior* (tail) ends; (*d*) the varying shape of the body along its length.

2. Its locomotion.—(*a*) the direction, speed, and manner of moving; (*b*) the effect of touching the moving animal; (*c*) whether it can move backward; (*d*) how it rights itself if turned over; (*e*) the feel of the under side of the animal when drawn over the finger; (*f*) whether it can crawl up glass (see *Nature Study and Life,* Hodge, p. 428).

3. Its structure and parts.—(*a*) the number of *segments* making up the body; (*b*) the position of the mouth and the shape of the first segment; (*c*) whether there are eyes present; (*d*) the presence of the *girdle* (a swollen ring, or belt, on the surface, most prominent in the spring, and furnishing a substance to protect the eggs); (*e*) the openings on the under side and the number of the segment in which they occur; (*f*) the *setæ* or bristles, projecting from the sides and bottom of the segments (visible with lens); (*g*) the *blood vessels* on the upper and lower sides of the animals, their length, and the colour of the blood.

If the work outlined above is covered, there will be no need for further studies with killed specimens.

To set up a laboratory observation box for studying their feeding habits, etc., see *Book of Suggestions to Teachers,* Walter, Whitney & Lucas, p. 27.

### DISCUSSIONS

1. The rôle played by earthworms in Nature's soil-making and working. See Darwin's *Studies* and his *Vegetable Mould and Earthworms.*

2. The regeneration of complete worms from the divided parts of an animal.

### OUTDOOR WORK

NOTE:

1. Whether the robins, returning early in the spring, are able to secure food supplies of earthworms, and how these birds locate, secure, and manipulate them.

2. Whether the breaking up of the frost in the ground affects or controls the appearance of the worms.

3. Whether they are found to be numerous and active in the ground at the time of gardening operations, and whether their comparative prevalence or scarcity is related to the richness of or the kind of soil.

4. Whether they are as numerous later in the season at the same place; where supplies for fishing purposes must be sought in the summer months.

5. Whether, on the approach of winter, they are near the surface or at some depth in the gardens.

6. Their occurrence at the surface after or during rain; how their appearance in rain barrels may be explained.

7. Their appearance (using a lantern) after nightfall on the surface of a well-watered lawn; the manner and speed of their disappearance on being disturbed or touched.

8. Their burrowing and burrows.—(*a*) how a worm placed on the surface of rather compact soil gets down into it; (*b*) how deep these burrows are to be found; (*c*) whether partially uncovered worms disappear backward or "head first"; (*d*) the force with which they

resist being pulled out; (*e*) the effect of pinching their "heads" when trying to draw them out.

9. The nature of the casts that may be found at the mouth of their burrows in the mornings.—their amount, texture, etc.; whether the openings of the burrows are plugged with anything.

10. The occurrence of drowned worms after rain; whether worms are to be found ordinarily in water-soaked or swampy soil.

## FISH

*References:*

*Check List of the Birds of Ontario.* Nash
*First Course in Zoology.* Bailey and Coleman
*Book of Suggestions to Teachers.* Waiter, Whitney & Lucas

### LABORATORY STUDIES—LIVING ANIMALS

Make the pupils acquainted with the Provincial Fishery Laws as given in the booklet entitled *Ontario Game and Fishery Laws, 1908,* mentioned in the instructions on birds.

*Using small specimens of local fish or goldfish in aquaria or temporarily in glass jars supplied with fresh water—*

NOTE:

1. The animal's locomotion.—(*a*) the directions of movement, rate, and gracefulness; (*b*) whether it can move backward; (*c*) how it raises, lowers, or turns itself in the water; (*d*) whether it ever becomes perfectly motionless; (*e*) the motions and sweep of the different fins; (*f*) whether the movements of the different fins have any inter-relationships.

2. Its respiration.—(*a*) the motions of its mouth and the *opercula* (gill covers) on the sides of the head; (*b*) whether these motions are incessant; (*c*) the direction of the accompanying water movement, as may be determined by small floating particles.

3. Its feeding.—(*a*) how it takes its food (mosquito larvæ, fine biscuit crumbs, etc.) into its mouth; (*b*) how the mouth and opercula are held while swallowing; (*c*) whether water is swallowed with the food.

4. Its development.—it may be possible to secure a few young fish from some nearby hatchery and keep them for observation in an aquarium furnished with a continuous supply of fresh water. (See *Text-book of Zoology,* Parker and Haswell.)

### LABORATORY STUDIES—MORPHOLOGICAL

*Using freshly killed specimens, if such can be secured—*

NOTE:

1. The "feel" of the fish in the hands.

2. The proportions, shape, general colorations, and markings. How do these suit the animal's needs in locomotion, speed, or hiding?

3. The general structure.—(*a*) the *scales,* their manner of overlapping, the number of rows and bare places; (*b*) the divisions of the body, *head, trunk, tail;* (*c*) the openings—mouth, nostrils, opercular slits, and two vents; (*d*) the fins—two pairs of *paired fins*: (1) *pectoral* (chest) and (2) *pelvic* (correspond to legs); the *median fins*: (1) *dorsal* (back), (2) *caudal* (tail), and (3) *anal* or *ventral* (belly).

4. The head.—(*a*) the position, size, and shape of the mouth; (*b*) the position, number, and movability of the

nostrils; (*c*) the position, size, shape, colorations, movability, protection, and toughness of the eye; (*d*) and *cutting off the operculum of one side*—the colour, number, overlapping, movability, general structure, and attachment of the gills.

### STUDIES WITH THE MICROSCOPE

Examine a scale, with the low power. (See *Text-book of Zoology,* Parker and Haswell.)

### DISCUSSIONS

1. The position of the fishes in the animal kingdom
2. The location, extent, and value of Canadian fisheries
3. How the appearance of the gills is a guide in the buying of fresh fish.

### OUTDOOR WORK AND STUDIES

NOTE:

1. The different species of local fishes. Collect specimens for the school museum. (See Nash's *Check Lists.*)
2. Their habits.—(*a*) in what kind of places they are generally found; (*b*) how and when they are caught; (*c*) what they feed on; (*d*) their natural enemies, etc.
3. The fish sold in the shops.—(*a*) the canned fish, the salt fish, the frozen fish; (*b*) where they come from; (*c*) how and when they are caught and prepared for market.
4. The modern methods of rearing artificially.—(*a*) the location of hatcheries; (*b*) the methods of securing spawn and milt; (*c*) the care of the young and their distribution; (*d*) the causes for the depletion of our fishing grounds; (*e*) location of local reserved fishing grounds and the plans used for insuring sport.

### SKELETON OF A FISH

In addition to the general structure to be made out from the mounted skeleton belonging to the school, parts of a skeleton may be brought from home. A fish that has been prepared for the table by steaming or boiling whole will provide good material for studies of spines, ribs, and vertebræ. Such a prepared fish lends itself, too, very well to observation of the manner in which the muscles are arranged.

The chief facts that should be brought out in the study are:

1. The vertebral character of the axis.
2. The complicated bony structure of the head.
3. The presence of ribs forming a support for the wall over the body cavity.
4. The similarity of the vertebræ and the limited amount of articulation among them.
5. The study of a single vertebra will give a clear idea of the meaning of *spine, spinal column, spinal cord, vertebral column, centrum,* etc.

### FROG OR TOAD

*References:*

*First Course in Zoology.* Bailey and Coleman

*Check List.* Nash

*Book of Suggestions to Teachers.* Walter, Whitney & Lucas

### LABORATORY STUDIES—LIVING ANIMALS

#### *Development of Frog or Toad*

To observe the different phases of development put a few freshly deposited eggs in jars of water or in aquaria. The mistake is often made of overloading the jars with too many eggs. Keep the water fresh by renewing it and remove any specimens that may die. As the tadpoles grow, some water plants, such as green algæ, should be added for food. The eggs of the leopard frog will be easiest to procure; they are the most common egg masses to be found in the ponds. Toad's eggs will be found twined about grass stems or lying along the bottom in two long strands. Do not set the dishes in sunlight, where the water will get too warm.

NOTE:

1. If possible, how the eggs are laid by the female frog.

2. The number, size, shape, colour, and buoyancy of the eggs.

3. The changes.—(*a*) the disappearance of the white portion by the overgrowth of the black; (*b*) the change from the spherical shape to an elongated one with a groove; (*c*) the appearance of a form with head and tail, capable of moving; (*d*) its emergence from the surrounding jelly and the development of gills; (*e*) the development of eyes and a mouth; (*f*) the disappearance of gills by an overgrowing *operculum* and the animal coming to the top of the water to breathe air; (*g*) the appearance of its hind legs; (*h*) the appearance of front legs; (*i*) gradual disappearance of tail, and emergence from the water on to the land.

These later stages will be seen best perhaps in specimens found out-of-doors in the summer.

*Using specimens set free on the table or under a glass cover—*

NOTE:

1. The size, coloration, general shape, proportions, and posture of the animal,

2. The skin, dryness or dampness, whether there are scales anywhere.

3. The divisions of the body.—head and trunk.

4. The legs.—their comparative lengths and directions of setting; the number, arrangement, and webbing of the toes.

5. The head.—the mouth, nostrils, eyes, and ears.

6. The tongue.—by gently prying open the mouth this organ may be seen and its shape and attachment noted.

7. Movements and activities.—(*a*) how it walks; (*b*) how far it jumps; (*c*) placed in a large dish of water, how it swims or floats; (*d*) the effects of touching its eye; (*e*) the pulsations of the nostril; (*f*) the movements of the body wall under its jaw; (*g*) any other pulsations about the trunk.

With a toad or frog in a school vivarium provided with a piece of moist turf, observation of its manner of taking food may be made (put in flies, grubs, etc.).

### DISCUSSIONS

1. The place of amphibians in the animal world; their relationships with the fishes

2. The truthfulness of the stories about living frogs being found embedded in rock

3. The economic values of frogs and toads.

### OUTDOOR WORK

NOTE:

1. The date of the first announcement of spring by the piping tree frogs or croaking frogs.

2. The order in which the different species seem to become active.

3. The breeding activities in the ponds, swamps, and ditches.—(*a*) their calling and fighting; (*b*) hiding when

disturbed, etc. (how long they can remain under water); (*c*) the numerous deposits of eggs. Collect some for the school aquarium.

4. (*a*) The time of cessation of the spring chorus; (*b*) the withdrawal of the tree frogs from the drying swamps and ditches; (*c*) the appearance of tadpoles where the eggs had been; (*d*) the difference between the original number of eggs deposited and the number of tadpoles hatched.

5. Their enemies.—(*a*) the presence of birds such as ducks, herons, and crows about their breeding grounds; (*b*) the occasional finding of a snake engorged with a frog or toad that it has captured; (*c*) whether there are enemies in the water as well as on the land.

6. Their feeding (this can be observed best with the toad).—(*a*) the time of the day it makes its appearance; (*b*) its presence about doorsteps or under electric street lights; (*c*) how it secures the fly or other victim.

7. Their wintering.—(*a*) their disappearance with cold weather; (*b*) their lying dormant under logs or stones about the rivers (frogs); (*c*) or buried in the ground in the garden (toad).

### SKELETON OF FROG OR TOAD

If a prepared specimen is in the possession of the school, proceed in general as outlined for the study of the bird skeleton and using the bird skeleton again for comparisons. It may be found to be an advantage to study the frog and fish skeletons together.

The chief things to be observed and emphasized are the central character of the axis, the manner of attachment of the legs to the axis, and the skeleton structure, which explain its great power of jumping.

When the study of a mammalian skeleton is afterward taken up (Autumn Term, Second Year), comparisons should be made regarding the bones comprising the legs and toes particularly.

A frog's skeleton may be prepared fairly easily by dipping an animal into boiling water for a few minutes and picking off the flesh.

### VISCERA OF FROG OR TOAD

See method suggested under "Birds".

### BLOOD FLOW IN TADPOLE'S TAIL OR FROG'S FOOT

By means of a glass tube used as a pipette, remove a tadpole from an aquarium and place it on a glass slide. After tiring itself in wriggling, it will probably remain still long enough to permit the observation. Use the low power of the microscope and focus on a thin part of the tail.

To keep a frog still, bind it firmly with a damp cloth to a small board. Draw out one of the hind legs, and by threads attached to two of the toes spread the web over a glass slide. Examine with a microscope, using the low power. By the use of a little chloroform the animal may be quieted.

Note:

The rate of blood flow; how the corpuscles travel; whether there are any temporary stoppages in any vessels; whether the flow is constant in any vessels.

### NATURE'S LOSSES AS ESTIMATED FROM FROGS' EGGS

At some small pond, make an estimate of the number of pairs of frogs breeding. Estimate also the number of eggs in all the egg masses deposited there. Allowing that the next year there will probably be about the same number of frogs breeding again in the same locality, calculate the waste of nature's production.

### DEMONSTRATION OF CHICK EMBRYOS

*Reference:*

*Text-book of Zoology.* Parker and Haswell, Vol. II, p. 409

This study should be preceded by the study of the structure of an egg, in the work of the previous autumn. Material may be brought by pupils who are having eggs hatched by incubators or by natural means.

Put three or four freshly laid eggs, marked with the date and hour, under a sitting hen seventy-two hours before they are needed for the class work; twenty-four hours after put three or four more similarly marked, and again twenty-four hours later three or four more. This will provide a supply of one, two, and three-day embryos. For comparisons, an unfertilized egg that has been under the hen for three days may be also used.

Break the eggs into dishes (soup plates) containing warm water. The yolks will lie in the water, permitting ready view of the developing chicks.

NOTE:

1. The comparative sizes of the embryonic areas of the different days.

2. The development of a head and the signs of a segmented body.

3. The bending over of the embryo; the development of a disproportionately large head; the coming into being of heart, blood-vessels, eye, and ear; the beating of the heart.

4. The changes that have occurred in the nature of the white of the egg and of the yolk.

## AUTUMN WORK OF SECOND YEAR.

### ECONOMIC INSECTS

*References:*

Consult books by Bethune, Saunders, Smith, and Chittenden listed on pages 43-4.

The nature of the season, the locality, or the local industries will determine the selection of the insect studies of this term. Those insects that have been most harmful or most numerous during the summer season will naturally be considered first. The studies taken one term will not necessarily be repeated the next year. By this changing of the topics from year to year, teachers will be enabled to become practically acquainted with many of our common economic insects. At the close of the spring term pupils should be informed of the work that will be taken up in the fall, and directed to make observations and collections for themselves during the summer. For some of the studies a supply of specimens will need to be collected by the teacher, as opportunity offers during the summer.

The following lists show the wide field covered by the subject. Some of the commonest insects are known as "general feeders" because they do not restrict themselves to any one particular food plant. Such are the cutworms (larvæ of moths), aphids or plant-lice, white-grubs (larvæ of may-beetles), wire-worms (larvæ of click-beetles), flea-beetles and grasshoppers.

These may be considered as suitable subjects of study, as well as the following insects having more restricted feeding habits:

#### ATTACKING FIELD CROPS

Wheat: The joint-worm and the hessian-fly
Clover: Clover-seed-midge
Peas: Pea-weevil

### ATTACKING VEGETABLES

Asparagus: Blue asparagus beetle and twelve-spotted asparagus beetle

Cabbage: White cabbage-butterfly and cabbage-maggot (a fly)

Cucumber, melons, squash, and pumpkin: The striped cucumber beetle, the spotted cucumber beetle, and the squash-bug

Onion: The onion maggot (a fly)

Potato: The Colorado potato beetle and the potato flea-beetle

### ATTACKING SMALL FRUITS

Currants: Currant saw-fly

Raspberry: Raspberry cane-borer

### ATTACKING ORCHARD TREES OR FRUITS

Apple: Codling-moth, apple-tree borers, oyster-shell bark-louse, tent caterpillar

Plum: Plum curculio

Peach: San José scale

General: Fall web worm

### ATTACKING SHADE OR FOREST TREES

Tussock-moths, cankerworms, tree borers, gall flies

### ATTACKING DOMESTIC ANIMALS

Stable fly, mosquito, black flies, bott flies, fleas, lice

### INSECTS OF HOUSEHOLD

Clothes-moth, carpet beetle, house-fly, cockroach, bed-bug, fleas, lice, ants

### BENEFICIAL INSECTS

Among the insects that must be considered beneficial to gardener, fruit-grower, or farmer are bees, lady-bird beetles, ichneumon-flies, and dragon-flies.

The class work should be taken up, as far as possible, along the lines indicated for the insect studies of the first year, that is, first, observation of the living animal; second, morphological studies of killed specimens.

## EXTERNAL CHARACTERS OF A MAMMAL

*Reference:*

Bailey and Coleman

### LABORATORY STUDIES—LIVING ANIMALS

While a satisfactory consideration of the external characters of a cat, dog, or rabbit might very well be based on observations made at home, in many respects it will be better to have one of these animals—or all of them if comparisons are desired—before the class.

*With a cat, for example, before the pupils—*

NOTE:

1. The divisions of the body.—*head, neck, trunk, tail, legs*—the relative lengths of these.

2. The covering of the body.—(*a*) What places are devoid of hair? (*b*) Are there any specially sensitive hairs? (*c*) Is there short hair among the longer hair? (*d*) Would the animal's colour be changed if the hair were clipped short? (*e*) Is the colour of a single hair uniform throughout its length?

3. The head.—(*a*) its poise ordinarily, and in alarm, surprise, hunting, etc.; (*b*) the relative size and position of the ears, mouth, eyes, whiskers, and nostrils; (*c*) the

motions and movability of these; (*d*) compare its eyes with human eyes.

4. The legs.—their comparative lengths; the straightness, heaviness, number, and position of the toes. Comparing them with the human body, locate the elbow, wrist, and hand in the front leg, and the knee, heel, and foot in the hind leg.

5. Movements and activities.—(*a*) Observe the action of the legs in walking, running, galloping, creeping. (*b*) What kind of tracks would the animal leave in the snow? (*c*) How does it climb, descend from a tree, seize its prey, play with its victim, drink, purr, protect itself, fight, warn an enemy, etc.?

4. The teeth.—these can be best studied from the skeleton. Compare the number in the upper and lower jaws—how are these set against one another? Judging from their shape, what different purposes do they serve? Compare them with man's teeth. Interpret the *dental formula* $i\,\frac{3}{3}$, $c\,\frac{1}{1}$, $p\,\frac{3}{2}$, $m\,\frac{1}{1} = 30$. (See *Text-book of Zoology,* Parker and Haswell, Vol. II, p. 536.)

### COMPARISONS OF MAMMALS

Comparisons of typical mammals will have to be based partly on outdoor observations and partly on museum specimens. The teacher should get together such skulls as may be picked up sometimes in the woods or fields; or, if a special study of farm animals is to be made, such as may be procured from butchers. The bones of the lower parts of the legs of the horse, cow, sheep, and pig will be useful also. Mounted skins of a squirrel, mole, and bat are needed. The skins of other wild mammals, such as the woodchuck, muskrat, mink, and weasel, would also be interesting.

The comparisons might be fixed and emphasized in a schedule drawn up after some such manner as the following (use drawings instead of word descriptions as far as possible):

| | Mole | Bat | Squirrel | Cat | Horse | Cow |
|---|---|---|---|---|---|---|
| Hair ...... | ........ | ........ | ........ | ........ | ........ | ........ |
| Feet ...... | ........ | ........ | ........ | ........ | ........ | ........ |
| Teeth ..... | ........ | ........ | ........ | ........ | ........ | ........ |
| Locomotion. | ........ | ........ | ........ | ........ | ........ | ........ |

After these practical studies on typical local mammals are completed, a broader view of the diversity of form in this class of animals might well be given by means of lantern slides or charts. Failing these or the time necessary for it, the pupils might be directed to read on the topic in the books by Jordan and Heath, Bailey and Coleman, or Hornaday. The subject will be found to be of great interest to them.

### SKELETON OF MAMMAL

For this study the school should be provided with a mounted skeleton. If this is not available, a chart might be used in conjunction with such loose, detached bones as may be picked up on field excursions. Comparisons should be made with skeletons previously studied, and also, if possible, with the parts of the human skeleton. The suggestions given for the study of the bird skeleton apply here also. The exercise is not to be a close anatomical study, but a general one leading to the recognition of the more important relationships and bones, for example,

NOTE:

1. The divisions of the *spinal column.—cervical* (neck), *thoracic* (rib bearing), *lumbar* (without ribs), *sacral* (vertebræ united), *caudal* (tail). Compare the size and direction of the spines.

2. The relationships of some of the parts.—(*a*) how the head is swung on the neck vertebræ; (*b*) how the vertebræ move on one another; (*c*) how the ribs articulate with the thoracic vertebræ; (*d*) how the legs are joined up to the main axis; (*e*) how the bones of the legs are related.

3. The divisions of the legs.—the front leg, connected with the *scapula* and made up of *humerus, radius,* and *ulna, carpus* (wrist), and *hand*, the hind leg connected with the *pelvic girdle—femur* (thigh), *tibia* and *fibula, patella* (knee cap), *tarsus* (ankle), *foot.* How many bones are there in the wrist, the ankle, the hand?

4. A vertebra made up of the *centrum, neural arch, neural canal, spine, facets of articulation,* and *processes.*

For testing the pupils' knowledge of the structures of skeletons, have them locate the position of bones, such as may be secured from roasts of meat, etc., or other odd bones that may be picked up for the purpose.

### VISCERA OF MAMM.

See suggestions given for the study of the viscera of bird. Since, however, this topic has such a direct application in the physiological interests that are bound to arise, an effort should be made to take it up in some practical way. A prepared dissection would answer best perhaps for a mixed class. Pupils who wish to work the matter out for themselves should be directed to follow the instructions given in *Studies in Zoology,* Merrill, or in *Practical Zoology,* Colton.

## SPRING WORK OF SECOND YEAR

### CRAYFISH

*References:*

Bailey and Coleman
Walter, Whitney & Lucas

#### COLLECTING

In gathering crayfish, seize them between the thumb and finger over the back; held in that position they cannot seize one with their claws. Do not try to bring many back in a small pail. It is better to carry them packed in damp moss or grass. Keep them cool and moist.

#### AQUARIA

Do not overload the aquarium with too many specimens or with very large ones. Remove dead specimens without delay. Keep the aquarium where it will not be warmed by the direct rays of the sun. A metal tray three or four inches deep supplied with water and a bed of gravel and sand answers well for keeping crayfish. If a number are to be kept for some time for laboratory studies, pack them in damp moss and keep them in a cool cellar.

#### LABORATORY STUDIES—LIVING ANIMALS

*Using living specimens in aquaria, shallow dishes such as soup plates, or, in some cases, free on the desks—*

Note:

1. The animal locomotion.—(*a*) how it moves its feet in walking; (*b*) how it carries its large *cheliped* (claw feet); (*c*) whether it can walk backward or spring up into the water; (*d*) whether its extended backward movement is jumping, swimming, or floating.

2. Other movements.—(*a*) the occasion and extent of the sweeping about of its feelers; (*b*) the directions and extent of the eye movements; (*c*) how it acts when it touches another crayfish or is touched by a pencil; (*d*) the constant churning movement near its mouth; (*e*) how its claws act in seizing anything; (*f*) how it puts a piece of food into its mouth.

3. Its process of growth—if opportunity offers, the process of moulting.—(*a*) where the exoskeleton splits; (*b*) how the animal gets out; (*c*) its condition and disposition after the moult.

4. Its young.—to some of the female crayfish gathered in the spring, young crayfish will be found attached; note their number, colour, manner, and place of attachment.

5. Its mode of respiration.—With a specimen in a shallow dish of water determine, by the movement of particles in the water, the direction of the flow of water caused by the churning of some of the mouth parts. Or, to make the movement more discernible, put a drop of coloured ink near the base of the hinder legs by means of a pipette. Can the crayfish live out of water for any length of time?

### LABORATORY STUDIES—MORPHOLOGICAL

*Using specimens either freshly killed or preserved in alcohol or formalin—*

Note:

1. The general shape, proportions, and colour.

2. The divisions of the body.—*cephalo-thorax* and *abdomen.*

3. The shell.—the unsegmented *carapace* over the *cephalo-thorax,* the overlapping ring-like parts of the segmented abdomen.

4. The abdominal appendages.—(*a*) the *tail fin* made up of five broad lobes; (*b*) the four pairs of *swimmerets* on a female; (*c*) the three pairs of *swimmerets* and two pairs of *spine-like appendages* in the male.

5. The thoracic appendages.—(*a*) the four pairs of *walking legs* and one pair of *chelipeds* (jaw-feet); (*b*) the number of joints, directions of setting from body, and the number that have claws.

6. The head appendages.—on the upper side, the *antennæ* (long feelers), *antennules* (short feelers), the *stalked eyes.*

The appendages on the under side of the head are numerous and complicated. To be seen rightly, they should be removed in order and fastened to a card (see Bailey and Coleman). There are three pairs of *maxillipeds* (foot-jaws), two pairs of *maxillæ* (thin jaws), and one pair of *mandibles* (strong jaws).

7. The breathing organs.—Expose the *gill chamber* by removing one side of the carapace; lay the specimen in a plate of water, and note the arrangement of feathery gills. Not the size, number, shape, structure, movability, and connection with the movement of the legs.

Compare a lobster with a crayfish.

## OUTDOOR WORK

NOTE:

1. Their occurrence.—(*a*) Are they common in streams, ponds, ditches, or lakes? (*b*) the size of the largest and the

smallest specimens; (*c*) how their colour accords with the bottom of the river bed.

