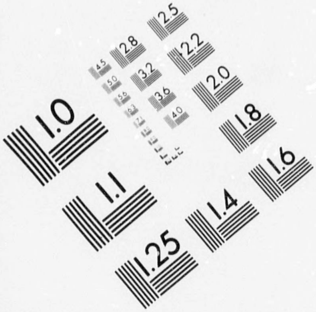

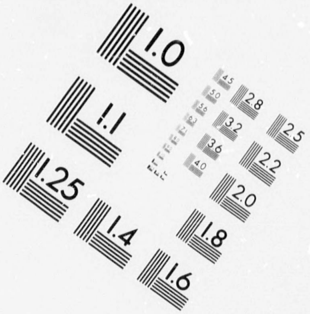

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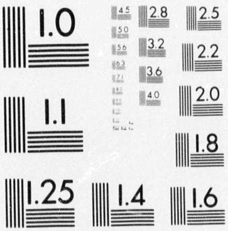

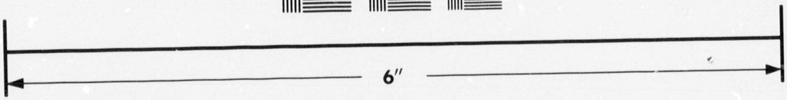

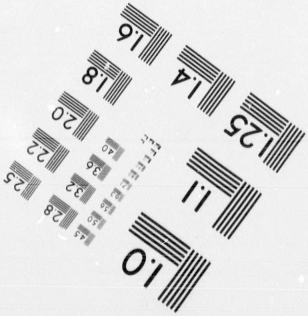

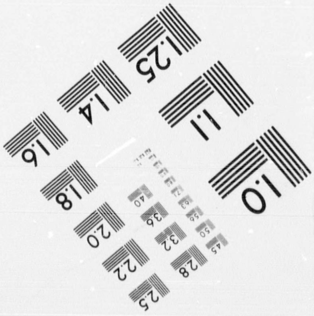

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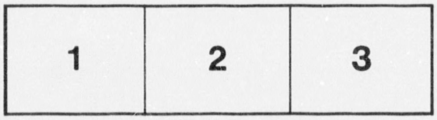
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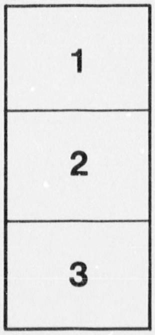
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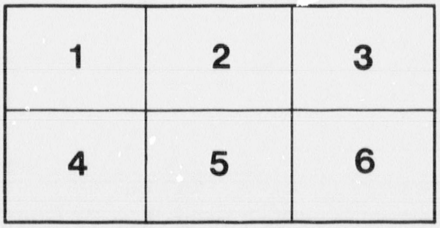
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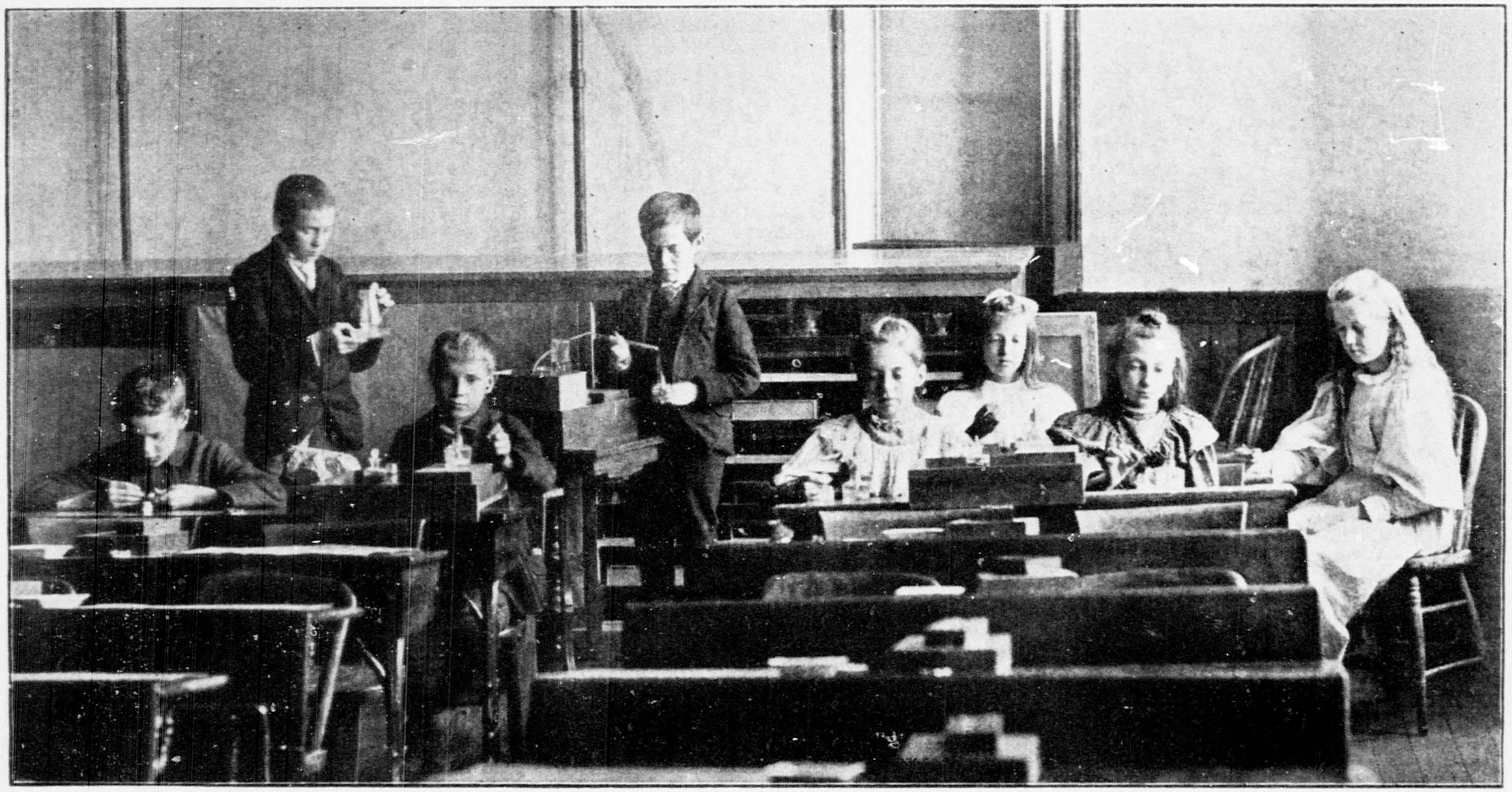

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GRADE VII PREPARING OXYGEN.
GRADE VI EXAMINING MINERALS.

New Brunswick School Series.
PRESCRIBED BY THE BOARD OF EDUCATION OF NEW BRUNSWICK.

TEACHER'S MANUAL

OF

NATURE LESSONS

FOR

THE COMMON SCHOOLS.

BY

JOHN BRITTAIN,
Instructor in Natural Science in the Provincial Normal School,
FREDERICTON, N. B.

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SAINT JOHN, N. B.
J. & A. McMILLAN, 98 PRINCE WILLIAM STREET.
1896.

To My Fellow Teachers:

This little manual is not intended to be of any special interest in itself. It only aims to be a useful index to some of the elementary chapters of the Book of Nature, and to indicate briefly the means by which children may be led to read them with pleasure and profit.

In order that our teachers, at least the younger ones, may be able to do their part well, it will be necessary for them to deepen their own interest, as well as increase their knowledge by further study of *that* great Book.

The teacher will also need to provide himself with a few works which will aid him in taking advantage of the labours of others to hasten his own progress. Elsewhere will be found a list of helpful books, some of which, or similar ones, the teacher of limited means will, by a little self-denial, be able to procure.

I have tried, herein, to outline a consolidated and correlated course of Nature Lessons which would include, essentially, everything embraced under the head of Natural History and Science in the Course of Study for the Common Schools — Lessons on Minerals, Plants, and Animals; Agricultural Topics; Physics — excepting Physiology and Hygiene, which are provided for in the prescribed text-books on these subjects.

So far as I know this is the first attempt at such a correlated course for our schools. It will doubtless be found to have many defects. I shall always be glad to receive hints from other teachers which may lead to amendments in a second edition. A complete series of suitable illustrations would, doubtless, have made this manual more serviceable, but would have added considerably to its cost.