2. Their manner of locomotion.—(*a*) Is it walking, leaping, or swimming? (*b*) How far do they go in one flight? (*c*) Where and how do they hide? (*d*) What are their movements when one tries to seize them? (*e*) How do they get back to the water if let go on the bank?

3. The occurrence of little mounds of earth around the mouths of round burrows near ditches or in damp places (commonly called "snake holes"); these are said to be made by a crayfish; try to trap one or dig it out.

4. The occurrence of so-called "soft-shelled crabs" and explain the condition. Explain also the empty crayfish shells found about the streams, and the occurrence of specimens with claws of unequal sizes.

5. Their feeding.—on the body of a dead fish, etc. Do they ever seize a baited hook?

6. Their enemies.—Examine the stomach contents of a fish, such as black bass; note the remains of crayfish in the excreta of the larger river birds.

### GENERAL DISCUSSION

The lobster industry.—its location, extent, methods of operation, shipping, marketing.

### WOOD-LOUSE OR SOW-BUG (ONISCUS)

*References:*

Kellogg
Silcox and Stevenson

This animal is almost unique among the crustaceans, in that it breathes by gills, but leads a terrestrial life. The allied "pill-bugs" roll themselves up into a ball when molested.

### LABORATORY STUDIES

*Using living or dead specimens—*

NOTE:

1. The size, proportions, colour, and markings of the body; whether its covering is soft or hard like that of the crayfish.
2. The divisions of the body.—*head, thorax, abdomen.*
3. The head.—*eyes, antennæ,* and *mouth parts.*
4. The thorax.—the number of segments and the legs.
5. The abdomen.—no legs, but plates that are the gills.

### DISCUSSIONS

1. The correctness of the names, "louse" and "bug"
2. Relationship to the crayfish.

### OUTDOOR WORK

NOTE:

1. The places of their occurrence.—(*a*) under damp boards, stones, rotting sidewalks, water-barrels, etc.; (*b*) whether they are found abroad in the daytime or active in cold weather; (*c*) whether there is much variation in size; (*d*) the other animals that may live among them.

2. Their locomotion.—(*a*) how they behave when molested; (*b*) their rate of motion; (*c*) ability to climb.

## SPONGE

*Reference:*

Bailey and Coleman.

### LABORATORY STUDIES

Secure a supply of sponges from a druggist—they may be borrowed—representing the different kinds and grades usually sold.

**Note:**

1. Their general shape, elasticity, colour, odour, texture, and value.

2. Their structure.—(*a*) the mark showing where they were attached to the sea bottom; (*b*) the location of the large and small openings and their relation to one another; (*c*) the structure of the material composing the sponge framework as seen by the microscope; (*d*) the horny nature of the substance (*spongin*) shown by burning a piece of it; (*e*) the presence of small pieces of a hard chalk-like substance in some of the sponges.

3. Their capacity for holding water.—Weigh one of the dried sponges, allow it to absorb all the water possible, and after allowing the excess water to drip out, weigh again, and estimate its power of absorption. Account for this property.

After this study of the skeleton of a horn sponge, the teacher should explain the structure and activities of the living animal and direct the pupils to read further for themselves.

### DISCUSSIONS OR READING

1. The position of sponges in the animal kingdom

2. The sponge trade—where they are found, how they are secured, prepared, marketed, and sold. (This subject might be given to one pupil or a group of pupils as a special study. It could then be given to the rest of the class in a paper or talk.)

## CORAL

*Reference:*

Bailey and Coleman

Our common fossil corals are pictured in Miller's *Minerals and How They Occur*. Some of these may be secured from local quarries, gravel pits, or beaches.

### LABORATORY STUDIES

*This subject should be treated in a way similar to that outlined for the lesson on the Sponge.*

*Have the pupils bring samples of different kinds of corals (either fossils or recent forms) that may be borrowed from curio collections or elsewhere. Also get samples of the corals used for necklaces, etc.*

NOTE:

1. The forms, colours, hardness, and weight of the masses.

2. The holes which mark the positions of the bodies of the *coral polyps* (so-called insects).

3. The effect of treating the coral with dilute hydrochloric acid.

With diagrams or charts, the teacher should explain the structure and life history of the coral polyp.

### GENERAL DISCUSSIONS

1. The occurrence of fossil corals in the glacial drift which came from the north

2. The formation of coral islands, etc.

3. The position of the coral polyp in the animal kingdom.

## STARFISH

*References:*

Bailey and Coleman

Miller's *Minerals and How They Occur* pictures fossil forms found in Ontario.

This study is to be taken in the same way as those of the Sponge and Coral.

### COMMON ANIMALS OF MINUTE SIZE

*Reference:*

Life in ponds in the spring

There are many common animals of minute size that will make profitable studies for pupils who take an interest in working with the microscope. These studies are not perhaps very suitable for class work, but may arouse young individual naturalists to a farther seeking out of nature's secrets.

Many of these animals are common in the ponds and ditches in the spring. They may be easily procured by dredging with a fine water net (this is like an ordinary insect net, only smaller and made with fine silk or linen net). The specimens may be kept in jars of water that have no fish or other predaceous animals in them.

The teacher's office will consist largely in pointing out the animals, showing how they may be examined, offering some explanations, and directing the interested pupil to books that will instruct further.

The animals may be withdrawn from the water by means of a pipette; glass slides provided with small concavities or fixed rings will be found very suitable for holding the specimens for examination with the microscope.

### SNAKE AND TURTLE

*References:*

Bailey and Coleman · Nash. (*Check Lists*)

#### LABORATORY STUDIES—LIVING ANIMALS

*Using common garter snake in vivarium or glass jar—*
NOTE:

1. Its movements.—(*a*) raising and lowering head; (*b*) projection of forked tongue (so-called "stinger"); (*c*) climbing up side of glass or netting.

2. The seizure of flies, grubs, or frogs that may be fed to it; how large frogs are swallowed.

3. Its harmlessness.—it may be handled without any fear of injury.

### LABORATORY STUDIES—MORPHOLOGICAL

*Using a dead specimen—*

NOTE:

1. Its length, proportions, and coloration.

2. The divisions of the body.—head, trunk, tail. Is there a neck?

3. The head.—(*a*) its shape and the arrangement of the scales; (*b*) the position of the eye and the presence or absence of lids; (*c*) the mouth and its extensibility; (*d*) the tongue, its shape, protection, and extensibility; (*e*) the presence or absence of teeth.

4. The body.—(*a*) the arrangement, numbers of rows, and overlapping of scales; (*b*) the use of the belly scales in locomotion.

*With a small turtle in an aquarium provided with a floating board for the animal to rest on—*

NOTE:

1. Its movements.—swimming, floating, diving, rising, climbing on the board, extending or withdrawing the head.

2. Its general behaviour.—whether it takes food or sleeps; whether it is very sensitive to disturbance, etc.

### LABORATORY STUDY—MORPHOLOGICAL

*Using a preserved specimen of a common turtle—*

NOTE:

1. The size, proportion, and coloration of the body.

2. The divisions of the body.—*head, neck, trunk, tail.*

3. The covering of the body.—*scales* on some parts, and a *shell* made up of a *carapace* on the upper side and a *plastron* on the lower side of the trunk. Note the number and arrangement of the plates of the shell.

4. The head.—(*a*) its shape and movability on the neck; (*b*) the eyes and their nictitating membrane; (*c*) the nostrils and their pulsations; (*d*) the mouth and horny jaws; (*e*) the ears with a flat, exposed ear-drum.

5. The legs.—(*a*) the directions in which they are set and their strength; (*b*) the number of toes on front and hind feet and the nature of the nails.

## DISCUSSIONS

1. The economic value of snakes and turtles

2. The truth of the stories about the swallowing of the young by mother snakes.

## OUTDOOR WORK

NOTE:

1. The date of the first appearance of these animals in the spring. Collect specimens for the school museum.

2. Their locomotion.—(*a*) manner of crawling, walking, or swimming; (*b*) the rate of speed at which they travel; (*c*) what they do when disturbed or pursued.

3. Their feeding.—(*a*) what their food consists of, how and when they capture it; (*b*) whether snakes molest birds or birds' nests.

4. Their growth.—the moulting of its skin by a snake. Do turtles increase in size through moulting?

5. Their methods of reproduction.—(*a*) the egg laying by female turtles and subsequent appearances of young; (*b*) the size of the smallest snakes to be found (our common garter is *viviparous,* that is, the young are born in a completely formed condition).

6. Their enemies.—hawks attacking snakes, etc. Is it true that young snakes are swallowed by the old ones for protection?

7. Their disappearance with the approach of cold weather. Where and how do they pass the winter?

## REVIEW OF ANIMALS STUDIED

The allotment of work for this term permits the giving of considerable time to reading. Pupils should be directed to the best books available, such as those listed in this Manual, and encouraged to read systematically, and to take notes on what they read.

The use of some form of schedule for comparing, summarizing, and classifying, will be found helpful in unifying the scattered or more or less unsystematic treatment of the subject. This plan may be used to advantage, too, as the work proceeds from term to term. The form may be placed across the black-board or made permanent by printing with India ink crayon on a chart made of window-blind linen.

## SCHEDULE FOR REVIEWING AND COMPARING ANIMALS

| Animals Studied | Chief External Characters | | | |
|---|---|---|---|---|
| | Divisions of body | Coverings | Appendages (legs, wings, fins, mouth parts) | Sense organs |
| Grasshopper | | | | |
| Cricket | | | | |
| Butterfly | | | | |
| Bee | | | | |
| Potato beetle | | | | |
| House-fly | | | | |
| Bug | | | | |
| Dragon-fly | | | | |
| Mosquito | | | | |
| Spider | | | | |
| Centipede | | | | |
| Crayfish | | | | |
| Wood-louse | | | | |
| Clam or Slug | | | | |
| Earthworm | | | | |
| Sponge | | | | |
| Coral | | | | |
| Starfish | | | | |
| Fish | | | | |
| Frog | | | | |
| Snake | | | | |
| Turtle | | | | |
| Bird | | | | |
| Cat | | | | |

SCHEDULE—*Continued*

| Chief Internal Characters | | Activities | | | | Related Local Forms |
|---|---|---|---|---|---|---|
| Skeletons | Viscera | Locomotion, feeding, respiration | Reproduction, life history | Economic importance | Classification | Studied or recognized |
| | | | | | | |

# BOTANY

## AUTUMN WORK OF FIRST YEAR

### SIMPLE INSTRUMENTS NEEDED

It is essential that each pupil should be provided with a simple outfit, including:

1. A scalpel or sharp penknife
2. A pocket lens
3. A pair of needles in wooden handles
4. A pair of small forceps.

In order to avoid the trouble and inconvenience often caused by the mislaying of instruments and consequent failure to produce them when most needed, it is recommended that a sufficient number of sets should be provided by the school authorities for the use of the pupils, and that these should be kept in the school and be distributed and collected as occasion requires. The cost would be very trifling, and the advantage of having the instruments always at hand is obvious.

### EXAMINATION OF A COMMON PLANT

#### MATERIAL FOR OPENING LESSONS

Of garden plants available in September, the petunia is suitable, as well as morning-glory, phlox, and sweet-pea; and of wild plants, the buttercup, mustard, and mallow may be mentioned, but, of course, the choice need not be confined to these.

## THE ROOT

Clear away the soil by shaking the root in water for a few moments; then, each pupil having a specimen in hand, proceed to study:

1. The form, teaching the appropriate name.

2. The direction of growth of the main root or roots; in general vertically downward.

3. The branching, and direction of growth of the branches, and the purposes served by the conditions noted.

4. The absence of green colouring matter and association of this condition with the absence of light.

Examine the rootlets for root-hairs, and note where they are most abundant. (This is done more readily with seedlings and, if any difficulty arises, the examination may be deferred till seedlings are available.)

Discuss the principal uses of the root to the plant, such as:

1. The anchorage of the plant in the soil.

2. Absorption of liquid nourishment through the root-hairs.

3. Storage of surplus food.

Where possible, have sketches made by the pupils to illustrate the points observed.

## THE STEM

Study:

1. The general direction of growth.

2. The presence of green colouring matter.

3. The succession of *nodes* and *internodes.*

4. The consistency of the stem, whether herbaceous or woody, and cause of its strength.

5. The duration of the stem.

6. Appendages (leaves).

Compare the stem with the root in regard to these points, and discuss in general the distinctions between stems and roots, and the important purposes served by stems as supporters of leaves and as a means of communication between root and leaf.

Sketch the stem, or a portion of it, to illustrate the node, internode, and appendages.

### THE FOLIAGE LEAVES

Study:

1. The general form of the leaves.
2. Their colour, and connection of colour with exposure to light.
3. Their position on the stem.
4. The extent of their growth, whether limited or unlimited.
5. The parts of the leaf: *blade, petiole,* and *stipules* (if present).
6. The venation, noting any differences between upper and lower surfaces as to veins, and discussing the purposes served by the veins.
7. Region of the green substance of the leaf. Tear off strips of the epidermis above and below, to prove that the green matter lies almost wholly between these layers.
8. The use of the petiole, and cause of its strength.
9. The development of buds in the *axils* of the leaves.

If convenient, have the pupils inspect a bit of epidermis through the microscope, to get some idea of the nature of the *stomata.*

Discuss in a general way the purposes served by the leaves. They need air and sunlight in order to carry on their work effectively. The stomata suggest connection between the air and the interior of the plant, and help to an understanding of the interchange of gaseous materials and of the giving off of water vapour. It is not to be expected, of course, at this stage, that any accurate account will be given of the chemical processes in the leaf. It will be sufficient to indicate that the leaves are able to take materials from the soil and the air and convert them into substances which can be used to build up the plant body. Later on, provision is made for experimental work, which will help the pupil to a better understanding of the functions of the leaf.

Illustrate by sketches, as far as possible, the points taken up in connection with the study of the leaf.

### THE FLOWER LEAVES

*The Calyx.*—Note:

1. The number of *sepals.*
2. Whether these are united or separate (cohesion).
3. Whether they are alike or different.
4. Whether they show evidences of leaf structure (such as veins, for example).
5. Whether attached to any other part of the flower (adhesion).

Examine flower buds and discuss the probable use of the calyx as a protecting organ.

*The Corolla.*—Compare with the calyx as to:

1. The number of parts (*petals*).
2. Union or separation (cohesion).
3. Shape of parts.
4. Colour.
5. Probable use to the plant, not only as a protective organ, but as a source of attraction to insects.
6. Whether attached to any other part of the flower (adhesion).

*The Stamens.*—Note:

1. The number.
2. The distinction of *filament* and *anther.*
3. The relation of the stamens to each other (cohesion).
4. Their relation to any other parts of the flower, such as calyx or corolla (adhesion).
5. The structure of the anther: its mode of opening, its mode of attachment to the filament.
6. The pollen: the appearance of the grains under a microscope, and compared with grains from some other flower.
7. Use of the pollen to the plant.
8. Insect-pollination and wind-pollination.

*The Pistil.*—Note:

1. The different regions of the pistil: the *ovary,* the *style,* the *stigma.*
2. The rough appearance of the stigma under the lens and its moistness. Its use.
3. The smoothness of the style as compared with the stigma.
4. The structure of the *ovary,* and its contents (*ovules* in young flowers and *seeds* in ripened ones).
5. The component parts (*carpels*) of the pistil as a whole, and whether these are consolidated together or separated (cohesion).
6. Relation to other parts of the flower (adhesion).

*The Receptacle.*—the tip of the stem supporting the flower.

When the general structure of the flower has been gone over, discuss the relative importance of the parts, and develop the idea that the ultimate purpose of the plant is the successful production, dispersal, and germination of seeds, in order to secure the continuance of the race of plants.

Have sketches made, where possible, to illustrate the points taken up.

## FRUITS

Trace, as far as possible, the development of the pistil after fertilization till the fruit is ripened.

Derive a definition of the term "fruit".

For further study, secure an abundant supply of typical forms, such as bean or pea, columbine, milkweed, rose, buttercup, shepherd's purse, mustard, garden stock, poppy, maple, elm, oak, gooseberry, grape, cranberry, orange, cucumber, tomato, pine, hawthorn, morning-glory, peach or plum, banana, etc., etc.

Teach the usual classification into *dry* and *fleshy* fruits, with the subdivision of the former into *dehiscent* and *indehiscent*.

Note also such forms as *accessory* (for example, apple and strawberry), *aggregate* (raspberry), *multiple* (pine).

Compare the popular idea of a fruit with the true meaning of the term, and secure accuracy of terms in the case of fruits such as those of the buttercup, sunflower, and Indian corn, which are not uncommonly referred to as seeds.

In all cases consider adaptations (*a*) for protecting and nourishing the ripening seeds, (*b*) for helping the dispersal of the seeds.

### FLESHY FRUITS

With such examples in hand as gooseberry or grape, peach or plum, apple or pear, develop the differences between *berry, drupe,* and *pome.*

Make a careful study of the *pericarp* in each case.

Consider also the bearing of such pericarps, when ripe, upon the question of seed dispersal.

Submit to the pupils such forms as cucumber, tomato, orange, banana, date, etc., for exercise in classification.

### DRY DEHISCENT FRUITS

For the study of the *legume* and the *follicle,* ripening pods of pea or bean, and milkweed or columbine, will be convenient.

Note the mode of dehiscence and the attachment of the seeds in all cases.

For the study of the *silique* and the *silicle* use fruits of shepherd's purse and garden stock or mustard.

NOTE:

1. The mode of dehiscence.
2. The falling away of the valves.
3. The persistence of the central partition.
4. The arrangement of the seeds around the edge of the partition on both sides.

With a supply of such *capsules* as those of horse-chestnut, poppy, plantain, morning-glory, etc., study the various modes of dehiscence illustrated by them.

In all cases have sketches made of the structures observed.

### DRY INDEHISCENT FRUITS

For the study and comparison of the *achene* and the *grain,* provide abundant specimens of wheat or Indian corn grains; and fruits of the buttercup or the sunflower.

Carefully distinguish a true nut, such as an acorn or a hazel-nut, from such drupe forms as walnut, cocoa-nut, and almond.

By means of such forms as the fruits of the mallow, carrot, geranium, maple, etc., teach the structure of the *schizocarp,* showing that while these forms break up into their component parts at maturity, each part, containing a seed, remains closed, and the fruit is thus really indehiscent.

The structure of the *samara* will be readily illustrated by means of the fruits of elm, ash, maple, etc.

Sketch all forms observed.

### DISPERSAL OF SEEDS

Discuss the need of provision for seed dispersal.

1. Dispersal by Wind.—Use as examples seeds (or fruits as the case may be) of dandelion, thistle, clematis, maple, ash, pine, milkweed, willow-herb, basswood, etc.

Note whether the wings, tufts of hair, etc., are attached to the fruits, or directly to the seeds.

In studying the dandelion, note the effect of the reflexing of the *bracts* as the ripening proceeds, of the rounding of the receptacle, of the drying of the *pappus* hairs, of the roughening of the surface of the achene.

For an example of extreme lightness combined with great abundance of seed, study an orchid capsule, if one can be had.

Try the effect of tossing a few pine seeds, or maple, ash, or basswood fruits, into the air.

Reference should also be made to the tumble-weeds of the prairie regions.

Note in general the great abundance of seeds produced by plants which rely upon the wind for dispersal.

2. Dispersal by Water.—Seeds of water-lily, if procurable, will serve to illustrate by their buoyancy the provision made in some cases for dispersal by water currents. Such dispersal is far less frequent than through other agencies.

3. Dispersal by Animals.—To illustrate this mode of dispersal, provide specimens of burdock, hounds-tongue, beggar-ticks, geum, galium, etc.

Examine with the lens, and have sketches made of the hooks, bars, etc., by means of which the fruits cling to clothing and to the fur of animals coming in contact with them.

The case of such fruits as beech-nut, thorn-apple, etc., should also be considered. Here the spines or prickles do not appear to aid in seed dispersal, their probable use being to protect the ripening seeds from attacks of small animals.

The use of the soft *pericarp* of fleshy fruits in attracting animals, and particularly birds, can be readily made evident. Note, also, that in most fleshy fruits the seeds are protected by hard or tough coats, so that they are either discarded by feeding animals, or, if swallowed, pass uninjured through the alimentary canal.

Dry fruits, such as nuts and grains, are commonly carried off by squirrels and other small animals.

In this connection, also, man's influence as a distributor must not be overlooked.

4. Dispersal by Special Mechanisms.—If possible, have specimens of the ripening pods of the garden balsam or the wild impatiens, and have perfectly ripe pods of peas and violets.

Note the effect of pinching the ends of the pods, and have sketches made of the appearance of the pods before and after the tension has been relieved by pinching.

## SEEDS

A supply of large seeds, such as bean, Indian corn, and morning-glory, should be provided, and both dry and soaked specimens should be ready for examination.

Compare dry and soaked seeds as to size and weight, and note results.

### SEEDS OF DICOTYLEDONS

Each pupil being provided with one or more well-soaked bean seeds, note first the external form and account for all outside marks. Make sketches to illustrate.

Wipe a soaked seed carefully and, by gently squeezing, demonstrate the position of the *micropyle.*

Remove the *testa* and examine its inside surface, noting any peculiarities.

Examine the *embryo,* making sketches and naming the parts.

Discuss the nature and use of each part.

Dissect the *plumule,* flattening out the leaves of the bud, and carefully examine with a lens to see the veins.

Illustrate the folding of these leaves with leaf forms cut out of paper.

Note the attachment of the *cotyledons* to the stem.

Demonstrate storage of starch in the cotyledons by applying the iodine test.

For comparison, carry through a similar series of observations with well-soaked peas and morning-glory seeds, taking careful note of resemblances and differences.

### SEEDS OF MONOCOTYLEDONS

Each pupil may be given one or more well-soaked grains of Indian corn.

Remind the class that the grain is something more than a seed, and carefully distinguish the pericarp from the seed-coats.

Examine the external features, making sketches and accounting for marks.

Having removed the pericarp, cut the seed vertically, perpendicular to the broad surfaces, and examine one of the cut surfaces.

Note the section of the embryo, and make out:

1. The single cotyledon.
2. The radicle.
3. The plumule.

Cautious use of the point of the needle will help in this examination.

Select a second softened grain; remove the coverings and carefully dissect out the complete embryo. Sketch in different positions.

Test the *endosperm* and cotyledon for storage or reserve food.

Any other grains may be treated in a similar manner, and compared with Indian corn.

For an excellent and well-illustrated account of the behaviour of a germinating onion seed, the teacher may consult Bailey's *Lessons with Plants,* page 323.

### SEEDS OF GYMNOSPERMS

Winged seeds of pine or spruce are not difficult to obtain. Being small, they are not so easy of examination as larger seeds, but with patience the more important features can be made out.

The seeds should be soaked for a day before being used for examination.

Inspect through the lens and make a sketch of the external appearance.

Try to find, with the lens, the micropyle at the small end of the seed.

Remove the coat and examine again with the lens.

Try to dissect out the embryo from the endosperm.

Try to count the number of cotyledons.

Test the endosperm for starch.

## PREPARATION FOR WINTER

### ANNUALS, BIENNIALS, AND PERENNIALS

Differences in mode of life to be discussed.

In annuals, the only reserve food is that stored in the seed for the use of the young plant at the time of germination.

Plants living for more than one year store away food materials to be used for the growth of succeeding years.

Biennials utilize the surplus food laid up in the first year in producing flowers and seeds in the second year, and are then exhausted.

The different types of perennials should be noticed: such as herbaceous, which die down to the ground each year, but maintain living underground parts, such as *rhizomes,* or *bulbs,* or *corms; trees* and *shrubs,* which may or may not entirely shed their leaves, and whose growing points perennate as buds.

Discuss the value, as a preparation for winter, of the fall of the leaves of deciduous trees, and call attention to the difference in form of the leaves of such trees and those of our common evergreens.

### STORAGE

For a practical study of the storage of reserve food such materials as the following are necessary:

*Roots:* Such as carrot, parsnip, beet, dahlia, sweet potato

*Leaves:* Such as cabbage and live-for-ever

*Tubers:* Such as potato and artichoke

*Rhizomes:* Such as iris, Solomon's seal, toothwort

*Bulbs:* Such as tulip, lily, hyacinth, onion

*Corms:* Such as gladiolus, crocus, Indian turnip.

Seeds have already been considered.

In all cases make out the true nature of the storehouse.

The "eyes" of the potato or artichoke should be dissected and their arrangement on the tuber noticed.

The true nature of these "eyes" should be taught, and the proper inference drawn as to the true nature of the tuber.

The corm should be compared with the tuber, and each of these with the bulb, and resemblances and differences noted.

The roots and other forms should be tested for sugar and starch, and results noted.

Read details of tests for grape and cane-sugar and for starch, as given in Atkinson's *College Botany,* pages 74-6.

Other forms of storage material may be mentioned, but it will suffice at this stage to limit the tests as above.

### WINTER BUDS

For this study a plentiful supply of twigs of different woods is necessary, such as horse-chestnut, maple, poplar, lilac, elm, oak, butternut, walnut, beech, apple, currant, etc.

**Note:**

1. The situation of the buds on the twig, whether *terminal* or *lateral.*
2. The leaf scars below the lateral buds.
3. The scales which protect the bud. If absent, as in the naked buds of walnut, butternut, and witch-hazel, note the fact.
4. Whether the bud scales, when present, represent leaves or, as in the horse-chestnut, only leaf bases; or stipules, as in the oak, elm, beech, and alder; or rudimentary leaf blades, as in the lilac.