I have made arrangements by which I can obtain for teachers, at cost, the minerals, apparatus, and chemicals necessary for the experiments in this course. For about $6 a supply, put up in a neat box, sufficient with the addition of such common things as are obtainable in any country district to last an ordinary school for several years, can be obtained.

The course of lessons outlined herein should not occupy on an average more than one hour per week of school time in each grade. There should never be two series of Nature Lessons going on together in the same department. For instance, if there is some work on minerals, and some on plants, laid down for the same year, the work on plants should be taken up and completed during the time of year most suitable for their study, and the work on minerals during the other part of the year. Some of the work can be done as well in winter as in summer, but in most of the grades it will be better to discontinue the Nature Lessons during the whole or a part of the winter, and make up for it by having them more frequently in the warmer seasons.

A great deal can be accomplished by school excursions on Saturdays or other holidays, or after school hours in the long days. I am acquainted with a number of teachers who have tried such excursions, and have found them not only enjoyable, but profitable to themselves and their pupils. It is quite as easy to maintain order out of doors as in the school room. Besides, if any pupil shows himself unworthy of the privilege, he may be excluded. The teacher must exercise judgment in selecting a suitable route and good weather, and be careful not to unduly fatigue the pupils or otherwise endanger their health. The parents should always be consulted, their advice asked, and consent gained. It is true that, although the Course of Instruction recommends such excursions in connection with the Nature Lessons, they are not obligatory. But there is no teacher who can do his best for his school without devoting some time to it outside of the regular routine. And the teacher who is not willing to do this is not, in my opinion, worthy of his profession. It is only by the practice of self-denial that teachers will ever attain to that influence and efficiency which will enable them to do the work which lies before them.

In conducting these Lessons the teacher must ever keep in mind that it is not their object to make scientists of the children. It is not the aim of the common school to specialize in any direction. A specialist in science who is ignorant in the other great divisions of human knowledge, and has no appreciation of poetry or art, is as unsymmetrical a being as an equally narrow-minded specialist in any other department. If such men are needed it is not the business of the common school to produce them. Let us strive to teach so that as our pupils' acquaintance with natural forms and processes widens, so will their appreciation of the beautiful in nature and reverence for its Author deepen.

> "Let knowledge grow from more to more,
> But more of reverence in us dwell;
> That mind and soul, according well,
> May make one music as before,
> But vaster."

Hoping that this little book may be able to establish by its *doing* its right to *being*,

I am,
Yours sincerely,
JOHN BRITTAIN.

COURSE OF NATURE LESSONS.

GENERAL OUTLINE.

CHAPTER I. THE INORGANIC WORLD

CHAPTER II. THE ORGANIC WORLD.

Division I. Plants.

CHAPTER III. THE ORGANIC WORLD.

Division II. Animals.

APPORTIONMENT OF WORK AMONG THE DIFFERENT GRADES.

SCHOOLS OF TWO OR MORE DEPARTMENTS.

MISCELLANEOUS SCHOOLS IN COUNTRY DISTRICTS.

Grades I and II. Part I...
Grade III. Same as for Grades III and IV above...........................
Grade IV. Same as for Grades V and VI above.................. ....
Grade V. Same as for Grade VII above...
Pupils who have completed Grade V. Same as for Grade VIII above.

REQUIREMENTS OF CANDIDATES FOR NORMAL SCHOOL ENTRANCE EXAMINATIONS, AND PRELIMINARY EXAMINATIONS FOR ADVANCE OF CLASS, IN NEW BRUNSWICK.

Candidates for Class I should have completed the work laid down for the first eight grades; for Class II, that prescribed for the first seven grades; for Class III., the work of the first six grades.

NOTE.—The Pulse Family is to be included in the work outlined in Chapter II, Section E, along with the Buttercup, Rose, and Lily Families.

PART I.

PRIMARY NATURE LESSONS.

Nature has a message for every little child. God speaks to his heart through the flowers, birds, and butterflies, as well as in the rain, the thunder, and the roar of the ocean. When he enters upon his school life he should not be, though often he virtually is, shut out from this healthy influence. The wise and earnest teacher will take advantage of it as one of the most effective aids in the symmetrical development of the child.

To do this with success, the teacher must not only be a close and sympathetic student of external nature, but of the inner workings, as well, of the child's heart and mind. Teacher and pupil must take each other by the hand—here, the instincts of the child will determine the path to be taken—there, the superior knowledge of the teacher will point the way.

The changing seasons in their round present a constant succession of topics.

SPRING.

The Melting of the Snow and Ice.

The Muddy Streams.

The Swelling of the Buds.

The Awakening and Growth of the Infant Plant in the Seed.

The Rippling of the Brook.
The Spreading of the Grassy Carpet over the Fields.
The Bleating of the Lambs.
The Arrival of the Birds.
The New Leaves upon the Trees.
The Songs of the Birds.
The Buttercup and the Violet.
The Nesting of the Birds.
The Awakening of the Sleeping Insect in the Cocoon.
The Shearing of the Sheep.
The Hatching of the Eggs.
The Croaking of the Frogs.
The Colors of the Flowers.
The Lengthening of the Days.

SUMMER.

The Falling of the Rain.
The Thunder and Lightning.
The Dew on the Grass and Leaves.
The Milking of the Cows.
The Chewing of the Cud.
The Food of the Birds.
The Bees and the Butterflies.
The Ebb and Flow of the Tide.
The Rising and Setting of the Moon.
The Light of the Stars.
The Cutting of the Grass.
The Digging of the Well.
The Food of the Domestic Animals.

AUTUMN.

The Cutting of the Grain.
The Golden-Rod and the Aster.
The Ripening of the Fruit.
The Food of the Caterpillar.
The Whistling of the Wind.
The Waves of the Sea.
The Building of the Cocoon.
The Departure of the Birds.
The Falling of the Leaves.
The Frost on the Grass.
The Shortening of the Days.
The Rising and Setting of the Sun.

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WINTER.

The Falling of the Snow.
The Drifting of the Snow.
The Icicles on the Eaves.
The Frost on the Pane.
Where is the Grass?
Where are the Birds?
Where are the Bees and the Butterflies?
Where are the Leaves?
The Buds on the Trees.

It is not expected that the teacher will take up all or only these subjects. Select a topic some time before the year presents it, and by communion with nature and the children prepare to deal with it in such a manner as will awaken the interest, and arouse and partly satisfy the curiosity of the young pupils. But do not begin by telling them a story or giving them a description of something they have never or scarcely seen. Take them first to *Nature*, that they may see for themselves. Then let them relate the story, or describe what they saw. Each Nature lesson thus becomes the basis of a language lesson.

The story or description may be followed by a discussion of the causes of the phenomena, if any of these should come within the range of the reasoning powers of young children.

Simple songs and poetical extracts, consonant in matter and sentiment with the lessons, should be interspersed. Let the children commit the choicest pieces to memory.

In the second year, the pupils may begin to write little compositions on the lessons, and to make tracings and drawings of plants and flowers which they have pressed and dried.

As an instance of how one of these lessons may be applied, let us take the "Swelling of the Buds" in the Spring. Twigs of the maple, beech, willow, horse-chestnut, or other tree, may be taken into the school, and one placed in the hands of each pupil. Notice the brown coverings of the buds, lead the pupils to see what it is they protect, and how well they are fitted to keep out the cold and moisture. Next notice the soft, downy blankets inside and take them off one by one. What is it they are keeping warm? It is the miniature flower, or branch, or stem, which has been formed the previous summer before the leaf fell, and which has been securely protected from the frosts and storms of winter. "In its case, russet and rude" the tender germ of flower or stem has been folded up "uninjured with inimitable art." Place the twigs in water, and put them where the warmth of the sun may reach them. In a few days the buds will begin to swell; first they will doff their brown waterproofs; next the blankets will be cast off, and the flower or stem within, with its leaves, will begin to unfold itself and grow stronger and larger each day.

PART II.

NATURE LESSONS FOR INTERMEDIATE AND ADVANCED GRADES.

INTRODUCTORY.

The teacher and pupils are about to undertake a series of incursions into their natural environment. They should enter it at the points of easiest access, and occupy and fortify those spots which will afford the best vantage ground from which to extend their conquests. In the following pages an attempt is made to present the work to be done in a natural and logical order.