Have the buds carefully dissected and note the arrangement of the scales and young leaves and how the latter are folded in the bud.

Discuss the relation between the leaf arrangement and branching.

Look for resinous coatings on or between the scales and note their uses.

Inquire into the functions of bud coverings, as protecting tender parts from mechanical injury and preventing loss of moisture.

If accessory or adventitious buds are present, try to account for them and suggest uses.

The advantages of pruning, in developing otherwise dormant buds, might be considered in this connection.

Call attention to the *exogenous* origin of buds as contrasted with the *endogenous* origin of rootlets, to the persistence of the growing point at the *apex* of each bud, and the absence, as being unnecessary, of a structure like the root cap, protection being afforded by the surrounding leaf forms.

### FALL OF LEAF AND FRUIT

Note the distinction between deciduous and persistent leaves, and observe the simple withering of the leaves of grasses, irises, lilies, etc.

Study the formation of the corky layer between the leaf and the stem in the case of most deciduous trees and shrubs, showing that provision is made for the fall of the leaf by the living plant itself, and that the scar where the leaf was attached has been formed before the separation of the leaf.

Note also the effect of the cork layer in shutting off supplies from the leaf.

Similar observations may be made in regard to ripened seeds, fruits, and other deciduous parts.

Discuss the value of the provision for the fall of the leaf as a preparation for winter.

## MARKINGS OF TREES AND SHRUBS

Twigs of all kinds, of several years' growth, will be needed.

Study the leaf scars, and again note their relation to the buds.

The position of the wood bundles in the petiole is well shown by the dots in the leaf scar of the horse-chestnut.

Examine the collections of scale scars of several successive years, and determine the age of the twig in hand.

Compare the bud scars with the leaf scars.

*Lenticels* are well illustrated by twigs of elder. The escape of air through these may be shown by dipping the twig in boiling water.

Make sketches illustrating the points observed.

## OUTDOOR WORK

This work will be carried on throughout the term, under the direction of the teacher, but not necessarily under his personal supervision, as it would be impossible, even if it were desirable, that he should always accompany the pupils while engaged in outdoor observation. The teacher can keep control of the work by indicating from time to time, as the class work progresses, the particular line which the outdoor work should take, in order to be most serviceable in relation to the laboratory work in hand. The records of the observations should be separate from the notes made in the class-room, should be regularly supervised by the teacher, and credit given for them when the question of promotion is taken up.

The teacher will, of course, give advice in regard to the work of collecting and preserving plants and seeds. Chapter VI of Ganong's *The Teaching Botanist* contains so complete and satisfactory an account of the best mode of managing collections that it would be superfluous to enter here into details which the teacher can so easily master for himself.

## SPRING WORK OF FIRST YEAR

### GERMINATION OF SEEDS

For the practical study of the phenomena of germination a plentiful supply of seeds will be required, as well as suitable germinating pans or boxes. For the latter any ordinary boxes (not too shallow) filled with sawdust or bog-moss will answer; or even moist sheets of blotting-paper placed upon a plate, with another plate inverted over it.

In order to be able to watch the development of seedlings without disturbing them, some boxes should be provided with one glass side, and this side should be made vertical in some cases and sloping downward and inward in others.

The seeds under observation should be placed against the glass side, and the boxes filled with moist sawdust or moss. It is well to have the glass fixed with putty round the edge.

Useful seeds for work in germination are pea, bean, Indian corn, onion, pine, pumpkin, oak, etc.

Soak a number of bean seeds in water and plant them half an inch or so below the surface in a germinating box.

Examine at intervals and note:

1. The bursting of the seed-coat.
2. The escape and downward growth of the radicle end to form the root.
3. The upward growth of the plumule end to form the shoot.
4. The expanding of the first leaves and the variation in form and position of the subsequent ones.
5. The production of root-hairs.
6. The lifting of the cotyledons above the surface, and their falling away when no longer needed.
7. The gradual establishment of the new plant.

Other seeds, such as pea, pumpkin, onion, etc., may be started at the same time in other boxes, and their behaviour compared with that of the bean.

Make sketches and notes of all points observed.

### CONDITIONS OF SUCCESSFUL GROWTH

When a number of seedlings have been studied and compared in this way, some simple experiments should be carried on, to find the more important conditions of successful growth.

For example, to test the bearing of warmth and moisture on germination, place some dry seeds in dry, loose sawdust and keep without water for several days in a warm place. Observe and record the effect. At the same time, treat other similar dry seeds in all respects in the same way, except that the sawdust shall be well sprinkled with water occasionally. A third lot of seeds may be treated in the same way as the second but, instead of keeping them in a warm place, expose them to a low temperature. Note and record what happens.

To find out whether air is essential for germination, seeds may be placed in a glass jar or bottle filled with water from which air has been expelled by boiling. Tightly cork the vessel and set aside for examination from time to time. Note and record what happens.

To determine whether heat is produced during germination, special care is required in arranging the apparatus. Soaked seeds should be placed in a jar through the cork of which a thermometer is thrust into the seeds. Another jar should be prepared in exactly the same way, but with seeds which have been killed by boiling. The two jars with the thermometers in them should then be placed side by side in a box with dry sawdust around and between them, and the readings of the thermometers compared at intervals of a few hours. (The thermometers must, of course, be compared before being used by being put together into water of different temperatures, and any differences in the readings noticed. If there are differences, these will be allowed for in the subsequent comparisons.)

### EVOLUTION OF CARBON DIOXIDE

To show that *carbon dioxide* is given off during germination, put a quantity of well-soaked peas or beans in the bottom of a glass jar or cylinder and cover the latter with a glass plate well smeared with vaseline. Put away in a warm place for twenty-four hours. Then, carefully sliding the cover to one side, pour in a little baryta water and note the result. Try also the effect of lowering a lighted splinter of wood into the jar.

The influence of depth of sowing on germination may be tested by placing seeds at different depths in a glass-sided germinating box.

### ABSORPTION OF WATER BY SEEDS

To find the amount of water absorbed by seeds put, say, 150 cc. of water in a graduated vessel and drop in twenty or thirty carefully weighed dry beans. The rise in the level of the water shows the volume of the beans. Take out the beans and leave them in moist sawdust for two days, weigh them again, and ascertain their volume as before. The seeds will be found to have absorbed more than their own weight and volume of water.

The examination of a seed in a former lesson showed that water can enter through the micropyle. Whether water can also be taken in through the seed-coat may be ascertained by suspending seeds so that they will be partially immersed in water, leaving the micropyle out of the water. After a few days the weight of the partially immersed seeds can be compared with their dry weight.

### GERMINATING POWER OF SEEDS

The percentage of good seeds in any sample may be tested by treating a definite number—say one hundred or two hundred—under similar favourable conditions for germination, and counting those which have sprouted after a reasonable time. For instance, in the Government tests, the time allowed for timothy seed is fourteen days, and for clover seed ten days, and in the case of the latter it is customary to count as good one third of the sound clover seeds which have not sprouted within the time limit. The germinated seeds are counted and removed daily, and attention is paid to the temperature at which the seeds are kept; for example, for timothy the temperature is to be 68° F. for eighteen hours a day, and 86° F. for six hours, as nearly as practicable; for clover, 68° F. for eighteen hours, and 64° F. for six hours. It is also important that the blotting-paper used should previously be sterilized by heating in an oven without scorching.

## ARTIFICIAL PLANT PROPAGATION

As a preliminary to this study, the attention of pupils should be directed to the habits of such plants as strawberry, couch-grass, Canada thistle, raspberry, potato, etc., which not only reproduce by seeds but also by *suckers, runners, stolons, tubers,* etc. The nature of these growths should be made out and, in the case of a strawberry runner, for example, the origin of the roots from the lower surface and of the leaves from the upper surface should be carefully noted.

*Slips* or *cuttings* of geraniums, willow, etc., should be started in wet sand, and the progress of the formation of roots inspected from time to time. As the cuttings will require considerable time to develop their roots, they should be started at least a couple of weeks in advance of the class study.

The process of *layering* can be illustrated very well with the garden verbena, by pinning down the branches to the soil with pieces of bent wire. These branches, especially if lightly covered with earth at the joints, readily strike root at these points.

To study *budding* and *grafting* it is better to see the living examples in the orchard, but the details of the processes may very well be explained in the class-room and practically illustrated with the help of suitable twigs, such as those of the apple.

It is, of course, essential to impress upon the pupils the advantages gained by these methods of propagation, in the way of ensuring the continuance of valuable varieties of fruits, flowers, etc., as compared with the results of propagation by seeds.

## STUDY OF SPRING FLOWERS

The flowers of the locality will be utilized, as they appear, for a study of the different organs and their modifications and as a basis for exercise in ordinary plant description.

The most essential technical terms should be taught as necessity arises, and, when possible, the idea of relationship between plants with similarly constructed flowers should be developed.

In all cases of irregularity, adnation of parts, etc., an effort should be made to determine the probable use to the plant of such conditions as present themselves.

Valuable exercises may be given in making and drawing longitudinal and transverse sections of flowers under examination, for the purpose of showing relation of parts. In making vertical sections, it is generally best to cut upward from below the flower. Of course a very sharp knife-blade is essential.

The following suggestions for the descriptive study of two common spring plants—dog's-tooth violet and Indian turnip—are taken from Atkinson's *Elementary Botany*, to which the teacher is referred for similar suggestions as to other plants.

### DOG'S-TOOTH VIOLET, OR YELLOW ADDER'S TONGUE

Entire Plant.—Observe the bulb from which the flowering *scape* arises; the small scale-like leaves overlapping it; the two large spotted leaves on plants which have the flower. In the case of non-flowering specimens, observe that there is only one large leaf. If an opportunity offers for an excursion in the woods where the plant grows, see if you can determine how the bulbs are formed at the ends of the runners. As to depth in the soil, compare the bulbs of the flowering and non-flowering plants.

**Inflorescence.**—The inflorescence is determinate, and consists of a single terminal nodding flower on a scape.

**Flower.**—Beginning with the outer *whorl* of members of the flower, determine the number of members in each whorl, as well as their form, relation to each other, and the relation of the different sets among themselves.

Sketch a member of the calyx, corolla (outer and inner sets of the *perianth*), and *andrœcium*. Sketch the pistil, naming the parts. Make a section of the pistil (preferably one in which the seeds are nearly mature) and determine the number of carpels united to form it. How is the number of carpels manifested in the stigma?

Construct a floral diagram to show the relation and number of the different members of the flower.

The flower of the adder's tongue is *complete,* because it possesses all the floral sets. It is *perfect,* because it possesses both the *andrœcium* and the *gynœcium*. It is *regular,* because all the members of the calyx as well as those of the corolla are of equal size.

## THE INDIAN TURNIP

**Staminate Plants.**—Sketch an entire plant, showing the corm (the thickened perennial stem) and the annual shoot with leaves and *spathe.* Cut away one side of the spathe to expose the long compact cluster (*spadix*) of staminate flowers within. Sketch the spadix, showing the mass of stamens as well as the sterile part of the shoot above. Dissect off from the axis several of the stamens. Note that the filament is very short and that the anther is irregularly lobed.

The Pistillate Plants.—Compare with the staminate plants. How many leaves are there? Is the number of leaves constant on all the pistillate plants? Cut away one side of the spathe and expose the spadix of pistillate flowers. Sketch. Observe that each flower consists of a single flask-shaped pistil, and that these are packed closely together. Note the delicate brush-like stigma. Search for plants which show both stamens and pistils on the same spadix. Where both kinds of flowers are present on the same spadix, on what part of the spadix does each kind appear? On the corms of different plants search for the lateral buds, which are young plants. Observe that they usually arise on directly opposite sides of the corm; that they easily become freed from the old corms; that they are young corms. Do they arise in the axils of the leaves or scale leaves which have fallen away?

Cut off a portion of the corm. Do not eat any portion, but touch the tongue to the cut surface. The flesh of the corm is very acrid.

## POLLINATION

The practical study of pollination will naturally be best carried on out-of-doors, but good work can be done with selected flowers brought into the class-room.

### WIND-POLLINATION

Provide flowers of such plants as plantain, poplar (but not willow), pine, oak, birch, alder, grass of any kind, but preferably Indian corn, if available.

NOTE:

1. The abundance and lightness of the pollen.
2. The mode in which the anthers are attached to the filaments.
3. The usually large and branched stigmas.
4. The exposure of the flowers to the wind.
5. The absence of nectar.
6. The usually inconspicuous character of the flowers.
7. Whether the stamens and pistils are contained in the same or separate flowers.

### INSECT-POLLINATION

Almost all conspicuous and scented flowers will serve for illustration.

Try to ascertain whether the flowers produce nectar, and find the position of the *nectaries*. The columbine, for example, secretes nectar at the bases of the long spurs of the petals; their nectar, therefore, is out of reach of insects with short probosces and can be obtained only by those with long probosces, or by humming-birds. The same may be said of the violet, larkspur, and many orchids. The buttercup has its nectaries at the base of the petals on the inside. The hollyhock bears a nectary on the inside face of each sepal, and many flowers have the nectar freely exposed on the surface.

Note also, that even if honey is not produced, the flowers may be visited by insects for the pollen, which they use as food. Wood-anemone, clematis, and St. John's wort are examples of these " pollen flowers ".

### ODOURS

Note, in regard to odours, that these are not necessarily agreeable. Purple trillium, carrion flower, and skunkcabbage have offensive odours, which doubtless serve to attract flies and carrion beetles.

Make a practice of looking for special devices to assist in the work of pollination. The common barberry, for example, has sensitive stamens, which fly forward when touched. In the dandelion, the united anthers open inward, and the hairy, upward-growing style acts as a brush to bring the pollen into view. If the two-lobed stigma does not receive pollen from another flower, the lobes curl backward, and the stigmatic face of each is brought against the pollen on the style; that is to say, if cross-pollination fails, self-pollination is resorted to.

Examine flowers to find out whether the stamens in a given flower mature before or after the stigmas, and consider the effect of any difference in the times of maturing which may be observed.

The common plantain shows instructive differences between the upper and lower flowers of the spike.

Study also the flowers of a geranium cluster.

Discuss the general advantages secured by cross-pollination such as:

1. The greater vigour of the resulting plants.
2. The tendency to transmit any useful variation in either of the parent plants.

### SELF-POLLINATION

Interesting examples are furnished by the small purple polygala, the violets, and wood-sorrel. In these cases, study the inconspicuous *cleistogamous* flowers, noting how self-pollination is inevitable so far as they are concerned. Compare also the time of their production with that of the ordinary showy flowers.

Besides plants with such special contrivances as these, a good many ordinary annuals also are self-pollinated.

Devices for protecting pollen against rain should be noticed; for example, the natural position of the flower, the closing up of the flower, the coating of the pollen-grains with wax, etc.

## INFLORESCENCE

The inflorescence naturally forms part of the study of each plant taken up for examination. The more essential terms should be taught as necessity arises.

*Cymose* and *racemose* types will be explained, and the simple relationship between such forms as *spike, raceme, corymb, umbel, head, catkin,* and *spadix* developed, these forms differing really in small details only.

Examples of solitary inflorescence, both terminal and lateral, will be found and noted.

Discuss any advantages arising from the grouping of flowers in clusters, such as that of all the flowers in a cluster being benefited by the same pollinating agency—a clubbing together, as it were, of the flowers to share in the favourable influences. The massing of colour also in these cases is suggestive.

In considering any cluster, note whether the flowers are all developed about the same time, or whether they develop successively during a considerable period, and consider the resulting advantages and disadvantages. For example, the successive development of the flowers may favour cross-pollination and may offer a greater variety of conditions for the successful production of seed, etc., while massing of the fully opened flowers has advantages of another kind, as already suggested.

### USE OF THE FLORA

Usually, explicit directions accompany the flora, so that it is not necessary to go into minute details here. Suffice it to impress upon the teacher that the plant under consideration should in all cases be carefully examined and details of structure noted down, before any reference is made to the flora. The mere finding of the name of a plant is of small importance in itself, but is of great value when utilized to confirm or check the correctness of a series of observations. Pupils should, therefore, be encouraged to use the utmost care in noting particulars of structure, being assured that the determination of a plant is then a comparatively simple matter.

## ROOTS

### VARIETIES OF ROOT FORMS

The usual distinction between *tap-root* and *fibrous* root will be taught and illustrated by examples, and the origin of *secondary* and *adventitious* roots pointed out. Study examples of dicotyledons, such as the bean, dandelion, carrot, etc., in which the *primary* root (the terminal portion of the radicle) continues to grow downward and to produce branches (secondary roots) forming a *tap-root system,* and compare with the behaviour of a monocotyledon such as Indian corn, in which the primary root hardly develops at all, while many adventitious roots appear at the base of the stems, forming a *fibrous root system.*

Call attention to such *tuberous* forms as the roots of dahlia and sweet potatoes and their uses as storehouses; to *aerial* roots and their uses as absorbers of moisture from the air and as climbing organs; to *water* roots which float in water without penetrating the soil at all (a hyacinth bulb will produce such roots, as will also slips of many plants, such as geranium, if suspended in water).

**Root-hairs.**—Examine seedlings, such as those of wheat, oats, etc., to determine the region of the root upon which root-hairs are most abundantly developed. Note that the tip and the older regions are without hairs.

Bring out the value of the hairs as increasing the absorbing surface, and as holdfasts enabling the tip the more effectively to push its way into the soil.

**Root Cap.**—Demonstrate the form and position of the root cap, by mounting in water on a slide under the microscope the tips of seedlings, such as cress, and note the situation of the growing points.

**Region of Growth.**—To establish the region of growth in the root, sprout some seeds, such as peas, in clean sawdust or blotting-paper and, when the roots are a couple of inches long, mark them across at short intervals throughout their length with fine India ink lines. Continue the process of growth and examine the roots at intervals for several days. The relative widening of the spaces between the marks shows clearly where growth is most active.

## STEMS

### WINTER BUDS

The study of winter buds, which was begun in the autumn, should be followed up in the spring, when the buds resume their growth. The observations should cover (*a*) the falling of the bud scales, (*b*) the lengthening of the axis, (*c*) the manner in which the young leaves are folded in the bud (*vernation*), and (*d*) the gradual expansion of the leaves, all designed to show that the bud is a stage in the development of a stem or branch, and that care is taken to ensure the close packing of the parts and the proper protection of the young leaves till they have attained some degree of firmness.

Varieties of Stem Forms.—The varieties of stem forms will be taught and illustrated by exsmples everywhere available. It is unnecessary to enumerate them here, as every text-book deals with the principal forms.

### ADAPTATION OF FORM TO HABIT

The question of adaptation of form to habit is a very important one and should be constantly kept in view. Erect stems require a certain rigidity of structure, and the arrangement of the supporting tissue in such stems should consequently receive attention.

Cross sections should be made of erect herbaceous stems, such as buttercup, bean, grasses, etc., and the situation of the harder parts carefully noted.

The value of the thin-walled tissue, also, in helping to produce rigidity by the turgescence of its cells, should be noced.

The arrangement of the supporting tissues in erect land plants may be compared with the conditions found in aquatic stems, where special support is afforded by the water in which they live. In these plants the chief strain on the stem is caused by the pull due to movement in the water, and consequently the harder tissues occur towsrd the centre of the stem, very much as in the case of roots.

Prostrate stems and climbers are usually slender, in accordance with their habits.

Stems used for storage have their own special forms.

The hollow stems of many rapidly growing herbaceous plants form interesting subjects of study. In these cases a minimum of the material appears to be combined with a maximum of strength, the material thus saved being used, it has been suggested, to produce more flowers and seeds.

### THE STEM STRUCTURE IN DICOTYLEDONS AND IN MONOCOTYLEDONS

This will be studied by means of transverse and longitudinal sections of representative stems. Judgment must be exercised as to the minuteness with which this part of the work will be carried out. In general, not much more should be attempted than can be accomplished with the aid of a good hand lens, but, if the school is provided with a good microscope or a lantern, some very satisfactory work can be done without undue sacrifice of time. The constituents of the stem and the arrangement of the tissues can be easily demonstrated, and perhaps the continuity of the bundles of the stem with the veins of the leaves and with the central cylinder of the root could be shown by making longitudinal sections of the stem through the bases of the leaves on the one hand and, in the case of a seedling such as that of the bean, through both the stem and root, and treating with aniline chloride or caustic potash.

Attention will be directed to outgrowths, such as *spines, prickles,* and *tendrils.* The distinction in structure between stem spines and prickles will be easily demonstrated by cross sections, which show the presence of vascular bundles in the former and the absence of them in the latter, thus proving the spine to have its origin in the deeper tissues of the stem, and to be in fact a modified branch, while the prickle is developed from the *epidermis* and *cortex.* Leaf spines and hairs should also receive attention, and the use of all these forms as protective organs should be discussed.

Tendrils may originate in the stem or in the leaf; examples of each kind should be examined, and their use as climbing organs demonstrated.

Attention should be directed to the remarkable property which the tip of the tendril possesses of responding to the stimulus of touch and coiling round a suitable object when irritated by contact with it.

Young tendrils of sweet-pea are slightly hooked at the tip. If the concave side of the tip is gently rubbed with a hard object, it soon begins to coil. The convex side is not sensitive in the same manner.

Growing stems of scarlet-runner or morning-glory readily show at their free extremities the movements of nutation. These can be watched and the rate of movement recorded.

The coiling of tendrils between the support and the stem of the plant, so as to form an elastic, spring-like coil, should be looked for, and the purpose served determined.

## FOLIAGE LEAVES

### GENERAL FOLIAGE

For the practical study of the general structure of the leaf, Professor Cavers recommends the boiling of some small leaves for ten minutes or so in caustic potash. If then, while holding a leaf under water, a strip is cut off round the margin, the leaf can readily be separated, with the help of a needle, into three parts, the *upper epidermis*, the *mesophyll* containing the veins, and the *lower epidermis*. These portions can then be mounted separately and examined with the microscope.

The structure of the stomata, with their guard cells containing *chlorophyll*, can easily be made out, and a comparison made between their numbers on the upper and lower surfaces. If possible, the communication of the stomata with the air spaces in the mesophyll should be exhibited, and the uses of the stomata discussed.

The absence of chlorophyll in the epidermal cells, except the guard cells of the stomata, will be noted. The cause of the opening and closing of the stomata should be considered.

The structure of the veins should be explained, and their uses as a supporting framework and as channels for the conveyance of liquids should be pointed out.

Attention should be called to the granules (*chloroplasts*) containing chlorophyll, and an experiment made to show that the chlorophyll may be dissolved out of the granules by means of alcohol. (The leaves treated may be first boiled in water and then covered with alcohol.)

The necessity of light for the production of chlorophyll can easily be shown, and the experience of the pupils may be drawn upon for examples of the effect of growing plants in darkness.

The relation between the presence of chlorophyll and the manufacture of food from the inorganic materials in the air and in absorbed water should be referred to, and the fact kept in mind that seedlings and other plants which grow in the absence of light have a reserve of prepared food to draw upon.

### PROTECTIVE STRUCTURES

The uses of hairs, waxy coatings, etc., as protective structures will be discussed. Young leaves in particular require protection in some form, to guard against excessive loss of water and against injury by excessive light or cold.

The "bloom" on such leaves as those of the cabbage sheds water from the leaf and checks transpiration.

Observations should be made of the relative density of the coating of hairs on the two leaf surfaces, and an explanation sought in case of marked differences.

### RELATION OF LEAVES TO SUNLIGHT

The relation of leaves to sunlight is a matter of great importance. Pupils should be encouraged to examine and compare as many leafy twigs as possible, as well as to study complete plants, in order to understand how different circumstances affect and modify leaf arrangements, so as to secure the most favourable exposure of the surfaces to light and air. Simple instances are the cases of opposite leaves, where each pair is at right angles to the pair next to it, thus avoiding shading, and of lower leaves extended upon longer petioles than the upper ones, with the same result. Many cases of leaf mosaics can also be readily found, especially among those plants which produce numerous root-leaves, such as the dandelion, plantain, etc.

Besides the contrivances in such cases, the effect of the cutting of the leaf blade into fine segments, as in the carrot, and of the complete division of the blade into separate leaflets, as in all compound leaves, will be noticed.

In this connection, attention should be directed to the power which many leaves have of adjusting the position of the surfaces so as to secure the most advantageous exposure, turning the edge of the blade toward the sun when the light and heat are greatest in the middle of the day, and returning to the horizontal position in the more moderate hours.

### SLEEP-MOVEMENTS

The so-called sleep movements also demand attention, and some effort should be made to explain the significance of the familiar phenomenon of the differing night and day positions of the leaves of clover, wood-sorrel, acacia, etc. The cause of the bending of stems toward or away from the light should also be explained. Read Cavers' *Plant Biology*, sections 317, 318.

# AUTUMN WORK OF SECOND YEAR

## COMPOSITES

At least one example of each of the forms should be studied.

The dandelion or chicory may represent the heads made up exclusively of *ligulate* florets.

The thistle or burdock may be used as a type of the head composed entirely of *tubular* florets.

The sunflower, cone flower, ox-eye daisy, etc., will serve for heads of the third type, having both *ray* and *disc* florets.

NOTE:

1. The form of the head.
2. The *involucre.*—number of rows of *bracts,* and any peculiarities about the latter.
3. The *florets.*—(*a*) whether ligulate or tubular, or both, (*b*) whether all open at the same time and, if not, which ones mature earliest.

Split the head from below upward with a very sharp knife, and examining the cut surface, note the receptacle.—(*a*) its shape (flat, conical, etc.), (*b*) the presence or absence of chaff-like bracts among the florets.