It is necessary that the teacher should make himself familiar with the ground to be covered, the routes to be taken, and the capabilities of his pupils. He must acquaint himself with the natural features and products of his district, and note those spots which offer the best and most convenient opportunities for observation and study, and for procuring material for work in the schoolroom. He should try the experiments beforehand, so as to be able to direct the pupils in performing them quickly and successfully.

In school, as far as possible, every pupil should perform, or, at least, assist in performing the experiments. It does not at all answer the purpose for them merely to look on while the teacher does the work. They will not take as much interest, and the educational effect will be greatly diminished. This method would reduce the pupils to mere learners at most, instead of training them to be what they ought to be—*doers* as well as *learners.*

Of course, in some of the experiments, as in those with hydrogen, and, generally, in such as require apparatus which cannot be provided for the whole class, it will be necessary for the pupils to content themselves as assistants.

Before the lessons begin, the teacher should form an unalterable resolution that he will not tell the pupils anything which they can find out of themselves with a reasonable expenditure of time and effort. There is but little of fact or of reason necessary to the logical development of the following series of lessons which is beyond the grasp of the average pupil.

Adhere as closely as possible to the "method of discovery." Because their predecessors have forestalled them, is no reason why the children should be prevented from making discoveries for themselves. It is true that under the guidance of the teacher they will be able to make them at an earlier age and with less effort. But that is no argument against it. The caterpillar passes through all the transformations which its progenitors did, and probably with greater ease and in less time on that account, yet it does not omit them.

Not only are the pupils to be allowed and *required* to do their own observing; it is of equal importance that they should be permitted to do their own *reasoning.* If their arguments be inadequate or their conclusions incorrect, the teacher should point out the defects and encourage them to fresh efforts. They will learn many valuable lessons from their mistakes.

But the teacher will probably find it easier to restrain his own propensity for *telling* than that of his pupils. It is of primary importance that the work be conducted in such a manner that the quicker pupils will not tell the slower ones before the latter have had time to reach the results sought. Lessons are often so managed that none but the brighter pupils do any original work. They thus deprive their duller or slower classmates of all the pleasure and all the profit to be gained by independent observation and research.

In many of the experiments which follow, spirit lamps are employed. With ordinary care, no danger is to be apprehended from their use. Nevertheless, the teacher should have a pail of water within easy reach for use in case of an accident through carelessness. Every teacher, of course, understands how to employ a woollen garment as a fire-extinguisher.

If necessary, a thin board or a wooden tray may be used to protect the desk when experimenting with minerals.

Teachers are at liberty to substitute for any of the experiments described herein others of their own devising which will more effectively or more conveniently accomplish the end in view in each case.

In many cases, the results of experiments and observations, and of processes of reasoning, sometimes the processes themselves, are not given herein. These omissions are intended for the benefit of both teachers and pupils—to contribute to the development of the virtue of self-reliance. Another object, however, is to enable inspectors and examiners to discover more easily whether the work has been done in accordance with sound educational principles.

CHAPTER I.

THE INORGANIC WORLD.

SECTION A: COMMON MINERALS DISTINGUISHED BY THEIR PROPERTIES.

During the summer and autumn the teacher should collect a good stock of the commoner minerals—quartz, feldspar, mica, hornblende, limestone, gypsum, limonite, hematite, magnetite, pyrite, siderite (clay iron-stone), manganese ore, and graphite. Several varieties of each species should be secured if possible, and enough in every case to supply a whole class. White and colored varieties of quartz can be found anywhere. Bits of rock crystal are not uncommon. Mica and the natural chalk can be got at a hardware store. Common limestone is generally within reach. Chippings of marble may be picked up at marble works. Limestone rocks usually contain transparent crystalline varieties. Clear crystallized gypsum (selenite) is of frequent occurrence in the plaster rock. The glacial boulders scattered over the country will often furnish specimens of minerals from distant localities. These boulders yield the best specimens of granite, as they show the difference between the weathered and the unweathered surfaces. Teachers can readily exchange minerals from their several localities. The Inspectors will often be able to assist in these transfers.