Carefully pick off a well-matured floret from the outer part of a dandelion head and, using the hand lens, note:

1. The ovary (inferior).
2. The pappus (representing calyx-limb).
3. The corolla (ligulate and *epigynous*).
4. The five stamens attached to the corolla, and having (*a*) their filaments free, (*b*) their anthers joined and forming a sleeve round the style.
5. The top of the style with its two-lobed stigma.

Make a complete sketch of the floret as thus seen.

Taking a fresh and well-opened floret again, let the pupil hold the lower end (ovary) with finger and thumb of the left hand and then gently pull the upper forked end of the style with the right. The style will break off below and be drawn up through the sleeve of the anthers. The sleeve, or tube, can then be split with the point of a needle and opened out to show the dehiscence of the anthers on the inside face of the tube.

Now take another floret not so far advanced, and have the anther tube split and spread out to show that the anthers mature and discharge their pollen before the stigma is ready to receive it (*protandry*).

NOTE, as far as possible:

1. The upward growth of the style, with its brush of hairs round the top, with which it sweeps the pollen upward.
2. The opening out of the forked top, in order to expose the inner stigmatic surfaces.
3. The final recurving of the two lobes, so as to secure self-pollination, if cross-pollination does not occur.

Consider the effect of the massing of colour by the clustering of the florets, any contrivances to aid in seed dispersal, and what different kinds of insects would probably visit florets with corollas of different length (the nectary being at the base of the style).

## WEEDS

The common weeds of the garden, the roadside, and the field will be studied, and these will, of course, vary with the locality. These plants are sources of trouble to the farmer and the gardener and, as a rule, are so constituted as to resist hard treatment of various kinds, such as exposure to drought, frost, poorness of soil, etc. They also not uncommonly produce great numbers of seeds and have special contrivances for successful seed dispersal.

The special advantages possessed by any given weed should be noted, and inferences drawn as to the best mode of treatment for controlling its spread. In the case of the dandelion, for instance, obvious points for consideration would be: (*a*) the stout perennial root; (*b*) the extremely short stem and the consequent development of leaves close to the ground where they can be trodden upon without injuring them, and where (helped also by their bitter taste) they are safe from grazing animals; (*c*) the numerous seeds; and (*d*) the admirable contrivances for dispersing them. When all these advantages are considered, the marked success of this plant in establishing and maintaining itself in spite of persistent efforts to check it will cease to appear extraordinary.

The Canada thistle is another example of a most successful weed, in spite of the relentless war waged against it. Not only has it a superior means of seed dispersal, but it is protected by its formidable leaf spines, and it has an unfailing resource in its deeply buried rhizomes, the cutting up of which by the plough only facilitates the further spreading of the weed.

The so-called Russian thistle, a comparatively recent importation, but which is said now to cover many thousands of square miles, is a good example of the "tumble-weed", so called because, after the ripening of the seed, the stem breaks off near the ground, and the plant, which is more or less globular in form, is blown over the flat lands, dropping its seeds as it rolls.

The attention of pupils should be directed in this connection to what is known as the "struggle for existence" among living organisms; only a little consideration being necessary to realize that a severe competition is constantly going on among plants, and that those possessing advantages over the others in the way of satisfying the conditions in which they live, tend to crowd out their less fortunate neighbours. This competition goes on under natural conditions, and the fittest survive under the process of natural selection. A somewhat analogous process is that by which the horticulturist selects and preserves seeds and cuttings of his best products only, year after year, and thus secures new and valuable varieties, and crowds out, by his interference, the less desirable ones.

Pupils should identify the common flowering weeds with the flora or, if any are too difficult, should be taught to recognize them by some of their more evident characters.

The admirable publications of the Dominion Government and the Department of Agriculture for Ontario, dealing with the approved mode of treatment of weeds, should be in the hands of every teacher of Botany.

## FUNGI

### SAPROPHYTES

In collecting mushrooms for examination, care should be taken to dig sufficiently deep to secure a quantity of the *mycelium* as well as the complete overground parts, and specimens should be such as to show the different stages of development.

With specimens in hand, note:

1. The difference in form between the overground and underground portions.

2. The various stages in the development of the former, as exhibited by splitting specimens of different ages.

3. The *pileus.*

4. The *gills.*—the spore-bearing surface under the microscope.

5. The *stalk.*

6. The *annulus.*

7. The absence of chlorophyll and the mode of life of the plant as a saprophyte.

8. Its purely asexual mode of reproduction.

Take a specimen with full expanded pileus and cut the stalk across close to the top; lay the pileus, with the gills downward, on a sheet of white paper, and leave it undisturbed for a few hours. On lifting the pileus carefully, a beautiful pattern of its under side will be found on the paper, due to the falling of immense numbers of *spores.* Inspect some of these under the microscope.

For the study of puff-balls both young and mature specimens are wanted. The general aspect of the plant body will be compared with that of the mushroom, and sections will be made through the younger specimens to show the internal cavities, the walls of which form the *hymenium.*

The similarity in the mode of production of the spores of the mushroom and puff-ball will be explained.

Ripened specimens, showing the ruptured *peridium,* will be compared with the younger specimens, and the dispersion of the spores illustrated.

In like manner the plant body of a polypore will be compared with that of the mushroom and the puff-ball, and the method of spore production investigated. (Read Bailey and Coleman, *First Course in Biology,* Chaps. XIV and XXIV.)

A simple lesson in classification should be given when all the forms have been studied, and the reason why these forms, apparently so different, are grouped together, should be made clear.

Sketches of all the forms examined should accompany the records.

### PARASITES

Any one of a number of common forms may be selected.

Mildew.—Taking lilac mildew as an example, leaves should be gathered at intervals and preserved, to show the stages of development, some in June or July at the first appearance of the fungus, and others at intervals of a month or so till the leaves fall.

NOTE:

1. The general powdery appearance of the upper surface of the earlier leaves, seen under the lens or microscope to be caused by the *conidia.*

2. At the same time the *mycelial* threads can be seen, and the branches which bear the conidia, as well as the manner in which the latter are cut off by partitions at the ends of the branches.

3. The use of these conidia as spores.

Compare the appearance of the surface of leaves gathered late in the autumn with that of the earlier ones, and note the dark dots in the former case.

With the lens observe the form of these *sac fruits.*

Crush a few of them (mounted in water) by pressing on the cover glass, and note the liberated spore sacs with the contained spores.

Compare these spores with the conidia, and discuss their use.

Wheat rust.—If wheat rust be selected for study, stems showing the red-rust streaks should be collected in early summer, and others, showing the black-rust stage, later on in the autumn; and, if a complete study is desired, barberry leaves showing the cluster cups should also be gathered in early summer and preserved for examination.

A brief account of the life history of the rust might be given, to include:

1. The scattering of the spores formed early in the season in the cluster cups on the barberry leaves.
2. The germination of these spores on the stems of the wheat or other grass.
3. The penetration of the tissues of the *host plant* by the mycelium.
4. The formation of the reddish *summer spores,* which can germinate at once if they fall upon a suitable plant surface, such as the wheat stalk.
5. The formation of the *resting spores* (the black rust stage) late in the season, and the postponement of their germination till the following spring.
6. The necessity of the barberry leaves as a basis for the germination of the resting spores in the spring.
7. The consequent effect if there are no barberry bushes in the neighbourhood.
8. The effects of the parasitic growth upon the host plant.

(Read Bailey and Coleman's *First Course in Biology,* Chap. xxiv, and Andrews' *Botany All the Year Round,* pages 279-284.)

Black-knot.—To study black-knot, affected twigs of cherry or plum should be gathered at different seasons. The young and forming knot can be studied only in the spring specimens. Later ones show the fully formed knot-like mass, having the velvety surface covered with the conidia-bearing *hyphæ.* The specimens gathered in late summer differ in surface aspect from the earlier ones, the hyphæ having shrivelled up. Sections will show the *perithecia* with the spore-bearing *asci* lining their cavities.

The life history should be outlined, and should include the penetration of the young bark by the hyphæ in the summer, the activity of the hyphæ and consequent formation of the knot in the following spring, the production of conidia in the summer, the development of *ascopores* in the autumn, and their ripening in the winter.

Remedial measures should be discussed, such as cutting out and burning the knot or, in very bad cases, cutting down and burning the whole tree.

## PHYSIOLOGICAL EXPERIMENTS

### ROOTS

In order to understand the absorptive action of root-hairs in their close contact with moist particles of soil, an experiment should be arranged to show *osmotic* action. A common form of such an experiment is to make a model of a root-hair out of a long, sound potato, by scooping out the substance of it, leaving only an outer wall of a quarter of an inch or so in thickness. If this is now half filled with a five-per-cent. salt or sugar solution stained with a little red ink, and immersed to the depth of the solution in a jar of water, observations made at intervals will show the gradual rise of the liquid inside the tuber. The analogy between the process and the action of the root-hairs, which always contain sugar or other matter dissolved in the cell sap, is easily seen. Other forms of the experiment are described in the text-books and may be substituted for the above.

If time permits, it will be well to set up an experiment to show the strength of the upward sap pressure from the root through the stem. This can be done with a plant such as a bean growing in a pot. The stem should be cut off a couple of inches above the soil and a glass tube attached to the stump with a bit of tight-fitting rubber tubing. The tube can be kept upright by tying it to a stick thrust into the earth in the pot. If a little water be now put into the tube and covered with a drop of oil to prevent evaporation, the gradual rise of the water in the tube, due to pressure from below, can readily be observed.

To show the tendency of roots to grow in the direction of moisture, seeds may be grown in moss in a germinating box with a wire gauze bottom. If the box is hung up, the radicles will make their way through the gauze into the air below, but will soon turn upward toward the moist moss.

The influence of light on root growth can easily be shown. A tumbler of water may be covered with a piece of muslin tied over it, and the roots of some seedlings thrust through holes in the muslin. If the tumbler is now placed in a box having a slit in one side to admit light, the direction of the root growth in relation to the light can be readily noted.

### SOILS

The soil in which a plant grows is a storehouse of moisture for the plant's use and contains also the necessary mineral ingredients for its food. Some conversation with the pupils, therefore, on the origin of soils, and a few simple experiments on their composition, will be appropriate.

The mechanical separation of certain constituents may be effected through the agency of water. A pound or so of good garden soil may be mixed with a small quantity of water to form a paste, and the paste so made may then be shaken up well in a glass jar of water and allowed to settle. The sand will be found at the bottom, the clay above this and clouding the water with its fine particles, while any *humus* or decomposed organic matter will float on top. The value of clay in the soil in "fixing" various materials which are essential for plant food and in increasing the power of the soil to hold water, should be pointed out, as well as the improvement effected in the physical character of heavy clay soils by treating them with lime. The nature of sandy and clay loams should be explained, as well as the importance of a due proportion of both air and water in the soil, and the danger of "water-logging". The subject of drainage will naturally come up in this connection.

## CULTURE SOLUTIONS

The water in the soil contains many substances in solution: Various salts of lime, potash, soda, iron, etc., many of which, while insoluble in pure water, become soluble in the soil water, in consequence of the carbon dioxide which it contains and of various chemical reactions. It is essential for healthy plant growth that the food materials should be in soluble form. Hence soils are improved by adding substances which contain plant food or which act chemically upon insoluble materials and convert them into soluble form. Tilling and manuring are the two most important modes of increasing the fertility of the soil. Manures are of value chiefly in proportion to their richness in nitrogen, phosphorus, and potash, these being the substances in which soil in constant use is most likely to become deficient.

The effects of different fertilizers upon the growth of, say, wheat grains, can be tested by sowing the grains in pots containing soil to each of which a suitable amount of a different fertilizer has been added, the other conditions of growth being kept as nearly uniform as possible.

The best method of proving that certain elements must be supplied in soluble forms to the roots of plants, if they are to have a healthy growth, is by using culture solutions. The essentials for most green plants are oxygen, hydrogen, nitrogen, sulphur, phosphorus, calcium, potassium, magnesium, and iron. The necessary carbon comes from the air through the agency of the green parts in the presence of light. For culture experiments glass jars of about a quart capacity may be used. The culture solution recommended by Professor Cavers is made as follows: Take four ounces of calcium nitrate and one ounce each of potassium nitrate, magnesium sulphate, and potassium phosphate; powder the salts to facilitate solution. This quantity will be sufficient for thirty-two gallons of water, and for smaller quantities of water a proportionately smaller quantity of the salts will, of course, be used. A few drops of iron chloride (or phosphate) should bo added to the solution. Seedlings of bean, Indian corn, pea, etc., may be grown till the roots are several inches long, and then transferred to the culture jars. These should have corks fitted to them, with a hole in the centre of each and a slit running out from the hole to the side for the reception of the plants. The jars can be darkened by covering them with any suitable material. Some of the seedlings will be grown in the solution as above, others in solutions from which one or other of the salts is omitted, and the effect of such omission observed.

Success in experimental work in the culture solutions depends a good deal upon attention to details, such as keeping the plant dry where it passes through the cork, to prevent damping off; replacing water lost by evaporation;

washing the roots occasionally; and renewing the culture fluid, etc.

It is needless to add that experiments such as the foregoing require to be arranged for in advance, and that the observations, to be of service, should extend over a considerable period of time.

### STEM FUNCTIONS

It is important to find out through what channels the liquids absorbed by the root-hairs pass up through the stem. This may be done by using twigs of different woods, such as oak, ash, apple, etc., and dipping the cut ends in red ink. After a time, varying somewhat with the conditions, cross sections may be made at different points and examined with the microscope, and the result noted. If the twigs are leafy, the leaves may be removed and the portions of the petiole, which have been stained, examined with the lens. Longitudinal sections are also useful in this connection. The experiments show that the upward movement is through the woody tissue.

If a twig of willow is girdled by removing a ring of bark, and the twig is then placed upright in a vessel of water, and the whole covered with a bell-jar, roots will in time be developed just *above* the girdling, which seems to prove that the elaborated sap travels *down* the stem through the bark.

### HELIOTROPISM

This is readily demonstrated by growing a plant in a window. The cause of the bending of a stem either toward or away from the light should be explained as due to unequal growth on the two sides of the stem.

Nutation movements of the ends of twiners and climbers have already been referred to.

## FOLIAGE LEAVES

To illustrate transpiration, a succulent shoot of any plant may be used. Pass the end of it through a cork fitted into a small bottle of water, and place a bell-jar over all. The moisture which soon appears on the inside of the bell-jar is evidence of transpiration. Instead of a shoot, an entire plant growing in a pot may be used, but in this case care must be taken to cover the soil tightly with some material which will prevent evaporation from it. An interesting variation of the experiment is to place the growing plant (with the soil tightly covered) on one scale of a balance and counterbalancing weights on the other. The loss of water from the leaves will soon be apparent in the disturbance of the balance.

To test for starch in green leaves which have been exposed to sunlight: First dissolve out the chlorophyll from such a leaf by immersing it in boiling water and then treating it with wood alcohol carefully warmed. If the leaf is then tested by application of iodine solution, the whole leaf is stained a purplish brown colour, showing the presence of starch.

Take a second leaf which has been in darkness for a couple of days. Dissolve out the chlorophyll as before and treat with iodine. The test for starch in this case fails, showing that the starch which the leaf had contained was removed during the darkness.

To show the exhalation of gas (mostly oxygen) from green water-plants in sunlight, place some pieces of any common immersed aquatic plant at the bottom of a jar of water and invert a funnel over the pieces, so that the small end of the funnel is below the surface of the water. Now fill a test-tube with water and carefully invert it over the upper end of the funnel. Set the apparatus in the sunlight and, when sufficient gas has collected in the test-tube, test it with a glowing splinter of wood.

The exhalation of carbon dioxide may be shown by confining a growing plant in a deep, dark jar or box along with a small open vessel of lime-water. The lime-water becomes turbid owing to the formation of calcium carbonate.

## SPRING WORK OF SECOND YEAR

### TREES

The scope of the work on trees is sufficiently indicated in the curriculum. A good deal of the work will necessarily be done out-of-doors in the presence of the trees themselves. The branching can, of course, be best studied before the leaves of the season are produced. Pupils should be led to see that the general aspect of a tree depends very largely upon its mode of branching, and such round-topped forms as the elm, maple, and apple should be compared with types like the Lombardy poplar and spire-like forms such as spruce and cedar, all such comparisons involving a careful study of the branching in each case.

Besides the general aspect of the tree, as resulting from its branching habit, a study should also be made of the bark of the wood as shown in different sections. For this purpose there should be in the laboratory a good collection of examples of the wood and bark of the commoner trees of the locality, for ready reference. The leaf, also, should receive attention, and an ample supply of preserved leaves should be always on hand. If properly taught, the young student should be enabled to recognize most of our commoner fruit and forest trees at sight.

The ordinary economic uses of our native woods will be touched upon in connection with the general work.

For the study of the conifers, any of our common forms, such as white or red pine, may be used. The buds can be had in abundance in the spring and are easily studied. The leaves will be compared both as to form and as to arrangement and duration with the ordinary types of foliage leaves, and a special study should be made of the staminate and pistillate flowers, including the pollen and mode of pollination. Ripe cones should also come in for examination, including the seeds and provision for seed dispersal. The economic uses of the coniferous wood and bark, also, must not be overlooked.

## GRASSES

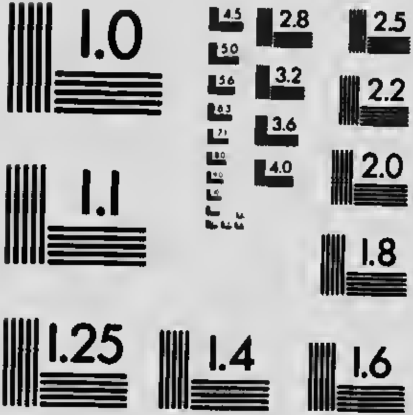
Almost any common grass may be selected for examination. If perennial, as a great many grasses are, the rhizome should be looked for, and notice taken of the thread-like roots characteristic of all the family.

The stalk, or *culm,* and the leaves with their sheaths and *ligules,* will be studied, and attention directed to the peculiarities of structure which make for strength in the stem.

As the inflorescence in grasses varies a good deal in appearance, a number of different types should be collected for comparison. Wheat is a good example of the *spike* arrangement. The spike, which forms the whole top, is easily seen to be made up of many similar pieces, which can be detached from the main stem, and which are known as *spikelets.* Each spikelet in turn can be resolved into several smaller parts, which are the single florets. The teacher should have a large diagram of the dissected spikelet and of the floret, showing all the parts, and the pupils

**MICROCOPY RESOLUTION TEST CHART**

(ANSI and ISO TEST CHART No. 2)



should be required to verify, by their own examination, the accuracy of the diagram. The ripened grain, which is the fruit, will be specially examined, and care taken to distinguish such a fruit from a true seed.

The immense economic importance of the grass family will be made clear.

### FERNS

Any common fern will answer for study. A very full and satisfactory account of the examination of the Christmas fern (*Aspidium acrostichoides*) will be found in Atkinson's *College Botany*. The examination as there described is more minute than is desirable at this stage of the pupil's work, but the teacher should make himself familiar with it, and exercise judgment as to the stress to be laid upon the different topics. The study of the *sporophyte* can be fully covered. The *gametophyte* offers greater difficulties and must be abbreviated, and the study helped out with diagrams.

The points to be covered are: (*a*) The nature and habit of the underground *stem;* (*b*) the mode of unfolding and structure of the *fronds;* (*c*) the position and structure of the *sori;* (*d*) the use of the *indusium;* (*e*) the *sporangium,* with special attention to the adaptation of the annulus for dispersing the *spores;* (*f*) the history of the spore, and the distinction between sporophyte and gametophyte; (*g*) the full round of life of the fern, as exhibiting the phenomenon of alternation of generations.

### ECONOMIC PRODUCTS

The intelligent teacher will require very little assistance in dealing satisfactorily with this branch of the subject. An admirable presentation of it will be found in Part IV of Kellerman's *Elements of Botany*. As the time which can be devoted to it in the Lower School is necessarily limited, the work should be carefully systematized. Probably the best way will be to deal with it by studies of examples of products derived: (*a*) From the juices and exudations of plants, such as oils, gums, sugar, etc.; (*b*) from stems, both over and underground, such as woods of different sorts, ginger, etc.; (*c*) from the bark, such as cork, tanning material, etc.; (*d*) from the leaves, such as tea, tobacco, etc.; (*e*) from the flowers, such as perfumes, etc.; (*f*) from the seeds and fruits, such as coffee, flaxseed, nutmegs, caraway, hops, etc.

The extent and variety of the products discussed must be limited by the time at the disposal of the teacher.

## REVIEW

If the work of examination of plant forms has been faithfully carried out, a good foundation will have been laid for a general view of the classification of plants, at least so far as the more comprehensive groups are concerned. The table of classification should be built up on the black-board as the discussion of the characters of the different groups proceeds, the necessary information being drawn as far as possible from the pupils themselves in the light of their previous studies.

## OUTDOOR WORK

For outdoor work in the spring of the second year the subject of "Plant Societies" is assigned. The teacher will be greatly helped in the management of this part of the work by reading the excellent chapter on Ecology in Andrews' *Botany All the Year Round,* or Chapter xxix in Atkinson's *Elementary Botany,* or Chapter iv in Bailey and Coleman's *First Course in Biology.*

# PHYSICS AND CHEMISTRY

## REFERENCE WORKS

The following list contains the names of the works in Physics and Chemistry which will be found, on the whole, most useful to the teacher.

### PHYSICS

*Lessons in Science.* Gregory and Simmons. Macmillans, Toronto. 90c.

*First, Second, and Third Year's Course in Physics.* Sinclair. Geo. Bell & Sons, London. 1s. 6d. each.

*Elementary Practical Physics.* Watson. Longmans, Green & Co. 2s. 6d.

These books are well adapted for elementary work in schools with moderate equipment. All contain sets of simple experiments, fully described.

*First Course in Physics.* Milliken and Gale. Ginn & Co. $1.25.

This work gives a survey of the whole field in an elementary way, and contains excellent illustrations and explanations of practical applications.

*Text-book of Physics.* Hall and Bergen. Holt & Co. $1.25.

A good book, with satisfactory experiments.

*Text-book of Physics.* Duff. Blakiston, Philadelphia. $2.75.

*Text-book of Physics.* Crew. Macmillans. $2.75.

These are recent works, tending to the mathematical side.

*Physics.* Ganot. Longmans, Green & Co. 15s.

Still unsurpassed for the description of machines.

*Magnetism and Electricity.* Hadley. Macmillans. $1.40.

*Heat.* Edser. Macmillans. $1.00.

*Light.* Edser. Macmillans. $1.50.

Valuable for their treatment of the special subjects.

## CHEMISTRY

*Experimental Chemistry.* Wilson and Hedley. Clarendon Press. Vols. I, 75c., and II, $1.25.

*Introduction to Chemistry.* McNair. Geo. Bell & Sons, London. 2s.

*Junior Chemistry.* Adie. University Tutorial Press.

These three books are specially useful in the elementary classes, contain excellent experimental work, and might be used as reference books by the pupils.

*Elementary Study of Chemistry.* McPherson and Henderson. Ginn & Co $1.25.

*Elementary Inorganic Chemistry.* Walker. Geo. Bell & Sons. 3s. 6d.

These books give an account of the whole field of inorganic chemistry from two entirely different standpoints, and are excellent reference books for the teacher.

*Modern Chemistry.* Ramsay. Dent, Toronto. 30c.

An admirable and thoroughly modern work in a small compass.

*Introduction to General Inorganic Chemistry.* Smith. Geo. Bell & Sons. 7s. 6d.

*Principles of Inorganic Chemistry.* Ostwald. Macmillans, $5.00.

Two invaluable works for the teacher, of which the former is the easier to read.

## CLASS MANAGEMENT

In conducting laboratory work the ideal at which one should aim is to have the pupils perform the experiments individually. An experiment performed by the teacher before the class will never be so clear or so completely understood as when the pupil prepares the apparatus and carries on the work himself. Almost all the experiments in this Manual are suitable for individual work on the part of the pupils. As far as possible, all members of the class should be performing the same experiment at the same time. Occasionally it may be necessary for them to work in pairs, as some experiments require two to perform them successfully.

When the teacher has decided on an experiment, let him, the day before, announce the problem to be investigated and ask each pupil to have a method ready for the next lesson. The next day he should discuss these methods briefly, and then give explicit directions as to the method by which he wishes the experiment to be performed. If it can be written on the black-board, so much the better. He should make his directions so complete before the experiment is begun that few or no directions need be given during the work, as it is very difficult to get the attention of the pupils after they have begun work, and it is distracting to them to have to be listening to instructions amid the noise of moving apparatus. The teacher may pass among the pupils, watching the careless and giving individual assistance.

Where it is necessary to distribute apparatus or reagents for an experiment, the teacher should appoint a member of the class to do the distributing, and the same person should collect at the end of the period. If a salt or a liquid is to be distributed, the pupils must be trained to get immediately a test-tube or a paper ready to receive it and to write down the name of the substance to be received. This distributing work may also be done by a pupil. The teacher is better employed in watching the progress of the class.

## APPARATUS AND SIMPLE MANIPULATIONS

**Tables.**—It is entirely erroneous to think that good work in Physics and Chemistry requires expensive desks, numerous sinks and taps, and running water. These all help, but very good work can be done without them: what is essential, is to have enough table room for all the pupils. Half a dozen cheap kitchen tables are very much more useful than one small but expensive desk. Kitchen tables will do very well in small schools, but whatever desks are used their tops should be covered with melted paraffin, and this should be ironed in thoroughly with a heavy hot iron; or they may be covered with floor wax.