But it will probably be found necessary to make some purchases. Although the iron ores are almost universally

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distributed in small particles in the soil and rocks, good specimens for class work are not to be found in many localities. Feldspar, although pieces of suitable size may sometimes be got out of granite rocks, will usually have to be brought from a distance.

The earnest teacher will find little difficulty in securing an adequate stock of all the minerals before mentioned.

If the school possesses no suitable cabinet the teacher and pupils should make, or cause to be made, a few wooden trays to hold the minerals. These trays may be packed in a large trunk. The cost of the required chemicals and apparatus will be trifling. Commercial hydrochloric (muriatic) acid may be obtained from a druggist at ten cents or less per pound. A little aqua ammoniæ will also be useful. These should be kept in glass stoppered bottles. Supply each desk with a small bottle for holding the acid, which, if strong, may be diluted with water. An ordinary cork will suffice for these small bottles. Pieces of glass tubing 2 or 3 inches long and about ¼ inch in diameter may be used for extracting the acid when needed to apply to a mineral. Show the pupils the effect of the acid on the skin and on cloth that they may exercise due care in its use. Place on each desk a spirit lamp, a piece of litmus paper, two slips of window glass, two test tubes, a cup of water, two pieces of small flexible brass wire each about 14 inches long.

The pupils should also have knives or files for trying the hardness and streak of minerals.

A pint of alcohol will last the lamps for a good while.

Some litmus powder for coloring white paper will be found convenient.

The teacher should have a good magnet with which to magnetize the blades of the pupils' knives.

Two small boxes will be needed for each desk, one to hold the minerals, the other the apparatus for two pupils.

It will be best to begin with two common minerals which differ widely. The contrasts brought out in the comparison will help to fix the properties of both in the mind. Let us select white quartz, and gray, reddish, or black limestone. Ask the pupils first to find which of the minerals will scratch the other, using a corner of each. When they have noticed that there is a very white mark left on each when rubbed by the other, but that only one of them makes a scratch in the other, ask them to account for these facts. The one which scratches the other is the *harder*, and the one which is scratched the *softer*. They will find that the white streak in both cases is the color of the powder of the *softer* mineral, although the mineral, in the mass, may be black. Tell them that the *color* of the powder of a mineral is called its *streak*. The streak of the harder mineral may be obtained by scratching one piece of it with another piece, or by breaking a piece of it into powder with a hammer. Let them now try to scratch a piece of glass with each mineral. They will succeed with the harder one only, and will infer that this one is harder than the glass, the other softer. Similarly, they will find that one of them is harder than ordinary

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steel, while the other is much softer. The teacher may now inform them that the hardness of minerals is expressed in degrees from one to ten, and that the hardness of the harder mineral is seven degrees; also, that any substance as hard or harder than that is regarded as *very hard.* The hardness of the softer mineral will not be more than three or four degrees.

Direct each pupil in making a coil at the end of a piece of rather fine brass wire, by winding one end of it around a lead pencil. Show them how to close the ends of the coil by bending the wire over them. About five inches of the wire should remain for use as a handle. This coil will be found indispensable in heating minerals. Before the lesson begins, thin slivers, for this purpose, should be prepared by carefully breaking up a piece of the mineral with a hammer. The smaller and thinner the slivers are the better. Each pupil will open a coil of wire slightly, at one side, insert a sliver of the soft mineral, squeeze the turns of wire together again, and steadily heat the mineral for about five minutes in the hottest part of the flame of the spirit lamp. Note the visible effect of the heat upon the specimen.

When placed on red litmus paper and dampened it will turn the paper blue.

Treat the hard mineral in the same manner and notice whether the heat produces the same physical effect upon it. It will not when dampened turn red litmus blue. It will also be found that if either mineral be dampened without being heated, it will not affect the color of the reddened paper.

The pupils will now apply a drop of hydrochloric acid to each mineral. Bubbles will form on the softer one, but not on the other. Teach them to use the term *effervescence* for this effect. Put the minerals into the cup of water to wash off the acid, and leave them there for a while. It will be seen that they are not soluble in water, at least not perceptibly so.