**Sinks.**—These should be small and shallow, with a flat bottom and never with curving sides. Each should be situated near one end of the desk, so that as much desk surface as possible is left on which to work. The tap should be near one side of the sink and should be high enough above the bottom of the sink to admit a tall bottle underneath, but very high taps should be avoided, as they cause splashing. These sinks will serve as pneumatic troughs, but, if they have curved sides, they are useless for this purpose.

**Drawers.**—If drawers are placed under the desks for individual apparatus, it is economical to have one drawer at each desk without a lock, in which to put unbreakable apparatus, such as burners, iron stands, matches, etc. These can be used by all the pupils working at this desk. If the sets of apparatus are small, each pupil may be asked to bring a box in which to store his apparatus, and the boxes can be put away on shelves at the end of the lesson. The boxes should be uniform, such as the tin ones used for soda biscuits.

Bottles.—Glass-stoppered bottles must be used for the acids and bases and other corrosive materials, and for the bases the clean stoppers should be dipped in melted paraffin, or they will be sure to stick. Gem jars are the cheapest receptacles in which to store bulky powders and other solids. All bottles must be labelled, and appearances are greatly improved if bottles uniform in shape but of several sizes are used. Dennison's labels can be purchased very cheaply. A preparation called Vitro Ink can be got from J. J. Griffin & Sons, London, W.C., England, with which the names can be written directly on the glass; this is quite durable if used as directed, and is not corroded by acids. Neat labels add greatly to the appearance of the bottles in the laboratory. Chemical-proof labels may be made as follows: Let the name be written on a paper label and stuck on the bottle. Heat the bottle until quite warm, then rub over the label a paraffin candle until a thin coating is formed. No chemical will corrode this.

To pour a liquid from a bottle, hold the bottle in the right hand, the test-tube, say, between the thumb and first finger of the left hand; take out the stopper with the last two fingers of the left hand and, holding it there, pour out the required liquid; then replace the stopper, gathering back into the bottle any drop of adhering liquid at the mouth.

Spirit-lamps or Bunsen Burners.—Spirit-lamps of brass are very durable and give excellent service, though they sometimes get a little hot. There should be two or more gasolene blast lamps to produce a vertical flame intense enough to reduce limestone to quicklime.

Gas Collectors.—A large granite-ware dish, ten inches in diameter and four or five inches deep, makes an excellent pneumatic trough for the collection of gases over water. Pickle bottles or small gem jars make good gas jars. To invert these in the trough, fill them with water, cover with a piece of paper just larger than the mouth, invert carefully, place in the water, and withdraw the paper. To collect gas in such bottles avoid the pneumatic shelf; just tip up one edge and put the mouth of the delivery tube underneath. Do not have more than two inches of water in the pneumatic trough, and then the gas bottles are not so likely to topple over. Use a rubber delivery tube from the generator to the collector.

Heating Glassware.—In heating flasks, beakers, evaporating dishes, test-tubes, etc., with solids in them, always have a close-meshed copper or brass gauze under them. This causes the different parts of the surface to be heated more uniformly and prevents breaking. When heating a test-tube with a solid in it, as when making oxygen from manganese dioxide and potassium chlorate, the tube should be held horizontally or with the closed end a little higher than the open one; this will prevent the water vapour, which is likely to condense in the upper part of the tube, from running down to the hot part and cracking it. It is well in heating such tubes to roll gauze around them, unless the heat requires to be concentrated at one point.

Rubber Stoppers.—The mouths of the large-sized test-tubes and of flasks should be of the same size, so that the same stopper will fit them. For this purpose rubber stoppers with two holes should be used, and, if only one hole requires to be used, the other may be plugged with a piece of wood or a piece of glass rod. All glass tubing to be used with flasks, test-tubes, etc., should be of one size—6 mm. is the best. In putting glass tubing through a hole in a cork or rubber stopper, wet it and twist the cork upon the tube—do not try to push the glass tube straight through the aperture. It should be pulled out in the same way. Immediately after the experiment, all tubes should be withdrawn from the stoppers, as it injures these to have tubes left in them, and it sometimes becomes difficult to withdraw the latter.

Glass Blowing.—The teacher and pupil must learn to bend the glass tubing and fit up their own apparatus. With an ordinary Bunsen flame or spirit-lamp, glass tubing cannot be bent perfectly. For this purpose a wide, flat flame must be used. Where Bunsen burners are in use, a fish-tail attachment can be purchased for a trifle, and this gives a proper flame. However, the bending can be done with a spirit-lamp, but the bore will probably be somewhat constricted at the bend. The tubing should be held horizontally, and brought cautiously down to the flame at first; it must be kept rotating, so that all sides will be uniformly heated. When it becomes quite soft, withdraw it from the flame, and then carefully bend it once; if it is not completely bent at the first trial, heat again, but just to one side of the bend, and again withdraw and bend. When the tube colours the flame yellow it is getting near the melting point. The gasolene blast lamp can be used for this kind of work.

To seal one end of a glass tube, have it cut off square, and, with the end in the flame and the tube held obliquely, keep it rotating, and it will seal very neatly.

To draw out glass tubing to a point, heat it as for bending, keeping it rotating all the time. When it becomes quite soft, withdraw from the flame and quickly pull apart the two ends until a narrow neck is formed. When cool, cut this neck across by means of a file.

To break glass tubing, make a mark on it at the point where it is to be broken, by drawing once across it the angle of a triangular file; hold the tubing firmly in the two hands with the fingers on the sides of the tube where the mark was made and the two thumbs directly opposite the mark; then bend with both hands away from the mark. Only small tubing can be broken in this way; larger tubing will require a special tube cutter.

In fitting up apparatus, do not use glass tubes which have been bent several times; use simpler tubes and fit them together with joints made of pure gum rubber tubing. This gives flexibility to the whole apparatus.

The end of a glass tube, before being used, should always be held in a flame till it melts slightly; this takes the rough edge off and gives a rounded form which will not cut rubber tubing or corks.

Deflagrating Spoons.—These can be made by binding a piece of school crayon with the end hollowed out, to the end of a stiff wire; this can always be kept clean, which is more than can be said of the ordinary spoon. A cover made out of cardboard serves as well as one of metal.

Evaporation of Solutions.—All evaporation of solutions should be performed in an evaporating dish over a water-bath; otherwise the solid will likely be scorched and discoloured. A good water-bath is made from a shallow beaker with half an inch of water in it, placed on brass gauze over a flame. Place the evaporating dish on this with a match between it and the edge of the beaker, so that the steam can escape.

FILTRATION.—Funnels about three inches in diameter are convenient for filtering. Filtering papers five inches in diameter will fit these funnels. To fit the paper to the funnel, fold it twice across two diameters at right angles and fit it into the funnel, having it three-ply on one side and one on the other. Be sure it fits tightly and does not project above the edges of the funnel. Wet the paper with water before adding the substance to be filtered. Never have the lower end of the funnel below the surface of the filtrate; if the base of the funnel touches the side of the vessel into which the filtrate is running, there will be no splashing. When pouring from a wide-mouthed vessel (as a beaker) into a funnel, if the lip is put in contact with a glass rod and the liquid is poured down the glass rod, there is less chance of waste by spilling.

## NOTE-BOOKS

The loose-leaf book is the best. A page poorly done can be removed easily, on review a page can be added, and if the work is not always taken in the most logical order—and often it cannot be—the records can be arranged properly.

The records should always be in ink and, of course, the utmost neatness is necessary. The note-book should contain such a record of an experiment that a person of intelligence would, by reading it, gain a clear idea of how the experiment was performed and what conclusions could be derived from it. Precision and terseness of statement are essential. If a diagram shows plainly the arrangement of the apparatus, it is not necessary that the pupil should also describe it in words. The neatness, the thoroughness, and the usefulness of the note-books depend, to a large extent, on how the teacher treats them during the first month. Model records of experiments should be written on the black-board. Every book should be read carefully, the errors corrected, and the notes rewritten by the pupil when necessary. After careful habits have been formed, the greater part of the class will look after themselves; a little attention devoted to the careless will act as a proper stimulus to all. The books should be examined several times during the year and valued, the marks counting in an estimation of the pupil's standing in the class.

The record of an experiment should always contain in order the following information, not necessarily under headings:

1. The date and number of the experiment
2. The purpose
3. The directions for performing it, with drawings
4. The observations
5. The explanation and conclusion.

Where possible, the observations should be in the form of tabulated results, and all the mathematical reasoning necessary to derive the conclusion from the observations should be recorded in the explanation. The drawings should be placed on the left-hand side of the page, and the teacher should insist on their being as large as the page will admit. Encourage the pupils to make drawings in ink; these should be diagrammatic and, while little perspective should be demanded, the pupils should not be discouraged from showing depth. The drawings should show the experiment at its most important stage. The parts may be labelled and the contents of bottles, test-tubes, etc., indicated. *No notes should be dictated under any circumstances. Each pupil should record the facts of the experiment entirely in his own language. While performing the experiment he should be required to make rough notes and sketches to be used as a guide and aid to memory in writing the permanent notes.*

The following example will convey an idea of what is meant:

EXPERIMENT 16

April 19, 1909

PURPOSE: To prove Archimedes' principle

DIRECTIONS: Weigh the catch-bucket empty, then weigh the glass stopper in air; immerse the glass stopper in the water which fills the overflow-can; catch the water that overflows in the catch-bucket; then weigh the glass stopper while immersed; lastly, weigh the catch-bucket with the water in it. Repeat this three times.

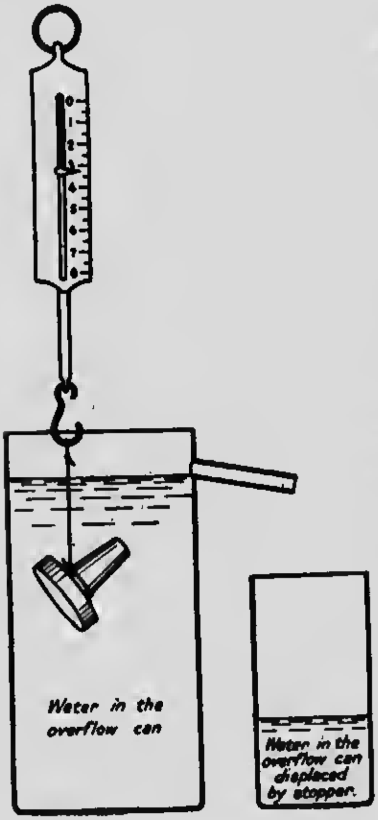


Figure 1

Observations:

| No. | Weight of Glass Stopper | | Loss of Weight of Stopper | Weight of Catch-bucket | | Weight of Water Over-flowed |
|---|---|---|---|---|---|---|
| | In Air | In Water | | Empty | With Water | |
| | g | g | g | g | g | g |
| 1.. | 72 | 49 | 23 | 45 | 78 | 23 |
| 2.. | 71.5 | 49.5 | 23 | 45 | 77.5 | 22.5 |
| 3.. | 72 | 48 | 24 | 45 | 79 | 24 |

Explanation: The water that overflowed was that which was displaced by the glass stopper, and in each case the weight of this water was approximately equal to the loss in weight of the glass stopper.

Conclusion: *The loss in weight of a body immersed in water is equal to the weight of the water it displaces.*

## APPARATUS

The following apparatus is necessary to perform the experiments in Physics and Chemistry suggested in this Manual:

### GENERAL EQUIPMENT

6 glass-stoppered bottles, 8 oz.
2 balances that weigh to centigrams
4 dry cells
100 feet insulated copper wire, No. 20
2 gasolene blast lamps
1 sonometer
1 spool piano wire for sonometer
1 organ pipe

1 electric bell
1 incandescent lamp with wire attachments
5 pounds glass tubing, 6 mm. in diameter
3 pounds capillary glass tubing, opening 1 mm. in diameter
1 pound glass rod, about 6 mm. in diameter
1 square foot sheet rubber—very thin
1 bicycle pump
3 metre sticks
2 cylindrical measuring glasses, 250 cc.
1 large round-bottomed flask, 1 litre
1 atomizer or scent-bottle bellows
1 set cork borers
1 triangular file
1 gross assorted corks
2 bar magnets
3 mortars and pestles
2 pounds mercury
1 dozen candles

### APPARATUS REQUIRED BY EACH PUPIL (OR GROUP OF TWO)

1 celluloid ruler about 30 cm. long
1 burette
1 pipette, 15 cc.
1 spring balance, 250 grams
1 lamp chimney
1 rubber stopper, with one hole, to fit the lamp chimney
1 iron stand with two rings, one 2″ diameter, the other 3½″
1 funnel, 3″ diameter
1 barometer tube
1 pinch-cock

1 pulley
1 metal cart for inclined plane
1 chemical thermometer
1 round-bottomed flask, 10 oz.
1 flat-bottomed flask, 8 oz.
1 rubber stopper with two holes to fit flasks
1 square of plate glass with two opposite polished edges
1 prism of glass with flat ends
1 tuning-fork
1 compass needle
1 sheet of copper, 5" x 2"
1 sheet of zinc, 5" x 2"
2 knitting-needles
6 test-tubes, 5" x ⅝"
1 test-tube, 6" x ⅞"
1 hard glass test-tube, 5" x ⅝"
1 watch glass, 2" diameter
1 crucible with cover, 1½" diameter
1 clay triangle
1 evaporating dish, 3" diameter
1½ feet rubber tubing to fit glass tubing
3 pickle bottles
1 test-tube rack (can be made from a chalk box)
1 granite-ware dish, 8" diameter, 4" high

### REAGENTS

¼ oz. magnesium ribbon
3 packages filter paper, 5" diameter
1 oz. phosphorus (yellow)
4 oz. mercuric oxide
8 oz. potassium chlorate
4 oz. manganese dioxide

4 oz. sulphur
1 oz. sodium
1 lb. granulated zinc
1 lb. sulphuric acid
Litmus paper
1 lb. marble (get at stone-cutter's)
1 gallon wood alcohol
1 quart gasolene
1 lb. quicklime
2 lb. iron filings
6 inches platinum wire

# PHYSICS

## WORK OF FIRST YEAR

### MEASUREMENT

The first subject dealt with in physics should be the metric system of measurements and the practical method of measuring lengths, areas, and volumes. The pupil should be made familiar with the length of the metric units by actually using them repeatedly in making measurements, and the relation between the English and the metric units should be found out by the pupil's own investigation and not merely by dictation on the part of the teacher.

Pupils entering the High Schools are careless in making measurements; they have little or no idea of the extreme accuracy necessary in building up the laws of science, and great pains are necessary on the part of the teacher in order that accuracy of measurement and observation shall become a habit. The path to success depends much on the first month while these early measurements are being made. The teacher must assign measurements of such a nature that he can readily detect how accurately they are performed. Examples of this kind will be given further on. Then he must keep the pupils at each of these measurements till they do them carefully and accurately. A week spent at one or two measurements seems a long time, but it may save much trouble later on.

The best rulers for pupils' work are the little celluloid ones marked on one edge in millimetres and on the other in fractions of an inch; these also are the cheapest. If a thick ruler is used, it must always be placed on edge.

A pupil, in measuring a distance, should not use the end of the ruler as a starting-point, but always a point near the end—say the ten- or twenty-millimetre mark. This is necessary because the first division on cheap rulers is seldom accurate.

The terminal point of measurement will very frequently lie between two divisions on the ruler. Train the pupils to divide this space by the eye and to state what decimal fraction of the division indicates the position of the terminal point, and thus get the distance accurate to one decimal point beyond that for which the ruler is graduated.

All measurements should be expressed in centimetres and decimal parts of a centimetre, and in inches and decimal parts of an inch; never allow inches to be expressed in vulgar fractions. Each measurement should be made at least three times and the average considered correct.

Before discussing methods of measuring different objects and, in fact, before entering upon the study of any topic, it is well to give the pupil an opportunity to think out a method of procedure for himself and to realize the difficulties to be overcome. This can best be accomplished by setting a series of questions for home work, the answers to be written in books and discussed in class; this should be done as a preliminary to the study of every topic that lends itself to such treatment. The following are suggested as suitable sets of thought exercises preliminary to dealing with measurement:

1. Explain as carefully as possible how you would obtain an accurate measurement of:

(1) The greatest breadth of the trunk of a tree
(2) The thickness of one page in a book
(3) The diameter and circumference of a cent
(4) The internal diameter of a glass tube
(5) The length of coast-line of Lake Ontario
(6) The distance from Montreal to Toronto.

2. If a circle were described on paper ruled in square millimetres, how could you find approximately the number of square millimetres it contained?

3. How would you find approximately the area of Ontario from the map in your school geography?

4. How would you measure the volume in cubic centimetres of:

(1) A brick
(2) A salmon can
(3) A quantity of shot
(4) An irregularly-shaped pebble
(5) The air contained in a Florence flask
(6) A tack.

It is needless to say that all of the above would not be given for one lesson. The methods suggested by the pupils will sometimes be crude, but wise correction of the defects will aid them to arrive at sound methods.

As has been directed already, experiments should be devised whose accuracy can be gauged at a glance. The following are suggestive experiments that may be performed:

1. Let a line be drawn on the science note-book and needle pricks placed in the line at A and B. Let the dis-

tance between A and B be measured in centimetres and in inches, and have results tabulated as follows:

| No. | Distance in Centimetres | Distance in Inches | Distance in Inches ÷ Distance in Centimetres |
|---|---|---|---|
| 1...... | ................ | ................ | ................ |
| 2...... | ................ | ................ | ................ |
| 3...... | ................ | ................ | ................ |

The last column, of course, gives the number of centimetres in an inch, and the teacher can detect the accuracy of the work in an instant, as the results in column 4 should all be the same.

2. Let the pupils draw a right-angled triangle, A B C right-angled at B, and measure its sides. Then let them fill out the following table on the black-board:

| No. | A B | B C | C A | A B × A B + B C × B C | C A × C A |
|---|---|---|---|---|---|
| 1.. | ...... | ...... | ...... | .......................... | ............ |
| 2.. | ...... | ...... | ...... | .......................... | ............ |
| 3.. | ...... | ...... | ...... | .......................... | ............ |

The accuracy of the work can be judged at a glance from the difference in results in the last two columns.

3. Let them measure the diameter and circumference of a cent and find how often the diameter is contained in the circumference. The diameter can be measured by placing on millimetre squared paper. The circumference is best found by encircling the cent with a thin paper band;

where the two edges overlap, prick with a pin and measure between the two pin-pricks. If the circumference of a glass tube is to be found, it should be encircled by a thin wire, say, five times; then the length of the wire measured and divided by five.

### PRACTICAL MEASUREMENTS IN AREAS

1. Draw a square 10 cm. to a side on squared millimetre paper; draw heavy lines so as to divide it into square centimetres. By counting have the pupils fill in the blanks in the following:

1 sq. dm. = — sq. cm. = — sq. mm.

2. Measure the length and breadth (*a*) in inches, (*b*) in cm., of a sheet of foolscap. Calculate its area in square inches and in square centimetres, and find out how many square centimetres in a square inch. Tabulate results.

3. Draw a circle of 4 cm. radius on squared paper and describe a square on its radius. Count the number of square millimetres in the area of the square and of the circle. In estimating the area of the circle a near approximation is reached by counting all the partial squares within the circle, dividing by two and adding this to the number of whole squares within the circle. Divide the first result by the second. It should, of course, give approximately $\frac{22}{7}$. Tabulate results.

4. Trace a map of Ontario on squared paper and measure its area as in (3) above.

Another method of measuring the area of an irregular figure is to outline it on heavy Bristol-board, cut out the outline and weigh it. Then weigh, say, 10 sq. cm. of the same material and calculate the area from the weight.

### PRACTICAL MEASUREMENTS IN VOLUMES

The pipette, the burette, and the measuring glass or graduate should be utilized for this purpose. In using the burette, the chief source of error results from not freeing the glass tip of air bubbles. This can most easily be done by turning the tip upward, when the air will rise out of it.

1. Measure the volume of a pint measure in cubic centimetres by means of the measuring glass.

2. Calculate the volume of a metal cylinder (salmon can) by measuring its height and the diameter of its end; also measure the volume by immersing in water in the measuring jar. Compare results. Tabulate.

3. Find the volume of a tack, small nail, or bullet, by immersing twenty of them in a burette.

4. Test the accuracy of a measuring glass by (*a*) the burette, (*b*) the pipette.

5. Measure the volume of a test-tube full of sand. Read the measuring glass with water in it, then pour in the sand, and notice the rise.

6. Measure the volume of air discharged at an ordinary expiration. By means of a tube discharge the air from the lungs into a large sealer filled with water and inverted in water. Use the measuring glass to find the amount of water left in the sealer and also to find the amount of water the sealer is able to contain; the difference is the volume of the air.

### MEASUREMENT OF MASS, DENSITY, AND SPECIFIC GRAVITY

A prime requisite for science work is one or more suitable balances. English firms now manufacture excellent ones for ten dollars or less. The balance should weigh up to 500 grams, and should not weigh beyond centigrams;

one in which the decigrams and centigrams are measured by a sliding rider is most satisfactory, as small weights are difficult to handle and are easily lost. Agate knife edges are quite unnecessary, and a very sensitive balance is not by any means a necessity, nor perhaps even a help. If balances as above cannot be provided, good work can be done with small spring balances at sixty cents apiece. These spring balances weigh to eight ounces or 250 grams, and any experiment in the Physics Course can be performed with them.

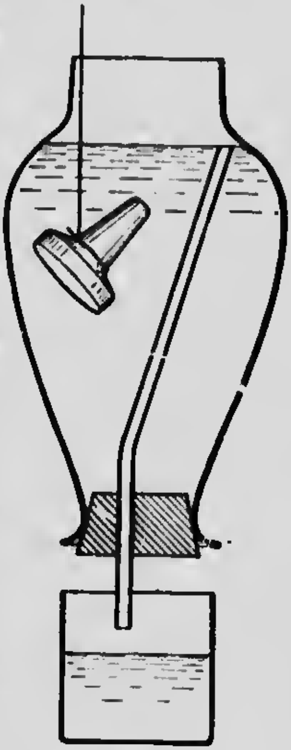


Figure 2

A very valuable piece of apparatus for specific gravity work is what Professor Hall calls an "overflow-can and catch-bucket" (Figure 1). The overflow-can is a small cylindrical copper vessel with a spout from near the top sloping gradually downward. The catch-bucket is a small can made of thin copper, which will hold three or four ounces. It must have a handle. Rub vaseline inside the spout, to insure the rapid and complete drainage off of the water. A still simpler form (Figure 2) can be made by selecting a lamp chimney with a very narrow constriction near the top; fit to it a rubber stopper through which passes a piece of glass tubing. This piece of tubing should extend to within an inch of the base of the lamp chimney and should be bent so as to lie near one side of the chimney. The apparatus is put in the ring of a retort stand with the narrow corked end down, and filled with water until it overflows into the glass tube. Then, when any body is immersed in the chimney, its volume of water will flow out through the tubing. (See *Ontario High School Laboratory Manual in Physics*, page 24.)

A Florence flask with a mark filed on the neck, if used carefully, gives very satisfactory results as a specific gravity bottle.

In suspending solids use a horsehair.

In weighing any solid in a liquid brush off all air bubbles with a feather. Also brush off the air bubbles from the inner surface of a flask when in contact with a liquid.

### PRELIMINARY PROBLEMS TO BE GIVEN FOR SOLUTION AT HOME

1. Explain exactly what is meant by saying lead is heavier than water.

2. You have 1 cc. of each of the following substances: arrange them in order of their weight, placing the lightest first—water, pinewood, coal-oil, iron, glass.

3. How would you find the weight of a cubic centimetre of water, if you had a burette and a balance?

4. How can an iron boat float on water?

5. If you had 1 gr. of each of the substances in (2), how would you arrange them in the order of their size?

6. How would you find whether a given solid is heavier or lighter than water?

7. How do clouds composed of drops of liquid water or ice remain floating in the air?

### EXPERIMENTS TO BE PERFORMED

1. Prove Archimedes' principle for solids that float and for those that sink in water. (Hall and Bergen, *Text-book*

*of Physics*, page 18) See model experiment, page 186. Use a piece of wood as a substance that floats. Before using such a piece, it should soaked thoroughly in paraffin. This can best be accomplished by immersing it in a tin of paraffin and leaving it thus on the stove for twelve hours. (Hall and Bergen, *Text-book of Physics*, page 23, and *Ontario High School Laboratory Manual in Physics*, Exercise 21)

2. Find the specific gravity of salt solution, using specific gravity bottle (Gregory and Simmons, *Lessons in Science*, page 26); also by weighing a glass stopper in air, in water, and in salt solution (Hall and Bergen, *Text-book of Physics*, page 25); also by burette and balance (Watson, *Practical Physics*, page 36).

3. Find the specific gravity of a glass stopper. (Gregory and Simmons, *Lessons in Science*, page 23)

4. Find the specific gravity of a piece of wood. Use overflow-can. Weigh the wood in air, push under water in the overflow-can by means of a needle, and weigh the water that overflows.

5. Find the specific gravity of a rectangular block by measuring and weighing, and verify the volume, as measured, by immersing it in the overflow-can and weighing the water that runs out.

The teacher must distinguish clearly density and specific gravity. Specific gravity is "the number of times a substance is as heavy as the same volume of water". This is probably the best form of the definition for junior pupils. The teacher should give no general formulæ for working out problems in specific gravity, nor, in fact, for any of the lower school work, but each problem should be reasoned out in concrete form. Emphasize the idea that in finding the specific gravity of a substance the endeavour must be, first to find the weight of the body, and then its volume. This will greatly help in the solving of problems.

## HYDROSTATICS

The chief features to be emphasized are:

1. That pressure in a liquid increases with the depth.

2. That the pressure in a liquid is exerted at right angles to any surface in contact with it.

3. That the pressure on any horizontal surface does not depend on the size of the containing vessel, nor on the amount of liquid, but on the vertical distance from that surface to the surface of the liquid, and also on the area of the surface.

4. That if a liquid is pressed on one square centimetre with a force of one gram, that pressure will be transmitted throughout the liquid and, wherever the latter comes in contact with a surface, it will press each square centimetre of that surface with a force of one gram.

5. Archimedes' principle, which has been already discussed.

These topics lend themselves to illustration by some very simple experiments that pupils can perform as well or better at home. Wherever home experiments can be used, the teacher should give very explicit directions and consider the results obtained by the pupils before having them perform in school the more complicated experiments which require apparatus not available at home. The following are suggested as a typical set that might be performed at home:

### EXPERIMENTS

1. Observe carefully the water in a kettle, and find if the levels in the spout and in the kettle are at the same height.

2. Fill three bottles with water, invert one in water and one in air; into the third put a cork with a small hole in it and invert in air. Explain the results.

3. Thrust a large empty pail, bottom down, into a tub of water, and decide which way the water is pushing the pail.

4. With a darning-needle make a hole in the bottom of a paper pail such as is used for carrying oysters or cream. (An empty tomato can will answer, and in this case the hole may be made with a small brad.) Thrust it down into water, bottom first, and watch the water enter through the hole; thrust it quickly to different depths; note the force with which the water enters the hole at varying depths.

5. Using a similar can or pail, make three similar holes through the side at varying depths and fill the vessel with water; note the force with which it issues from each hole, and decide how the pressure changes with the depth.

The above experiments are examples of many that can be given on different topics for home work; in this way the teacher can economize school time and probably create an interest in science in the home circle as well.

The experiments frequently used in our schools to illustrate the five properties mentioned above require expensive apparatus or are difficult to manipulate and unsatisfactory in results. For the following experiments the apparatus is simple and the results easy to obtain; each pupil should perform them.

1. *Relation Between Pressure and Depth.*—(Gregory and Simmons, *Lessons in Science,* page 37) In performing this experiment, pupils should use as deep a jar as possible, and make sure that the small arm fills with water. If air bubbles stick in it, work up and down in it a straw or sliver of wood, holding it under water. Mercury is poured through the small arm until it nearly reaches the top of this arm.

2. *Pressure Depends Only on Depth, not on Amount of Water.*—(Gregory and Simmons, *Lessons in Science,* page 38) As a substitute for a narrow-necked bottle, the student might use a funnel or a lamp chimney made to fit on the U tube by a rubber stopper with a piece of glass tubing.

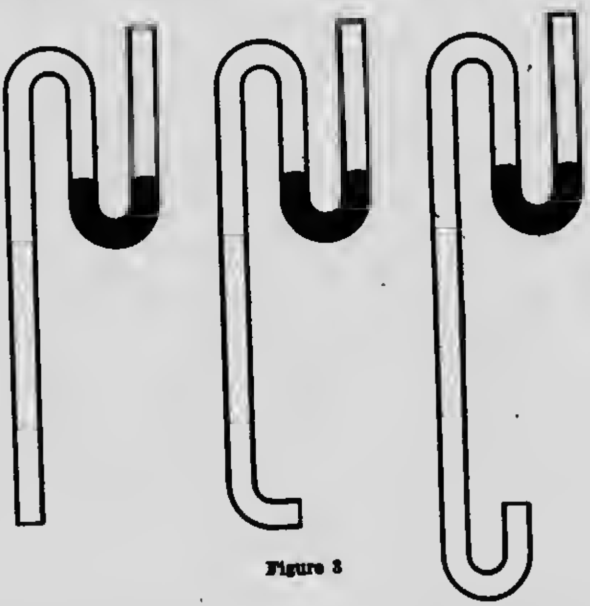


Figure 3

3. *Pascal's Principle.*—If a hollow metal globe with openings covered by rubber is used, after the globe is filled with liquid let the whole piece of apparatus be immersed

in water to prevent premature bulging of the rubber membranes. A pressure applied inward upon one membrane then produces an equal bulging outward on all the others. The principle can be equally well illustrated with a hollow rubber ball. Puncture it in a number of places with a sewing needle; then through a small hole cut in the ball fill it with water; if the ball is now squeezed while a finger is held over the hole, the water will be projected from the different punctures to approximately the same distance.

4. *Pressure is the Same in all Directions.*—Take a set of tubes as in Figure 3. They must be made of tubing not more than 6 mm. in diameter. Each piece must be bent, as in the Figure. When immersed to the same depth, the water is forced into each tube, and the air transmits the pressure of the water. Mercury is placed in the bend of each tube, and the difference of level in the two arms measures the pressure the water exerts on the inclosed air.

5. *Water Seeks its own Level.*—In the bottom of a lamp chimney fit a cork stopper through which three or four holes are bored. Bend $3/8$ in. tubing, as in Figure 2, and pour water into the lamp chimney. (See Milliken and Gale, p. 44.)

Use the principles proven above to explain such phenomena as fountains (water seeks its own level), water pressure in waterworks system (Pascal's principle), forcing of corks into bottles immersed in deep water (pressure increases with depth), heavy iron-ribbed helmet for head in diving-suit (pressure increases with depth), flowing wells (water seeks its own level), an iron boat floats (Archimedes' principle), hydrostatic press (Pascal's principle), hydraulic elevator (Pascal's principle).

## PNEUMATICS

The explanation of all the phenomena of gases should be based on a careful experimental demonstration of the following propositions:

1. *Air has weight.*

2. *Air exerts pressure.*

3. *Air, unlike liquids, expands indefinitely, and its volume varies inversely as the pressure to which it is subjected* (Boyle's Law).

4. *Pressure in air is equal in all directions.*

1. Air has Weight.—The simplest way to prove that air has weight is to place a little water in a *round-bottomed* flask and fit to it a rubber stopper with a glass tube inserted; on the outer end of the tube place a short piece of pure gum rubber tubing; boil the water in the flask until all the air is expelled, then close the flask by a pinch-cock attached to the rubber tube, taking away the flame at the same time. Weigh the flask carefully when cooled, suspending it by a thread; then, leaving it still on the balance, open the stop-cock; the air can be heard rushing in and the balance pan goes down. This experiment can be successfully performed by omitting the water and sucking the air out of the flask by the mouth. To make sure that no saliva adheres to the tubing when sucking out the air, insert a piece of glass tubing into the rubber and, after exhausting the air, withdraw this tube.

2. Air exerts Pressure.—The barometer, of course, is used to measure the air pressure. The most suitable form for the pupils is the siphon barometer (Gregory and Simmons, *Lessons in Science*, page 42). The short piece of

tubing should be twelve inches long, and a funnel should be attached to it by rubber tubing through which the mercury is poured. When making a barometer of the cistern type, it is well, when the tube is filled to within two inches of the top, to invert the tube several times, as the two inches of air sweeping along will drain the mercury of air bubbles. When the tube is filled, do not close the end with the thumb, as many text-books direct, but with the first finger, and the inversion will be much easier. A barometer tube with the open end expanded like a thistle tube is now for sale by certain dealers. Such a tube is useless, as are tubes with a bore so small that mercury will run down into them only with the greatest difficulty.

For use in the barometer, the mercury must be clean and dry. The simplest way to clean mercury is to add water with a little nitric acid in it and shake thoroughly for some time; then rinse with water till all the acid is washed out, drain off as much water as possible, absorb the rest with blotting-paper, and strain the mercury several times through a dry, clean towel; it may finally be filtered through ordinary filter paper with a few needle holes punched in it.

Be sure to show by slanting the barometer tube that the air pressure is measured by the vertical distance between the two levels and does not depend at all on the length of the mercury column.

Pupils are slow to grasp the fact, even after the barometer is explained, that the air presses on the whole surface of the earth with about the same force as would a sea of mercury spread over its surface 76 centimetres deep. This must be made clear, and problems involving finding the pressure in grams or pounds on given areas must be worked until the idea of the air's pressure is clear.

Pupils have no difficulty in grasping the fact that air forced into a balloon or bicycle tire will press strongly against the walls, but they fail to see why the air in a bottle merely corked should exert a pressure equal to that of the outer air. Let them be reminded that as air is forced into a bicycle tire by the force exerted on the piston of a pump, so when the bottle is open, the whole pressure of the air behind is forcing air into it until a balance is reached. If this analogy is grasped, it should follow easily that the air in the bottle, as well as that in the tire, exerts pressure against the sides of the containing vessel.

Pupils should clearly understand the expression "the pressure is 76 centimetres" to be an abbreviation for the statement that the pressure of the gas is equal to the weight of a column of mercury 76 centimetres high, spread over the surface.

When pupils make a siphon barometer, as described above, it is instructive to attach a rubber tube to the short arm and (*a*) blow down it and thus force air into the short tube, (*b*) suck through the tube and thus rarefy the air in the short arm and observe and explain the results.

The two factors determining the variations of pressure at a place are (*a*) changes of temperature of the air, and (*b*) of the amount of water vapour in it. The first is easily made clear to pupils, but they almost invariably think much water vapour should make high pressure. A good method of dispelling this error is to tell them that if a cubic foot of dry air and a cubic foot of water vapour both at the same temperature and pressure are weighed, the air weighs about one and two-thirds times as much as the water vapour. If the two cubic feet are mixed, a cubic foot of the mixture will weigh much less than a cubic foot of the dry air, hence moist air weighs less than dry air, and the moist air will produce low pressure.

3. **Boyle's Law.**—Two methods are commonly adopted for proving Boyle's law (*a*) that with a J tube with the short arm closed, and (*b*) that with a stationary closed tube and a sliding open one, the two being connected by a rubber tube. A method more economical of mercury and with more simple apparatus and more accurate results, is the following: Take a piece of glass tubing 1 metre long with a very small bore (not more than 1 mm.). Half fill it with mercury by suction; then, holding it horizontally, seal the end away from the mercury in the lamp flame (page 183). The air shut in the tube is the quantity whose volume is to be measured. Measure the length of the air column (*a*) when the tube is horizontal, (*b*) when vertical with the open end up, (*c*) when vertical with the open end down. If P is the height of the barometer and L is the length of the mercury column in the tube, the pressure in the first case is P, in the second case P + L, and in the third case P — L. Results may be tabulated as follows:

| Volume | Pressure | Pressure × Volume |
|---|---|---|
| $V^1$ | $P$ | $V^1 \times P$ |
| $V^2$ | $P + L$ | $(P + L) \times V_2$ |
| $V^3$ | $P - L$ | $(P - L) \times V^3$ |

Other pressures and volumes may be obtained by holding the tube obliquely and measuring the vertical distance from the upper to the lower end of the mercury column. (Remember the slanting barometer.)

In examining the results, it is well first to prove from observations that the product of the pressure by the volume is constant, then from this result the pupil can be easily made to deduce the usual statement of Boyle's law.

Emphasize the fact that the *quantity* of gas is unchanged in all the measurements of pressure and volume, and be sure the pupil realizes that it is *the pressure the inclosed column of gas exerts* that is being measured—not the pressure exerted on the gas.

4. Gases Press in Every Direction.—This is illustrated in Gregory and Simmons, *Lessons in Science,* page 41.

A number of very instructive experiments, in which only glasses and bottles are necessary, can be assigned for home work preliminary to those of the laboratory. They can be gathered from any text.

Air pressure is utilized in many pieces of apparatus, such as the siphon, air-pump, water pumps of various kinds, air-brake, pneumatic tires, pneumatic tubes, etc. Some of these should be explained, and models, or better, the machines themselves, should be examined and sketched by the pupils. It will be found that most of them can be explained by the application of Boyle's law.

If the following principle dependent on Boyle's law is first explained, it will apply to all the pumps and many other pneumatic machines. If part of the air is taken from an inclosed space, the remainder expands to fill the whole volume, and hence the pressure is decreased; if more air is forced into an inclosed space, that means that a volume of air is crowded into a smaller space, and hence the pressure will increase according to Boyle's law.

Let these properties of gases be used to explain balloons, clouds floating in air, and settling of dust from the air.

As examples of wind pressure, the working of windmills, the flying of kites, the sailing of ships, and the destructiveness of severe storms may be used.

After having examined the properties of liquids and gases, the distinctions between them and solids should be treated.

By drawing attention to such things as expansion by heat, solution, evaporation, diffusion, etc., lead up to the correlation of these phenomena by means of the molecular theory of matter and the kinetic theory of gases.

The distinction between solids, liquids, and gases in terms of the molecular theory may then be stated. Emphasize that this is a convenient theory, but not an actual observed fact.

## MECHANICS

THE LEVER.—This is perhaps the simplest to understand, and the teacher might well have the pupils experiment with it first. Have them perform experiments 56 and 69 in Watson's *Elementary Practical Physics.*

Describe the three classes of levers according to the relation of the fulcrum, resisting force, and acting force. Give examples of levers, such as a claw-hammer, sugar-tongs, pliers, pump-handle, scissors, nut-cracker, crowbar, wheelbarrow, oar, grocer's balance, the bone of the fore-arm, etc., and let the pupils classify them.

THE INCLINED PLANE.—For experiments with the inclined plane, have the pupils perform experiment 71, Watson's *Elementary Practical Physics.*

Half a dozen trials should be made, varying the load on the cart and the inclination of the plane.

PULLEYS.—Pulleys will have to be bought, as spools with iron axles through them, even when well greased, do not give very accurate results, but they are better than none at all.

Hang a single pulley from a retort stand and pass a thread over it attached at each end to a scale pan; then put a weight in one pan and add shot to the other until the first weight just begins to move up. Weigh the shot. (Repeat with different weights.) It will be seen that in each case the shot and its pan weigh slightly more than the weight and its pan; the less friction there is the more nearly the two approximate. All the advantage a single pulley in this way can give is an advantage of position.

Next, tie a string by one end to the lower side of a beam and, holding the other end loosely in the hand, hang a pulley with a weight attached in the loop, so that the pulley rests on the string. Attach the free end of the string to a spring balance, and hold the latter so that the two parts of the string are vertical; then read the pull registered on the balance as it is pulled up when different weights are suspended from the pulley. When the hand holding the balance moves up a foot, measure how far up the weight moves. If W is the weight of the pulley and its attached weight, F the weight registered on the spring balance, $D_1$ the distance through which the weight moves, and $D_2$ the distance through which the spring balance moves, tabulate the results as follows:

| W | $D_1$ | $W \times D_1$ | F | $D_2$ | $F \times D_2$ |
|---|---|---|---|---|---|
| | | | | | |

Repeat the experiment several times, using different weights and moving through different distances. It is not advisable with the lower school work to discuss the three systems of pulleys.

The three simple machines, the lever, the inclined plane, and the pulley, can all be shown to involve the one principle, namely, that *the weight, multiplied by the distance through which it moves, equals the force, multiplied by the distance through which it moves.*

The other machines are not suitable for simple experimentation and may be merely referred to. The attention of the class should be called to the fact that all machines, no matter how complicated, are but combinations of these simple machines. (Analyse the bicycle into a combination of the wheel and axle and pulley.)

## WORK OF SECOND YEAR

### HEAT

The most important special apparatus for successful experiments in heat is a good supply of thermometers. The ordinary laboratory glassware suffices for the remaining articles needed. There should be one thermometer for each pupil, or for each group of two. The most suitable ones are chemical thermometers about ten inches long, and of such diameter as to pass easily through the hole in a rubber stopper. They should be graduated from—10°C. to 110°C. and should be divided into degrees. Those with a paper scale inclosed in a glass tube are satisfactory and are the cheapest.

Before beginning experiments the pupils should examine the thermometers, make careful drawings of them, learn what the marks of the scale mean, and read the temperature of the room from the scale. The temperature should always be read to the first decimal point; if the mercury stands between 23° and 24°, have pupils understand that they should not read it 23°, because it is closer to 23° than to 24°, but that the part of a space beyond 23° should be estimated by the eye and the temperature recorded in degrees and a decimal. In reading temperature, pupils should learn to wait until the mercury becomes fairly steady; a temperature read while the mercury is rapidly rising or falling can, of course, never be very accurate. Always stir a liquid thoroughly so as to make it as uniform as possible before determining its temperature.

**Sources of Heat.**—A brief discussion on this topic is all that is necessary. The student's own experience will supply abundant examples of heat being derived from friction, chemical change, and electrical energy, and, accordingly, experiments to illustrate such facts are hardly necessary. The facts that *condensation of a gas causes it to become warmer* and *expansion causes it to become cooler* are not so familiar and should be illustrated by experiments. A bicycle pump should be used to condense air in a tire or rubber football; the pump soon becomes quite warm from the heat produced by the condensation. The pupils who have bicycles will have observed this. By moving the piston rapidly up and down when no air is being condensed, convince them that the heat is not a result of the friction between the piston and the barrel; the heating is not produced. If the condensed air is let out of the football or tire, and a thermometer is held in it as it escapes, the temperature will drop, showing the result of the expansion of the gas. These facts should be made perfectly clear on account of their far-reaching importance in physical geography. On these is based the chief explanation of the formation of clouds, as air currents rise to higher regions where pressure is less. There these currents expand and become chilled as a result of their expansion, and the moisture in them condenses to form a cloud. This is the most common cause of cloud formation.

**Expansion of Solids, Liquids, Gases.**—Neither a ball and ring nor a pyrometer is necessary to show the expansion of solids by heat. Place a metre stick over the top of the rod of a retort stand, using the rod as a fulcrum, and let 95 cm. project beyond one side and 5 cm. beyond the other. Fix the end of the short arm in any convenient way, so as to keep the metre stick horizontal (a support beneath the end and a weight upon it will serve the purpose).

On a card fixed behind the long arm, the height of the end of the latter is marked. The iron stem of the retort stand is then heated by means of a spirit-lamp, and the end of the long arm will very soon begin to rise; on withdrawing the lamp it will very soon begin to fall. The usual methods for showing the expansion of liquids and gases by heat, by means of a flask full of liquid or gas with a tube projecting, are described in all text-books. (Gregory and Simmons, *Lessons in Science,* page 100)

Temperature.—This is a difficult term to define. The analogy between bodies at different temperatures and between bodies of water at different levels will be helpful. When the bodies of water are connected, the water flows until the levels are equal; so if two bodies are united by something through which heat will flow (a conductor), the one from which heat flows is at a higher heat level than the other—in other words it is at a higher temperature. Temperature can be considered equivalent to "heat level".

Thermometry.—The pupils should test the fixed points in a Centigrade thermometer by immersing the bulb in melting ice and in boiling water (Gregory and Simmons, *Lessons in Science,* page 106). Also let the bulb be placed in steam. Have the pupils ascertain the effect produced on the melting and on the boiling point by adding salt to the ice and to the boiling water. They should watch carefully the changes in the water as its temperature rises to the boiling point. Long before it boils bubbles of air appear on the sides of the flask or other container and rise to the top; then bubbles of steam appear at the bottom, but are condensed before they reach the top; finally the bubbles of steam which start at the bottom break through the top, and the water is said to boil.

The effect of pressure on the boiling point should be illustrated by experiments. For pressures below normal, the usual method of illustration is that with the flask of water which is boiled, stoppered and inverted and then has water poured over it (Gregory and Simmons, *Lessons in Science,* page 127). In this experiment there are two directions to be observed; be sure to use a *round-bottomed* flask, and pour the water on it carefully; if these directions are not heeded, the flask will probably be broken.

There is a very simple method of illustrating very accurately and quantitatively the effect of increased pressure on the boiling point. A Florence flask half filled with water is fitted with a rubber stopper having two holes; through one hole passes a thermometer whose bulb is in the water, through the other is passed a tube bent twice at right angles; the short arm of the tube passes just through the stopper, the other arm should be twelve or fifteen inches long. Boil the water and read the temperature when steady. Now pass the long arm to the bottom of a deep vessel of hot water; keep the flame strongly under the flask while this is being done and afterward. Wait until the thermometer becomes steady and read the temperature of the boiling water, which now will be higher. The steam now has to overcome the air pressure plus the pressure of the water column between the bottom of the long arm and the level of the hot water in the deep vessel; measure this depth. Estimate it in millimetres of mercury. By adding to it the barometric pressure, the pressure corresponding to the new boiling point is ascertained. By having different heights of water in the deep vessel, the pressure can be varied within certain limits.

In explaining the different thermometers and the relation among them, it is best to draw three thermometer tubes on the black-board all of the same length and at the same height. Draw a horizontal line through each, and call it the boiling point; draw another and call it the melting point. Write the names of the thermometers—Centigrade, Absolute, and Fahrenheit—above each thermometer and mark the fixed points in each as 0°C., 100°C.; 273°A., 373°A.; 32°F., 212°F. It is well to introduce absolute temperatures in this way, as they are put on just the same basis as the others. There is no mystery about them, and, when Charles' law comes to be formulated, there will be no difficulty in using them.

The general formulæ for converting Centigrade to Fahrenheit or Absolute, etc., should not be given to junior classes. In fact *no* general formulæ should be given them, as they use such helps mechanically, and the advantage of reasoning out problems is lost. After using the drawing on the board to show that $1°C. = 1°A. = 9/5°F.$, give the pupils the general caution always to reckon temperatures from one of those fixed lines, preferably the melting point and, before doing any converting, to reckon how many degrees the given temperature is from the melting point. Let them always have before them such a drawing as the one on the black-board when converting from one scale into another.

**_Example 1._—What would −40° C. be in the Fahrenheit scale?**
**−40° C. is 40° C. below the melting point.**
**∴ it is $\frac{9}{5}$ of $\frac{40}{1}$° = 72° F. below the melting point.**
**But the melting point is 32° F.**
**∴ 72° F. below melting point is −40° F.**

**_Example 2._—What temperature is 41° F. in the Centigrade scale?**

The temperature is 41° F., but melting point is 32° F.
∴ temperature is 41−32=9° F. above melting point.
∴ temperature is $\frac{5}{9}$ of $\frac{9}{1}$ =5° C. above melting point.
But melting point is 0° C.
∴ 41° F.=5° C.

Anomalous Expansion of Water.—A simple, easily worked experiment to illustrate this is a desideratum. Hope's experiment is perhaps the most satisfactory one. (Watson's *Elementary Practical Physics,* page 165) If temperatures are read every minute, it will be noticed that the top temperature changes very little till the bottom temperature reaches 4°C., then the bottom one remains steady at 4°C. and the top one drops to 0°C., and freezing begins.

An experimental proof that is clearer to the pupils, but which requires close measurements, is one described in Gregory and Simmons' *Lessons in Science,* page 129.

The economical importance of this should be stressed. The water at the bottom of a pond or lake never sinks much below 4°C., although the upper part is covered with ice. It is in this warmer water at the bottom that fish collect in the winter.

The diagram in Gregory and Simmons' *Lessons in Science,* page 132, illustrates very well changes in volume of water when heated from —10° to 100°C. It may be drawn on the black-board and discussed with the class.

Latent Heat.—A very instructive experiment which forms a fit introduction to this subject is the one described in Watson's *Elementary Practical Physics,* page 173.

To show that a mixture of ice and water can have only one temperature, put a beaker containing the ice and water into a freezing mixture, and put thermometers into both the beaker and the freezing mixture; if the water is kept stirred, it will remain steady at 0°C., although the freezing mixture goes very much below this point. After five minutes, transfer the beaker to a vessel containing hot water and stir the contents of the beaker for five minutes; the temperature still remains unchanged. Throughout the experiment, notice which is increasing in amount—the ice or the water. In the first case, the contents must be losing heat, but, as the temperature remains unchanged, the water changing into ice must give out as much heat as the water loses to the freezing mixture.

In finding the latent heat of fusion and the latent heat of vaporization the usual methods described in text-books are good. (Gregory and Simmons, *Lessons in Science,* pages 148, 151) The trap may well be omitted in finding the latter, as it is a constant source of trouble to the pupil, and is of doubtful utility. In case it is not used, have the middle part of the glass delivery tube sloping obliquely upward, so that any condensed water will run back into the flask. The arm of the glass tube passing into the calorimeter should be as short as possible.

Specific Heat.—The specific heat of a substance should be defined as the amount of heat necessary to raise one gram of the substance through 1°C.

The different capacities for heat of bodies can be well shown by placing equal weights of turpentine and of water in two test-tubes and letting them stand until they both are at room temperature. Put a thermometer into each, immerse them in the same vessel of boiling water, and watch the temperature. The temperature of the turpentine will rise much more rapidly, although they must both receive heat at the same rate, as the surrounding conditions are the same and both are non-conductors.

In the quantitative experiments with heat, a great deal of the success of the results depends on care and accuracy on the part of the pupil. Quickness, care in reading temperature, and a dozen other things must be attended to. The sources of errors should be thought out by the pupil, and he should decide how they would affect the result. In fact after the record of each experiment is made, he should state the sources of error and how he would make the error as small as possible. By "source of error" is not meant his blunder, but an error that is unavoidable with the apparatus used. If he has read the temperature 39°C., when it should have been 34°C., that is a blunder; but if ice is added in a "latent heat of fusion" experiment, it is bound to have some adhering water, which will lead to an error. That would be called a "source of error". No more thoughtful exercise can be practised by the pupil than that of determining the sources of error and how they will affect the result.