Let the pupils hold their magnets, or magnetized knife blades, near small pieces of the minerals. If they are attracted by the magnet, they are said to be *magnetic;* otherwise they are *unmagnetic.*

Note the color, lustre, transparency or opacity, etc., of both minerals.

The teacher should now, but not before, give the names of the minerals.

Require the pupils to write careful notes on their lessons. At least, they should exhibit in tabular form the results of their examination of each mineral. These tables may be used afterward as standards for identifying specimens found by the pupils in their excursions. The following is a convenient order for tabulating results:

1. Hardness.
2. Streak.
3. Effect of heat.
4. Effect of acid.
5. Effect of water.
6. Effect of magnet.
7. Crystallization.
8. Color, lustre, etc.

In recording hardness, any mineral which can be scratched with the finger nail may be set down as *very soft.* One which cannot be scratched with the nail, but is easily scratched with the knife, is *soft.* One which can be scratched by the knife, but with difficulty, is *hard.* If it cannot be scratched distinctly with the knife, but yields to quartz, it is *very hard.*

Marble, chalk, and other varieties of limestone (carbonate of lime, calcite) should next be examined in the manner described, and compared closely with one another and with quartz. Marble shows little glistening surfaces when broken. Chalk is much softer than the others— hardness about 1 degree. But they are all soft; they all have a white streak; they all effervesce when treated with the acid; they all become white and crumbly when heated; the heated product, when dampened, always turns red litmus blue.

The pupils are now prepared to believe that these are all varieties of the same mineral, limestone or calcite. They may be told that the lustreless white substance obtained by heating them is lime, whence comes the name limestone. They will be able to tell, or to find out by inquiry, how lime is made on the large scale, and will be led to see that the method is really the same as that which they employed.

The examination of the principal varieties of quartz is next in order. They will all be found to be very hard, unaffected by the heat or acid, and insoluble in water. They differ much in color, as do the varieties of limestone. The pupils will already begin to see that minerals cannot be distinguished by their colors.

Before leaving these two minerals their crystals should be compared. It will be found that calcite crystals will split along smooth surfaces running in definite directions. These crystals are, therefore, said to possess *cleavage*, and the surfaces along which they split are called planes of cleavage. Their edges are indicated by lines running across the faces of the crystals. No such planes can be found in the crystals of quartz, although lines of *fracture*, where the crystals have begun to crack, may sometimes be mistaken for the edges of cleavage planes. Quartz crystals are devoid of true cleavage. They are terminated by six-sided pyramids, that is, they have six triangular faces on the end. Calcite crystals vary greatly in form, and some of them look remarkably like crystals of quartz. But their softness, as well as cleavage, and their effervescence when treated with acid, at once distinguish them from quartz.

It will be interesting and instructive for the pupils to prepare crystals of some substances which are soluble in water. For instance, let them, at home, make strong solutions of common salt and alum, hang a thread or two in each, and set them away where they will be undisturbed. In a day or two, if the crystals which form are very small, the threads may be hung in another solution that the crystals may grow. Note carefully the difference in form between the crystals of common salt and alum.

The pupils may be led to see that if they could dissolve the massive (uncrystallized) pieces of quartz and limestone they might obtain quartz and calcite crystals. They will also infer that the crystallized forms of these minerals must have been liquefied, or at least softened, in some way, before they crystallized.

The class should now be able to proceed with the examination of the other minerals with but little direction from the teacher.

For class use, the larger specimens may be broken up into pieces about as large as plums. In studying different varieties of the same mineral, note carefully those properties which are common to them all, as these are the only ones essential to their determination. A few notes on the remaining minerals in our list are given here for the benefit of the teacher.

One of the most abundant of minerals is common feldspar (orthoclase). Although hard (6 degrees), it can be scratched by quartz. It has cleavage planes running in two directions. With care, specimens can be found which will show the intersection of two of these glistening planes. They make a right angle with one another. Note the various colors of the specimens. Enumerate the observable differences between feldspar and quartz — between feldspar and calcite.