As an illustration, the sources of error in finding the latent heat of fusion by adding lumps of ice to a glass beaker of water at 50°C., until it is cooled to 20°C., may be stated. (1) The ice will have adhering water. The heat absorbed by the ice in melting is divided by the mass of ice melted, but that mass has been taken too large (as some water was counted ice); the latent heat will therefore be too small. This error could be diminished by drying the ice as much as possible before adding it to the water. (2) The heat given out by the beaker and thermometer in cooling from 50°C. to 20°C. helped to melt the ice, but was not counted; hence there was really more heat absorbed by the ice than was counted, and as latent heat is got by dividing the heat absorbed by the mass of ice, this error will make the result too small. This could be avoided by reckoning the amount of heat given out by the part of the glass and thermometer in contact with the water. (3) Part of the heat of the water and glass escapes into the air. This is counted as melting the ice, so that the amount of heat is counted as greater than it really is. This would make the latent heat too large. This source of error can be diminished by surrounding the beaker with flannel or other nonconductor.

There are many practical applications of the properties of heat that should be discussed. Under expansion could be taken the following:

Why thick glass vessels break when suddenly heated; what arrangements are made for expansion in laying railroad iron, in hot water and steam pipes, in water mains; the method of putting tires on wheels; iron bridges having one end placed loosely on an iron roller; sagging of telegraph wires in the summer; contorted appearance of iron pipes and girders in a burned building; why a stove pan is made of two pieces one within the other; the appearance of cracks in the ice of a frozen river or pond; the breaking of water pipes by freezing.

## LIGHT

Light lends itself especially well to individual experiment, and any apparatus necessary can be constructed by the teacher or purchased for a very small amount. A good deal of the experimental work can be assigned to be performed at home in the evenings, especially where a dark room is necessary.

The teacher should clearly understand that all the phenomena studied in connection with this topic depend on five fundamental properties of light:

1. It travels in a straight line through a homogeneous medium.

2. It is reflected according to the laws of reflection.
3. It is refracted according to the laws of refraction.
4 It is dispersed.
5. It is absorbed.

All images in mirrors, plane or curved, are produced as results of reflection. All images in lenses are results of refraction. All colour is a result of dispersion and absorption. These five fundamental properties of light should by illustrated by experiments and made perfectly clear, and should then be applied to explain some of the common phenomena of our daily life.

LIGHT TRAVELS IN A STRAIGHT LINE.—This is best illustrated by the experiment in Gregory and Simmons' *Lessons in Science,* page 170.

The following are explained as a result of this fact:
1. The image produced by the pin-hole camera
2. Shadows
3. The law of inverse squares.

Have each pupil make a pin-hole camera at home. (Gregory and Simmons, *Lessons in Science,* page 170)

Let each pupil study images produced by this camera as to size, position, colour, etc., and also notice the effect of placing the tissue-paper screen nearer to and farther from the pin-hole. The explanation of the formation of this image is difficult to make clear to students. The following method may help: Consider each point of the candle flame to be shooting out rays (like bullets) in all directions, then only one "light bullet" from each point will pass into the tube, namely, the one that goes in a straight line through the pin-hole; those striking the tissue-paper screen are visible to the eye, and every point in the candle flame will be represented by its corresponding point on the screen. It is easy to see that the ray shot from the top of the candle flame will hit the screen at the lowest level, and vice versa; the ray shot from the right will strike at the left of the screen; all points will be reversed, vertically and horizontally; hence the image is inverted both laterally and vertically. The lateral inversion can be seen by looking at the image of a house or tree as formed by the pin-hole camera.

SHADOWS.—These can be studied by the pupils at home, and the results recorded in note-books and discussed in class. The teacher must give very specific directions, however, or the work will not be well done. Let the lamp flame and the sun be used as sources of light; use opaque objects larger and smaller than the lamp flame and examine the shadows on a screen at different distances. Such objects as a cent, a marble, a piece of square cardboard, a hair held vertically, etc., should be used to produce shadows.

PLANE MIRRORS.—For proving the laws of reflection and studying images in plane mirrors, the simplest and most satisfactory mirror is one made from a piece of window glass about five inches long and one inch wide. Paint one side of it with a dull black paint and use the other as the reflecting surface; images seen in it will not be so bright as in a silvered mirror, but they are bright enough. In an ordinary silvered mirror, all rays are refracted twice, once when entering the glass and once when leaving it, and this interferes with results to a considerable extent; with the glass painted black, all reflection takes place from the front, as any rays that enter are absorbed by the black paint. This glass should be fastened by passe-partout to a block of wood 5" x 1" x 1".

The laws of reflection can be proven by means of this glass as follows: On a sheet of paper, pinned down, rule a line, and place the front of the mirror along this line. Place two pins in a line oblique to the mirror; have the heads of the pins the same height above the paper, then place two more pins in the paper so that they are in line with the images of the first two pins seen in the mirror. Push the four pins to such a depth that the head of the one nearest the eye covers from view the head of the second and the images of the heads of the first two. By removing the pins and mirrors and ruling lines along the incident and the reflected rays as indicated by the pin-holes, then drawing a perpendicular at the point of incidence and measuring carefully with a protractor the two angles, the first law is proven: that is, *the angle of incidence is equal to the angle of reflection.*

By measuring the heights of the heads of the four pins above the surface, their heads will be proven to be in the same plane, and as the heads appeared in line, the rays travelling along the heads of the first and second must have been reflected along the heads of the second and third, hence the two rays were in the same plane, and this plane was parallel to the paper or perpendicular to the mirror. This proves the second law, namely, that *the incident ray, the reflected ray, and the normal to the surface at the point of incidence are all in one plane.*

IMAGES.—In dealing with plane and spherical mirrors and with lenses it is necessary generally to find accurately the position of the image. If the image is real, it can be shown on a screen and hence easily located, but if it is virtual it is often very difficult to locate. By what is called the method of parallax, images of either kind can be very easily and very accurately located. This is well explained in Watson's *Elementary Practical Physics*, page 130.

Apply this method to find the position of an image of an object as seen in a plane mirror. (Watson's *Elementary Practical Physics*, page 131)

After some practice, the pupils will be able to locate images in this way rapidly and accurately. By this method of parallax let them find the images of a pin placed between two mirrors when parallel and when at an angle, and thus prove the laws of the position of such images; for instance, in the latter case, that they are on the circumference of a circle.

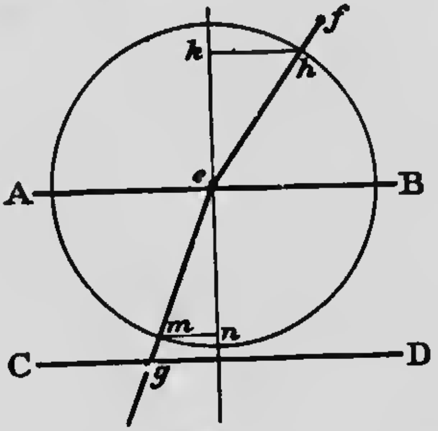


Figure 4

Refraction.—This phenomenon can best be studied by means of a prism with flat ends and with a square piece of thick plate glass with two opposite sides polished. A piece of glass, such as is used to cover the smaller weights in a box of weights, will do; several microscopic slides piled on one another will also answer very well. The glass is placed on a paper, and lines A B and C D are ruled on the paper along its polished sides. Place two pins at *g* and *e* and then, *looking through the glass*, place a pin at $f$ so that the three pins at $g$, $e$, and $f$ appear in a straight line. After taking away the glass, complete the Figure as in the drawing. With centre $e$ describe a circle cutting $ef$ and $eg$ in $h$ and $m$, and from $h$ and $m$ draw lines at right angles to the normal through $e$, and the ratio of $hk$ to $mn$ is the index of refraction. This experiment should be repeated three times with the pins $g$ and $e$ at different positions. Results should be tabulated as follows:

| No. | $hk$ | $mn$ | $\underline{hk}$ |
|---|---|---|---|
| 1............ | ............. | ............. | ............. |
| 2............ | ............. | ............. | ............. |
| 3............ | ............. | ............. | ............. |

At once the result can be generalized. (See *Ontario High School Laboratory Manual in Physics*, Exercise 79.)

The course of a ray from air to water can be traced in an exactly similar way: Rule a straight line on a board, and place two pins in the board, one of which is on the line. Place the board on edge in the water so that one pin is below the water and the level of the water is along the line ruled, the second pin being just above the water level. If now a third pin is placed in the board above the water so that the three pins appear in line, then the rays can be traced as before and the results tabulated.

The course of a ray can be followed through a triangular prism in a similar way, and the pupil will observe that the ray is bent toward the base both in entering and leaving the prism.

For home work a series of simple experiments may be given in observing substances placed in water, or partly in water and partly above water.

**Dispersion.**—Experiments to illustrate this phenomenon are not easily performed. The room must be as dark as possible; a narrow pencil of light should be admitted through a very narrow slit cut in the window-blind and a prism held in front of this; then a spectrum will be cast on the screen. A spectrum can be produced with a gas flame or lamp flame if the room is quite dark. Inclose the lamp in a box with a slit on one side, about 2 cm. long and 2 mm. wide. Turn the edge of the lamp flame to the slit. If a prism is now placed in front of the slit, with its edge vertical, a spectrum will be produced on the screen, and, by placing different coloured papers in the different parts of the spectrum, the facts of absorption can be illustrated. A pure spectrum can be produced by this method if, before the prism is interposed, a convex lens is placed a little more than its focal length in front of the slit, and the screen is placed so that it receives the image of the *slit.* Then place the prism just in front of the lens, and move the screen to receive the spectrum, but keep it at about the same distance from the lens as before.

The spectrum colours can be recombined by placing a second prism exactly similar to the first just in front of it, and with its angle facing in the opposite direction.

In all the above experiments avoid holding the prism or lens in the hand; use proper holders. Prisms with flat ends will stand on books or blocks built up to the required height. Prisms with faceted ends should be avoided.

A rotating disc for combining the colours of the spectrum can be made from a disc of cardboard. Two holes should be made in it on the diameter, about half an inch on each side of the centre. Through the holes run a string about three feet long and tie the ends together. The disc can then be made to rotate rapidly after the manner of the ordinary buzz-saw toy. The colours can be fitted upon it by cutting circular pieces of paper of each colour and then taking sectors out of each of approximately the same size. If the disc in rotation appears blue, cover part of the blue with white; if red, cover part of the red, and so by trial it can soon be fitted to show white only.

The colour of an object—say a green one—is often explained as caused by the absorption of all the rays of light falling on the object except the green ones, the latter being reflected and so causing the body to appear green. This is not an exact explanation. The light enters the body, and all the rays except the green are absorbed; the green rays are reflected from the internal parts and pass out again, and it is these rays internally reflected that give the colour.

The following experiment will help pupils to gain a clear conception of the cause of colour in bodies, as just explained. Paint a bottle having four flat faces with dull black carriage paint, all but a narrow slit 10 cm. x 1 cm. on one face. Fill the bottle with a coloured liquid such as litmus, or a solution of potassium permanganate. The liquid, viewed through the slit, appears perfectly black, as all the light passing in is completely absorbed either by the liquid or by the coating of dull paint. Now put some chalk dust in the liquid, and immediately it becomes brilliantly coloured, as the rays that enter are internally reflected from the white particles.

## SOUND

The work in sound is not very suitable for individual experiments, as the apparatus is rather expensive. In pur·

chasing apparatus, do not buy a supply of small tuning-forks; the prongs of these should be at least five inches long and one-half inch wide.

With a little mechanical skill a satisfactory sonometer can be made (be sure to use piano wire only). Different tensions can best be obtained by stretching the string over a pulley and suspending from the end a pail into which water can be poured till any required tension is produced.

If glass tubes are not available, good results can be obtained with cardboard tubes such as are used for mailing purposes.

VIBRATORY MOTION AND WAVE MOTION.—The first fact to teach is that all sound originates in a vibrating body, and experiments to familiarize pupils with the motion of the pendulum should be performed. Then should be emphasized the fact that, while sound originates in a vibrating body, it is transmitted through a material medium by a wave motion. The difference between a vibratory motion and a wave motion must be made very clear, and that while the wave moves forward through the medium, the particles of the medium are vibrating back and forth, each through its point of equilibrium. The particles do not advance, though the wave does. It must also be made clear that the wave moves forward a wave length while the particle makes a complete vibration.

TRANSMISSION OF SOUND.—Sound is transmitted through solids, liquids, and gases, but not through a vacuum. A very instructive experiment for solids and gases can be assigned as work to be done out of school. Let two boys, A and B, station themselves, say, two hundred feet apart along a railway track and, while A puts an ear to the rail, let B strike the rail with a stone; A will hear the sound *twice*, the first and louder sound comes through the metal rail, the second comes through the air; by varying the distances between the boys the interval between the two sounds can be made to vary.

Pass the stem of a tuning-fork through a flat cork. Make the fork vibrate and then place the flat cork on the surface of water in a large dish; at once the sound becomes louder, showing that it passes through the water.

The ordinary method of illustrating the fact that sound will not pass through a vacuum is rarely successful in school practice, even if a good air pump and an electric bell inclosed in a bell-jar are available. The following method is fairly successful and might well be tried: Into a *round-bottomed* flask of at least a litre volume fit a rubber stopper with two holes in it. Plug one hole with a short piece of glass rod; through the other put a longer piece of glass rod with a small toy bell suspended by a thread from the end which enters the flask. Now place a little water in the flask, put in the stopper with the suspended bell, and shake; the bell can be heard. Withdraw the short glass plug and heat the water in the flask until nearly all the water is boiled away, insert the plug again, and at the same instant remove the flame. Cool the flask by pouring water over it. The bell is now suspended in a vacuum, except for a small quantity of water vapour, and, if the flask is now shaken, the bell cannot be heard.

The ease with which sound can be transmitted through some solids may be utilized to make a simple form of telephone. A circular hole about eight inches in diameter is made in the bottom of a soap box, and over this hole is stretched and tacked a piece of good leather; another box is fitted up similarly; these boxes are fastened rigidly at the two stations, such as opposite sides of the street or even several hundred feet apart. They are then connected by a continuous piece of wire which at each end passes through the centre of the leather and is fastened to a button which presses tightly against the leather. The wire must not touch anything between the two stations.

PITCH OF SOUNDS.—This can be illustrated by a toothed wheel or stretched strings, and the relation of the pitch to the length of the string and to the tension should be illustrated by means of the monochord. A home-made one can be easily constructed, and piano wire should be used with it.

CONSONANCE.—This is used in two senses in Physics. The one probably meant in the Course of Study refers to the sympathetic vibration that one body takes on from the influence of another vibrating body in the neighbourhood. When the stem of a vibrating tuning-fork is pressed against a table, the table begins vibrating at the same rate and with greater loudness—this we say is an example of consonance. All sounding-boards act in a similar manner.

RESONANCE.—This can be illustrated best by a tuning-fork and a glass or cardboard tube one inch or more in diameter and two feet long. One end of the tube is placed in a vessel of water and the vibrating fork is placed over its mouth. The end of the tube is raised or lowered in the water until the sound reaches its maximum.

STRINGED MUSICAL INSTRUMENTS such as the piano, guitar, violin, banjo, harp, etc., should all be related to the monochord. As, in the latter, different pitches are got by differences in the length, tension, diameter, and material of string, so in these stringed instruments the variety of pitch is got by changing one or more of these factors. Study in each one which factors are utilized. Have the pupils examine the piano at home, and have as many as possible of the other instruments brought to school by different pupils. In the piano they will notice that the strings are of different lengths,and some are made of greater diameter by combining several wires into a single string. Consider the piano tuner's method of securing the desired pitch by increasing or decreasing the tension of the strings by turning the screws to which they are attached. Let the pupils find out at home, if possible, how the piano string is struck. The violin should be dealt with in a similar manner, and the use of every part of the instrument discussed, as well as the method by which the different pitches are produced. It is not enough to talk about these instruments; they should be before the class and be examined.

WIND INSTRUMENTS.—The resonance jar should form the introduction, sound being produced by blowing across its mouth. An organ-pipe is a resonance jar with a mouth-piece for blowing across its end effectively.

The most useful form of organ-pipe for experimental work is an open one with three holes at intervals along its side. It can be made a closed pipe by putting the open end against a table. Corks can be used for opening or closing the lateral apertures.

Make quite clear that with a single tube the pitch may be made to vary (*a*) by blowing with different degrees of force, (*b*) by opening or closing the ends, (*c*) by opening different lateral openings. Apply these facts to explain such instruments as the tin whistle, bugle, flute, clarinet, cornet, trombone, etc.

Have as many as possible of these instruments before the class and have each thoroughly examined by the class to see which of the above three methods are used to get the wide range of pitches produced in each. It is little use merely to talk about these instruments; they should be present for practical examination.

Reflection of Sound.—Concave mirrors with a watch at one focus and a funnel leading to the ear at the other focus can be used to illustrate reflection, but the experiment needs much care and is not very convincing to a junior pupil. The following method is better: Have two tubes each about five feet long and about three inches in diameter; iron pipes will do if available, or square pipes made by nailing narrow wooden slats together may be utilized. On a table draw a line, along which a mirror is to be placed. Draw a line at right angles to this, and two oblique lines, one on each side of the perpendicular and forming equal angles with it. Place the tubes along these oblique lines, and at one end of one tube place a watch on some absorbent cotton. Now put the ear to the end of the other tube, and wait until the ticking of the watch can be heard distinctly (a book should be placed between the other ear and the watch). If the mirror is then removed, the sound can no longer be heard.

Echoes.—If practicable, the pupils should carry out such an experiment as the following: Standing, say, two hundred feet from the broad side of a large building, such as a barn, the intervening ground being level and horizontal, let the experimenter shout a short word and listen for the echo. Note the time between the shout and the echo. Then move back to double the distance and repeat the shout. Again note the time between the shout and the echo.

## MAGNETISM

The school should be equipped with at least two good bar magnets, and as many more as are necessary can then be made by using these to magnetize knitting-needles or rods of hard iron cut off to a suitable length at a hardware store; for small pieces of soft iron to test the strength of magnets and for experiments in induction, small soft wire nails are good; and for small pieces of hard iron, steel pens may be used. The most delicate form of compass-needle required is a sewing needle magnetized and suspended from a paper stirrup by a piece of unspun silk. The simplest form of stirrup is made from a piece of gummed paper 1 inch x ¼ inch, folded across the middle. A knot is tied on the end of the silk, and this is fastened between the ends of the gummed paper. The free end of the silk is held between the finger and thumb, or, better, fastened to a support. Such a stirrup as this, if large enough, can be used for suspending any magnet. The most satisfactory compass for physical work is a small one graduated to degrees, and having a transparent glass top and bottom. Fine steel filings can be got from any one who sharpens saws, if notice is given him to preserve them. For some purposes soft iron filings are better, and they can be easily purchased.

In experimenting with magnets it is very essential that no pieces of iron be near the apparatus; gas pipes, water pipes, tanks, or iron nails often cause unexpected and confusing results.

In bringing one pole near the pole of a suspended magnet, to test whether repulsion or attraction takes place, the approach must be made very slowly, or unlooked-for results will be obtained; since, when a pole is brought very close to a magnet, its inductive effect may be so great that the polarity of the magnet may be reversed.

The relative effects of two magnets on a compass-needle may be crudely determined by placing one after the other at a fixed distance from the needle and counting the needle's rate of vibration; the faster the vibration period, the stronger the attraction or repulsion.

Polarity.—Pupils should first study the effect of a magnet on iron filings, and find that the filings cluster around the poles; then, using two magnetized knitting-needles—one suspended by a stirrup, the other in the hand—prove that like poles repel and unlike poles attract. The like poles in the knitting-needles can be found by suspending each in turn in the stirrup and marking the ends pointing north. The relative strengths of a pole of a knitting-needle and that of a bar magnet can then be compared by the vibration method, as indicated above.

Magnetic Field.—In studying the magnetic field, the iron filing method is very pretty, but the pupil seldom grasps the fact that each filing is a little compass-needle, or magnet, and that it is along the lines of the filings that the magnetic forces are acting. A slower method, but more accurate and more convincing, is the following: Place a magnet on a large piece of paper and run a lead-pencil around its margin; place a compass-needle (preferably small and with glass top and bottom) near one end of the magnet; place a dot opposite each end of the needle; then place the needle further from the magnet, so that the end of the needle which was nearest to the magnet is now over the outer dot; place a dot opposite the outer end of the needle as before. Continue this until the compass reaches the edge of the paper or comes back to the magnet. Join all the dots with a curve. In a similar way get lines coming out from all around the magnet. This will give a magnetic field, and the pupils will have a much clearer conception of what a line of force means. Iron filings may now be sprinkled on the paper and tapped, and it will be seen that they form along these lines.

THE INDUCTIVE ACTION OF A MAGNET.—This can be well illustrated by hanging nails or steel pens from the end of a magnet. The different retentivity of the nails and the pens is shown on removing the suspended row of either; the pens will still hold together pretty well, while the nails will almost at once lose their magnetism and fall apart.

The inductive action of the earth can be shown, as in Watson's *Elementary Physical Science,* page 195.

INCLINATION.—To show the angle of inclination some sort of dipping needle must be procured. Any pupil may make a satisfactory one which will illustrate the principle and allow the angle to be measured with a fair degree of accuracy. Pass an unmagnetized knitting-needle through the centre of a small cork in the direction of its long axis. Then pass a sewing needle through the cork at right angles to the direction of the knitting-needle, to serve as an axis. Adjust the knitting-needle in the cork, so that it will retain a horizontal position when the ends of the axis rest on the edges of two glass beakers and the knitting-needle points east and west. Put a small nail into the cork at right angles to both the needles and on that side of the cork that is uppermost when the needle is balanced between the beakers. By adjusting this nail and the knitting-needle, the latter may be made to retain any position in which it is placed—vertical, horizontal, or oblique. Now magnetize the needle by rubbing one end with the north-seeking pole of a magnet and the other end with the south-seeking pole of a magnet, and set it pointing north and south. It will then indicate the dip fairly accurately.

Gregory and Simmons, *Lessons in Science,* page 209, give another method, which is more difficult to carry out, but gives fair results.

## ELECTRICITY

The experiments in this department will be limited, as it is only intended that the pupil should gain a knowledge of the nature of the electric current and a few practical applications. For the current necessary to perform the experiments three or four dry cells are necessary, and these should be renewed every year. The objection to them is that they do not give a steady current, and hence are not good for electrolysis and for electrical measurements; however, they prove fairly satisfactory for the former, and very little of the latter will be undertaken in the Lower School Course.

**Current Indicator.**—For indicating the presence of a current and its direction, a wire may be placed above or below a compass-needle. To get a more sensitive indicator, wind twenty or thirty turns of wire about a beaker near its open end, and after laying it on its side so that the coil is in the magnetic meridian, place a compass in the mouth of the beaker, supporting it so as to bring it near the centre. Let the ends of the wire dip into pill boxes containing mercury, and then connect the terminals of the electrical generator, whatever it may be, by dipping them into the mercury.

**Resistance and Potential.**—The pupil should study the simple cell, as described in Gregory and Simmons, *Lessons in Science*, pages 129, 130. Then the teacher should show that other metals may be used for the plates; also that other liquids may be used, such as brine, or hydrochloric acid, or potassium hydroxide solution. Next show that some liquids, such as alcohol or coal-oil, will not serve, and that some solids, as wood or glass, will not do for the plates. Show also that the plates must be connected by metal wire, and that wood, string, or glass will give no deflection. In this way the pupils can be taught the requisite arrangement to get a current, and they can be given proper ideas of resistance, conductivity, difference of potential, and current strength. Have each pupil take plates of iron (an iron nail), zinc, copper, lead, and carbon, immerse them in pairs in weak sulphuric acid (1 of acid to 10 of water), and, by connecting with the mercury cups of the current indicator and noting in each case the direction in which the needle is deflected, arrange them in an electro-motive series.

**The Heating Effect.**—This can be shown by connecting the dry cells in series and joining the terminals by a short piece of one of the strands that go to make up picture wire. If not hot enough to glow, try whether it is hot enough to light a match applied to it.

**The Electro Magnet.**—This can be illustrated by winding insulated copper wire, No. 20, around a stick of carbon or a large lead-pencil, connecting the terminals of this wire with a dry-cell battery, laying the coil on paper, and plotting its magnetic field as was done for the magnet. Show an increase of strength by slipping a piece of soft iron through the coil and noticing the action on a compass-needle at various distances.

ELECTROLYSIS.—This can be shown as follows: Fit a cork in the narrow end of a lamp chimney; bore two holes in the cork and pass two small electric light carbons through it, so that they will project a couple of inches into the lamp chimney; attach a bit of copper wire to the outer end of each. Now pour melted paraffin into the chimney until the cork is well covered, being careful not to let any fall on the projecting carbons. When the paraffin is cold, almost fill the chimney with water containing a small quantity of sulphuric acid (1 to 50). Fill two test-tubes with the same solution, cover the test-tubes with little pieces of paper, invert in the liquid in the chimney, and put one over each carbon. Have the lamp chimney supported in a ring of a retort stand. On connecting the wires with the battery terminals the gases will be given off.

THE ELECTRIC BELL AND INCANDESCENT LIGHT.—These should be examined by each pupil. The incandescent light apparatus should be examined in all its available parts—not merely the bulb, but all the attachments to be seen in a room. These should be taken apart by means of a screw-driver and put together again. The electric bell should be connected up with a battery by each pupil, and drawings of both should be made and the course of the current indicated by arrows. Talking about these things is time wasted when they can be studied practically.

# CHEMISTRY

NOTE.—In both Physics and Chemistry, practice in the preparation and manipulation of apparatus should form part of the Course. Where practicable, the Course should also include simple operations in glass-blowing and lathe work, and in hard and soft soldering.

## COMBUSTION IN AIR

Before performing any experiments, strive to produce the right attitude on the part of the pupil by giving a home exercise of the following nature:

Have each pupil write in his note-book in a vertical column the names of five or six common substances that burn in the air, and fill in answers to the following questions regarding each:

Is the substance a solid, a liquid, or a gas?

Is any substance produced when it burns?

Is any ash left behind?

Do you think the ash weighs more or less than the original substance?

Is the burning accompanied by a flame?

Have each pupil tabulate results in the following manner:

| Name of substance | Solid, liquid, or gas | Product of burning | Ash or not | Flame or not | Any other observations. |
|---|---|---|---|---|---|
| Coal | | | | | |
| Kerosene | | | | | |
| Wood | | | | | |
| Gas | | | | | |
| Candle | | | | | |
| Sulphur | | | | | |

After the pupils have tabulated these results, discuss with them the answers to such questions as the following:

Is burning always accompanied by a flame?

Does the burning substance always disappear?

Do substances begin to burn of themselves, or, if not, how is the burning started?

Is heat always produced in a case of burning?

What is the burning substance always in contact with?

If the answers to such questions are carefully discussed, the pupil will be prepared to investigate some problems connected with burning that are not so obvious of solution. Each member of the class should perform the following experiments:

Experiment 1. *To study the burning of magnesium in air and to investigate the resulting ash.*

Apparatus required: 5 cm. magnesium ribbon, piece of copper wire, sheet of white paper, test-tube, litmus paper, funnel, filter-paper, watch crystal, emery-paper.

Clean the magnesium ribbon with the emery-paper and note its properties, such as colour, flexibility, hardness when tested with a knife, etc. Then roll into a loose spiral around a lead-pencil, make a loop at one end, hook into a loop on the end of the copper wire, and hold the free end of the coil in the flame of a lamp or Bunsen burner until it begins to burn; then remove and hold the burning magnesium over the sheet of white paper, so as to catch any ash that may drop. Examine the ash carefully, and note how it differs from or resembles the magnesium in colour, hardness, flexibility, lustre, etc.

Test its solubility as follows: Grind some of the ash to a powder, place in a test-tube, add an inch of water, and boil for a minute. Then filter (the teacher will give full directions as to mode of filtering). Place one drop of the filtered liquid on a watch glass, and a drop of tap water alongside of it, and hold between finger and thumb over a flame until both drops are evaporated. Both leave deposits, as the tap water always has salts dissolved in it. The solubility can be judged by the difference in amount of the deposits; in this particular case there will be a very slight difference, as the magnesium ash is almost insoluble in water.

Test the filtered liquid with litmus as follows: Put pieces of red and of blue litmus paper, not larger than the little finger nail, into a test-tube containing half an inch of the solution, and similar pieces into a test-tube containing the same amount of ordinary tap water; after five minutes compare the litmus papers in the solution with those in the water; if any change has taken place in any of the pieces, note the tube in which it has occurred and also the character of the change. (Always use this method for testing with litmus where the effect is not marked.) Let the pupil write his explanations and conclusions at home, and as a guide suggest such questions as the following to be answered in his report:

Is the ash a different substance from the magnesium?

Do you think the ash contains the magnesium?

If so, how would the weight of all the ash compare with that of the magnesium?

If the ash does not contain the magnesium, what has become of it?

Does the ash look like one substance or like a mixture?

EXPERIMENT 2. *To find whether the ash formed when magnesium is burned weighs more or less than the magnesium.*

Apparatus required: 10 cm. magnesium ribbon, crucible with cover, pipe-clay triangle, retort stand, Bunsen burner or gasolene blast lamp, balance.

Discuss particulars with the class first, and try to get from them suggestions for a practical method of collecting all the ash.

Clean 10 cm. of magnesium ribbon with emery-paper, roll into a spiral, place in a clean, dry crucible, cover with the lid, and weigh carefully to the nearest centigram. Place the crucible on the triangle and heat very gently at first, and then increase the heat until the bottom of the crucible becomes red hot; with a piece of copper wire raise one edge of the lid slightly for an instant; repeat this at short intervals until the magnesium ceases to glow brilliantly when the edge of the lid is raised; continue heating for five minutes with the lid partly raised, so that there will be free access of air. Let the crucible cool, and then place on the balance and weigh again. Tabulate results as follows:

Weight of crucible + lid + magnesium .....g
Weight of crucible + lid + ash ..........g
Increase in weight ..................g

Test the white ash as in Experiment 1, and see if it is the same substance.

In discussing the result with the pupils, draw from them the different interpretations. The increase in weight might be due to the crucible absorbing something from the flame or air, or to the magnesium absorbing something from the air. Discuss methods of testing the first supposition. What would the constant lifting of the lid and the attendant glowing indicate, as to which is the correct interpretation? The final conclusion will be that the magnesium has absorbed something from the air. Try to get the class to indicate a method of repeating the experiment, but excluding largely free access of air to the magnesium.

**Experiment 3.** *To test if magnesium gives the same ash as in Experiments 1 and 2, when heated so as to exclude free access of air.*

Apparatus required: The same as in Experiment 2, with the addition of some clean, dry sand.

Place the cleaned magnesium in the crucible, then half fill the crucible with clean, dry sand, place the lid on the crucible, and heat for the same length of time as before and with equal heat, but in this case leave the lid tightly on the crucible throughout the experiment. Cool as before and examine the magnesium. Has it changed to ash? Is there any sign of change on the surface, or has it a bright metallic lustre as at first? This change is due to the small amount of air among the particles of sand. Does this corroborate the conclusion from the preceding Experiment?

**Experiment 4.** *To study the effect of heating other substances in air.*

Apparatus required: Phosphorus, thin iron wire, thin copper wire, pieces of lead, carbon.

Phosphorus must never be touched by the fingers, and always be cut and kept under water. The pieces used should be small.

Have different members of the class take different substances and discuss results together. Clean pieces of phosphorus, copper, iron, and lead, and after examining each as to colour, flexibility, hardness, lustre, etc., place each in a crucible and heat with a hot flame for ten minutes.

(The pupils who use the iron, copper, and lead may weigh them before and after heating.) Do these substances act similarly to magnesium when heated? Which of them takes fire and burns? Examine the new substance formed in each case (scraping it off the metals), and describe its colour, tenacity, hardness, brittleness, solubility in water (see Experiment 1), and effect on litmus (see Experiment 1). Try to find out why some should just change on the outer surface.

If these Experiments have been carefully performed and properly discussed, the pupils will have discovered the following facts about burning:

1. When substances are heated in contact with the air they often burn.
2. When they burn, the substance is destroyed and a new substance is formed.
3. The new substance is heavier than the old one, and hence is formed by the old one absorbing at least a part of the air. Hence the new substance is composed of the original substance + part or all of the air.
4. Some substances, such as iron and copper, unite with air when heated without taking fire.
5. Some substances when heated in air do not change.

EXPERIMENT 5. *Do iron, copper, lead, phosphorus, etc., change when in contact with air, even when not heated?*

Apparatus required: Iron wire, copper wire, lead clippings, a thin shaving of phosphorus.

Have the surfaces of all the substances perfectly clean; leave them in contact with air for a few days, and then compare their surfaces with those of freshly cleaned ones. The effect on the iron will be increased if it is suspended in a corked bottle with a little water in the bottom. Do these substances still unite with the air? Is the action slower or faster than when they were heated?

Experiment 6. *Do these substances unite with all the air or with only a part of it when left in contact with it?*

Apparatus required: A small pickle bottle, a rubber stopper to fit the bottle, a round porcelain dish 8″ in diameter and 3″ deep, phosphorus, iron filings, a muslin bag, alcohol, lamp or Bunsen burner, deflagrating spoons.

The work with phosphorus may be done in the laboratory, that with iron filings may be done by the pupils at home.

1. Using phosphorus.—Have the bottle perfectly dry and cool, and place in the bottom a piece of phosphorus as large as an apple seed. Cork very tightly with the rubber stopper, then place the bottom of the bottle about one foot above the flame of the lamp, and keep turning the bottle so as to prevent breakage by heating too rapidly. When the phosphorus begins to burn, remove the bottle from the flame and let it stand as long as white fumes come off. When perfectly cool put the mouth of the bottle under water in the porcelain dish and withdraw the stopper. Notice the height of water in the bottle. Put the stopper into another bottle, invert the latter in water, withdraw the stopper, and notice the height of water in the bottle. Which bottle had the most air in it at first? Which has the most air in it now? What became of part of the air in the first?

Put the rubber stopper back into the first bottle while the mouth is still under water, take from the water and place on the dish. Place a fresh piece of phosphorus in a deflagrating spoon, loosen the stopper in the bottle and bring the phosphorus close to the mouth of the bottle, adjust the length of the spoon so that the phosphorus when placed in the bottle will not reach the water, ignite the phosphorus by bringing a hot wire into contact with it, withdraw the stopper, and plunge the burning phosphorus into the jar. Does the phosphorus burn as it did in the outside air? Is the air in the jar like ordinary air? Will phosphorus burn in it?

Pour the water from the bottle, scrape some of the deposit from the bottom where the phosphorus was, place on mica and touch with a hot wire. Does it burn like phosphorus? Is it phosphorus? Why did it not all burn when first heated in the bottle?

2. Using iron.—Tie a teaspoonful of iron filings or iron tacks in a muslin bag, tie the bag to the end of a short stick and thrust the stick with this end upward into an inverted pickle bottle; stand the bottle mouth downward in water in a soup plate and notice the level of the water inside the bottle. Let the apparatus stand for two or three days, and, after examining the level of the water, withdraw the stick and iron filings, still keeping the mouth of the bottle under water. Put a piece of cardboard under the mouth, remove the bottle, place it right side up on a table, and plunge a lighted splinter into it. Does the splinter continue to burn? Has the air been changed by the iron filings? Has some of the air been absorbed by the iron filings? Look at the iron filings and see if they are changed. Into what substance have they been converted? Are all the iron filings changed into rust? Do you think they would be all converted if left longer? Try it. As a result of these experiments the teacher should draw from the class the conclusion that these substances absorb a part of the air but not all of it.

## AIR AND ITS CONSTITUENTS

Before experimenting, give the pupils a set of questions tending to bring out clearly the facts about air that the preceding experiments on combustion have taught.

When a substance burns in air, does the burning take place where it and the air are in contact.

Is part of the air absorbed by the burning substance?

If a large quantity of the substance is burned in a limited quantity of air, will it in time absorb all of the air, or is there always a part left?

Is the part left different from air?

Will the part left support combustion?

If the part of the air absorbed by iron in being converted into rust were extracted and mixed with the part of the air left in the bottle (Experiment 6 (2)), do you think it would produce air?

Experiment 7. *To extract from mercury oxide the part taken from the air, and to study some properties of this constituent of air.*

Apparatus required: Hard glass test-tubes, rubber stopper, rubber tubing, pneumatic trough, mercury oxide.

First explain to the pupils that mercury oxide is mad by heating mercury in contact with air for several days, and that the mercury, in being converted into mercury oxide, absorbs part of the air just as phosphorus does when it burns in air, and as iron does when it rusts. Let each pupil examine mercury, so that he can recognize it again when he meets it. Its metallic lustre and liquid state will always distinguish it.

Fold a long, narrow strip of stiff paper once lengthwise, so as to make a trough that will pass easily into a test-tube; into one end of the trough put as much mercury oxide as will lie on a ten-cent piece; transfer the powder to the bottom of a *hard glass* test-tube, by holding the test-tube in a horizontal position and sliding the paper into it; then turn the tube upright and withdraw the paper. Make a test-tube holder by folding a sheet of paper into a narrow band and doubling it over the tube; place the paper band near the open end and hold between the thumb and finger of the left hand. Now, holding the tube in a horizontal position, heat at first gently, and then strongly, gently rotating the tube with the right hand, and always keeping well in the flame the end containing the solid. Occasionally thrust a long pine splinter, glowing at the end but not blazing, well down into the tube, until there is evidence of something besides air in the tube. When this stage is reached, insert a rubber cork with a delivery tube and collect, in the ordinary way over water, a test-tube full of the gas which comes off. Let this stand over water and continue heating the mercury oxide until the red powder has almost completely disappeared. Then scrape out some of the contents of the tube with a knife and examine it on paper. Examine the gas in the test-tube as to colour and smell. Is it very soluble in water? Place the thumb of the left hand over the mouth of the test-tube full of gas, lift from the water, turn with the mouth up, and plunge into it a long glowing (not blazing) splinter of wood. What is the metallic liquid left in the tube? Is the gas collected ordinary air? How does it differ from air? If this gas came off the red powder and left mercury behind, and the red powder was formed by heating mercury in air, is this gas a constituent of the air?

Now the class should see that one of the constituents of air has been isolated. Inform them that the name of this constituent is oxygen, and when other substances, as magnesium, phosphorus, etc., unite with it, the substances formed are called oxides, as magnesium oxide, phosphorus oxide, etc.

EXPERIMENT 8. Lavoisier's experiment (to be described but not performed). *To show that the weight and volume of air absorbed by heated mercury are equal to the weight and volume of the oxygen produced by heating the resulting red oxide.*

About 4 ounces of mercury were heated nearly to boiling in a flask A, which communicated with a vessel B full of air, standing over a vessel of mercury C. After several days, the volume of air in B had shrunk by 7½ cubic inches, and the surface of the mercury was covered with a deposit of the red oxide; this oxide was gathered and weighed 45 grains. Lavoisier next placed the red oxide in a bulb tube A connected with a cylinder B full of mercury and inverted in a vessel of mercury. He then heated the oxide until it all disappeared. The volume of the gas in B was measured, and found to be about 7½ cubic inches. The weight of the mercury left was found to be 41½ grains. But it is known that 7½ cubic inches of oxygen weigh about 3½ grains.

Give the pupils the figures of this Experiment and bring out its great importance. It proves conclusively that the amount of oxygen obtained by heating the oxide just equals the amount both by volume and weight that the air lost.

Now show ways of obtaining larger quantities of this constituent of the air, as by heating potassium chlorate and manganese dioxide, and study the combustion of some common elements in oxygen. It is not necessary to describe these experiments in detail, as they are given in all text-books.

Notice the difference in behaviour when these substances burn in air and oxygen; compare the products formed in the two cases, and let the pupils decide whether the oxygen acts in a similar way in both cases, except that it is more concentrated in one case and hence gives more intense results.

To obtain a supply of nitrogen, treat several bottles of air with iron filings as in Experiment 6 (2), wetting the bag of iron filings, and test the nitrogen as the oxygen was tested. The pupils will see that the gas is quite inert.

Experiment 9. *To examine a mixture of oxygen and nitrogen in the same proportion as these are present in air.*

Apparatus required: Pickle bottles, iron filings, oxygen generating apparatus, phosphorus, sulphur, etc.

Extract the oxygen from three bottles of air by means of damp iron filings, as in Experiment 6 (2). Fill another bottle with oxygen and let it stand until the gas is at the same temperature as in the other bottles. Bring the mouth of the bottle of oxygen under the mouths of the bottles of nitrogen in turn and displace the contained water with the oxygen. While doing this, look closely for any visible change in the mixed gases. Feel the bottle; or, better, immediately after mixing, take a bottle out of the water and thrust a thermometer into the gas. No changes of any kind can be observed.

After the gases have had time to mix, take the bottles from the water by slipping glass plates under the mouths, and burn in them phosphorus, sulphur, and a splinter of wood; test the products as when these were burned in oxygen. Now burn these same substances in bottles of air and test the products in the same way. The conclusions the pupil should be able to draw from this experiment are that a mixture of oxygen and nitrogen is identical in properties with air, and that when these two gases are mixed there is no evidence of any chemical change in them.

Experiment 10. *To prove that air contains water vapour in small quantities.*

Apparatus required: Glass tubing, rubber tubing, salt, ice or snow, and a beaker.

Bend a piece of glass tubing of 5 mm. bore into a U that will fit into the beaker. Having taken care that the inside of the tube is perfectly dry, attach the rubber tube to one end of it and immerse the U in the beaker filled with a mixture of snow and salt. Now suck air through the tube; examine it from time to time until moisture appears in it.

Experiment 11. *To show that air contains carbon dioxide.*

Apparatus: Bottle, test-tube, rubber tubing, scent bottle, bellows or atomizer bellows, lime.

Into a bottle put some small pieces of quicklime, half fill the bottle with water, cork it, shake well, and allow it to stand until clear. Pour off some of the clear liquid into a test-tube; this liquid is lime-water. Attach the bellows to a piece of glass tubing and force air through the lime-water; it will in time turn milky. (This may have to be continued for fifteen minutes before it becomes distinctly milky.) Now if oxygen or nitrogen is forced through lime-water, no effects are produced, so that there must be still another constituent of air; this is called carbon dioxide.

If a bellows is not accessible, air can be drawn through the lime-water by suction in the following way: Fit a rubber stopper into the bottle or tube containing the lime-water, and pass two glass tubes through the stopper, one extending to the bottom of the bottle and the other just passing through the cork. Suck through the short tube.

The pupils should feel throughout the foregoing set of Experiments that they are carrying on an investigation, namely, to find out the different constituents of air and to study these constituents as to their properties. The last two constituents will be investigated later.

## WATER AND ITS CONSTITUENTS

Lead the pupils to understand that they are about to conduct an investigation to find out (*a*) the constituents of water, (*b*) the properties of these constituents, (*c*) some properties of the water itself.

The methods of procedure should be first discussed. Let each pupil first of all evaporate a single drop of rain water, of well water, and of river water on a watch glass over a very small flame; each drop will leave a stain on the glass, showing that it contains some solids. Explain that these are impurities in the water.

As we started our investigation of air by trying to burn magnesium in it, we might begin in the same way with water; but water, instead of supporting combustion, is generally thought of as extinguishing a flame. However, if we use water in the gaseous state, so that the conditions will be more nearly like those of the air experiments, results may be more satisfactory.

Let the pupils place some water in a flask and boil it vigorously until all air is expelled from the flask. Wind magnesium ribbon in a spiral about a lead-pencil, take off and fasten on the end of a wire, ignite by the flame of a match, and plunge down into the flask; the magnesium continues to burn and a white ash is left. The pupils should withdraw this ash and examine it, as in Experiment 1, to see if it is the same material. They find that it is, and they should be led to see that as it contains oxygen this must have been extracted from the water vapour, and so oxygen is one constituent of water.

As oxygen is quite a different substance from water, and as it is contained in water, the latter probably has at least one other constituent.

Is this constituent left in the flask? If a part is evaporated, no solid is left, so the other constituent is not a solid. The liquid left is exactly like water, and hence there is no other liquid mixed with it, so the natural inference is that the other constituent is a gas. Let the pupils try to devise a method of collecting it.

The following experiment, which should be performed by the teacher, shows how this constituent can be collected. Fit up a flask with a rubber stopper through which is passed an elbow glass tube having a piece of rubber tubing attached to the outer end. Have a spiral of magnesium wire projecting from the bottom of the rubber stopper, and have ready a bottle of water inverted in the pneumatic trough. Now boil a little water in the flask, ignite the wire, thrust into the flask while the water is still boiling, press the cork, and hold there until no more gas collects in the gas bottle. (Be sure to withdraw the rubber tube from the water before taking the flame away from the flask.) Test this gas with a burning splinter and it will be found to act in an entirely different manner from any of the gases studied so far. The name of the gas may now be given. It is hydrogen.

Next show that other metals, such as sodium and potassium, act in a similar way on water, except that the water does not need to be heated. Then let the pupils perform the usual experiments with these metals and water, and be sure to have them evaporate some of the liquid, so as to see that a white solid is formed, as with magnesium.

When using these metals with water, it is a good plan, if the gas is to be collected, to get some lead tubing about one-fourth inch in diameter, cut off pieces two inches in length, and hammer them at one end till perfectly sealed; put, say, the sodium well up into the tube and, keeping the open end down, lower under the mouth of the gas jar, and then gradually turn the open end up, so as to admit water. A glass tube sealed at one end does almost as well as lead, but may crack.

Hydrogen may now be made in larger quantities from zinc and dilute sulphuric acid. Mix the acid and water by pouring one part of acid into ten parts of water. After mixing, pour the liquid on the zinc; if a little copper sulphate solution is added, the gas comes off more readily. Study its properties by the usual experiments.

It is unsafe for a junior pupil ever to light a hydrogen jet; the teacher should perform any experiments involving this.

It is a common inference, whenever a mist is formed on cold glass or drops of a clear liquid appear, that such a mist or liquid must be water. But such a substance should always be tested. A good test is to bring a small particle of sodium in contact with the liquid. If it becomes warm or takes fire, the liquid is water. The pupil may try with sodium other clear liquids, as kerosene, turpentine, and benzine, and note results.

Another simple test for water is with copper sulphate heated until it turns white. A drop of water added to this gives the blue colour again. No other water-like liquid will do so. Of course *mixtures* that contain water will give the water test.

Now that water has been analysed and found to have as constituents oxygen and hydrogen, these gases should be mixed to see if water results from the mixture, as air resulted when its constituents were mixed. The teacher might inform the pupil that in water the two gases are united in the proportion of two volumes of hydrogen to one volume of oxygen. Let each one make such a mixture and try the effect of lowering sodium or potassium into it; no ignition takes place. Let a lump of burned copper sulphate be lowered into it; it does not turn blue, so the mixture is quite unlike water.

Show, finally, that the two gases can be united in the presence of heat to form water. To do this let the flame from an ignited hydrogen jet play obliquely on the bottom of a round-bottomed flask filled with cold water, or, better a mixture of water and ice. Have a watch glass below the flask to catch the condensed drops and test these with sodium and burnt copper sulphate.

## LIMESTONE AND ITS PRODUCTS

Have the pupils place moist litmus paper in contact with limestone and note the absence of any action. Let them also test the solubility of limestone in water. Then have them grind up a very small quantity (a lump not larger than a grain of wheat); weigh the powder, and heat in a crucible before a gasolene blast lamp for fifteen minutes. Now weigh again, test with litmus, and also as to solubility. Compare the results with those of the experiment where magnesium was weighed and heated in air. They will see that something has been driven off in the heating process. The material remaining is quicklime.

To a fresh lump of quicklime, add a little water so as to make slaked lime; lead the pupils to comprehend that the quicklime has not merely *absorbed* water, but that it has *united* with the water to form an entirely new substance which is quite dry, white, and powdery. Let them heat it over a water-bath to see it does not lose its water. Let it be tested for water with sodium or burnt copper sulphate.

Explain the difficulty of collecting the gas that is driven off when limestone is heated, and state that the same gas can be driven off by adding an acid to the limestone. Then have the pupils prepare some of this gas as the second constituent of limestone. To find the constituents of this gas—carbon dioxide—use the same method as for finding those of air and steam; get a bottle of the gas collected over water, and plunge into it burning magnesium ribbon; test the white ash formed to show that it is the same as when the magnesium burns in air or water. A black deposit will be left in the jar; if this black deposit is tested, it is found to be insoluble and to burn when heated on mica; hence it is carbon. So the gas is proven to contain carbon and oxygen.

Show the effect on lime-water, and use as a test. Show the relation between this last experiment and the first experiment performed on limestone. In the first, the limestone is broken up into lime and carbon dioxide; in the second, these substances are united to form limestone again.

Test the burning of a candle, of wood, or of charcoal, for the production of carbon dioxide. To do this, burn in a large glass bottle each of these till extinguished; then add a tablespoonful of lime-water and shake.

Test the air expelled from the lungs for carbon dioxide. Test a solution of carbon dioxide with litmus.

## CHEMICAL TERMS

No attempt should be made to give a formal definition of such things as mixture, chemical compound, etc. Rather point out the characteristics of each. Air is a good example of a mixture; the two constituents retain their own individual properties in air, as has been shown, and the properties of air are largely the sum of the properties of its constituents. There is no evidence of heat or any other change when the two are brought together; these are both characters of a mixture. In a substance such as water, formed by uniting oxygen and hydrogen, we have a good example of a compound; here, when the two are brought together at room temperature, they form merely a mixture, but when the temperature is raised by bringing a flame in contact with the two, there is a violent production of heat, and water is formed, the properties of the latter being quite unlike those of its constituents.

The action of heat on magnesium and limestone shows the basic experimental difference between an element and a compound; the former increases in weight when heated, the latter decreases in weight. The former, to make a new substance, must have something added to it; the latter can give rise to a new substance by a process of separation. Substances like magnesium, which, when they form new substances, never decrease in weight, are elements; but those, like limestone, which can decrease in weight in the formation of a new substance, are compounds, which really means that they break up into two or more substances.

The heating of magnesium in the crucible, when exposed to the air and when covered with sand, illustrates the difference between physical and chemical change. In the first case a substance with entirely new properties, or a *new* substance, is formed, and we call the change *chemical;* in the latter, although the magnesium becomes heated and changes in colour, size, etc., yet we recognize it as still the same substance; and we call the change a *physical* one.

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