Mica and transparent crystalline gypsum (selenite) may well be studied together. They are soft minerals. Selenite can easily be scratched with the finger nail. Its hardness is 2 degrees. Mica, black or white, is little, sometimes not any, harder. In heating the mica a few little bits should be placed in a small test tube kept closed by the finger. The tube may be held by a wooden holder, similar in form and size to a clothes-pin, cut out a little near the end to receive the tube. After heating the mica, heat a piece of selenite in the same manner. In one case the mineral will withstand the heat without apparent change; but in the other, it will be converted into a soft, white, lustreless powder, while drops of water from it will settle on the sides of the tube. It will also be found that although both minerals cleave into thin sheets, that those of one of them are brittle and of the other elastic. Give the names of the minerals after the pupils have discovered that they differ from one another and from any mineral previously examined. Then tell them that the white powdery substance in the bottom of the tube is calcined plaster of Paris.

Hornblende so frequently replaces mica in rocks that they should be studied in connection with each other. The greater hardness and heaviness of hornblende, and its lack of elasticity, will distinguish it from mica. Asbestos is a variety of hornblende.

Study limonite, hematite, and magnetite together. They are hard minerals — in their compact form — although limonite is not as hard as the others usually are. It must be observed, however, that these as well as other hard minerals seem very soft when reduced to a fine powder, or when they occur naturally in a fine state of division. The streak of limonite is yellow, of hematite red, of magnetite black. It will be found that although the magnet will not attract the first, and the second only rarely, it has a strong attraction for magnetite. Heat a bit of hematite and another of magnetite in the same closed tube. Then replace them by a small bit of limonite. One of them yields water. When small pieces of limonite and hematite are strongly heated in the wire coil, they will become magnetic, and their streak will be changed.

Pyrite resembles gold in color, but its hardness, nearly equal to that of quartz, and its brittleness, distinguish it from that mineral. Notice the beautiful effect produced when a lump of pyrite is briskly struck with a file. Try to get the same effect in the case of feldspar, quartz, and calcite. When a little powdered pyrite is heated in the closed tube, a yellow deposit appears on the sides of the tube above the mineral. The color, and the sulphurous smell which may be perceived on holding the tube near the nose, indicate that this deposit is sulphur.

Submit these and the remaining minerals—siderite, common manganese ore (pyrolusite), graphite, and rock salt—to all the tests which were applied to calcite and quartz, carefully recording results.

If specimens of manganese ore cannot be obtained, the powdered black oxide of manganese may be examined instead. Note the properties which distinguish it from magnetite. Upon testing the black lead of their pencils, the pupils will conclude that it is the same as graphite. They should find out why, although it contains no lead, it is called black *lead.*

Rock salt will be found to differ from any mineral studied before in being soluble in water. Find, by submitting common salt to the same tests, whether it is the same as rock salt. Also observe the effect which this mineral, while being heated in the wire coil, has upon the color of the flame of the spirit lamp.

Let the pupils review all the minerals which have been examined, repeating any of the tests whose results have been forgotten. Then the teacher should hold an examination. Supply each pupil with a box or envelope containing specimens of the various minerals, including varieties which differ somewhat from those which were used in the lessons. The pupil will identify the specimens, wrap each in a piece of paper, write the name of the mineral on the paper, and state clearly in writing the considerations which enabled him to reach a decision in each case. He should of course be allowed the use of sufficient apparatus.

Lastly, require every member of the class to make a collection, correctly labelled, of all the known minerals to be found in the neighbourhood.

SECTION B: THE ELEMENTARY COMPOSITION OF COMMON MINERALS, AND SOME PROPERTIES OF THEIR ELEMENTS.

Fit a cork, through which the stem of a funnel passes, into a bottle of air. Pour water into the funnel. If the apparatus has been fitted tightly, the water will not run through the tube into the bottle until the cork has been loosened. The air is said to occupy the space in the bottle because it excludes the water until it escapes itself. It will at once be seen that the water, the glass, and the cork possess the same property displayed by the air. Agree to call anything which thus occupies space by the name of *matter*. Give other examples of matter.

A separate portion of matter is called a *body*. The amount of space included within the limits of a body is called its *volume*. The amount of matter in a body is called its *mass*.

Fill a test tube with colored water—red ink will answer for coloring—and close it with a cork which has a glass tube, of small bore, several inches long, tightly fitted through it. The water will rise for some distance up the tube in forcing in the cork. Hold the tube slantingly, and warm it along the side with a spirit lamp, but do not boil the water. The water will gradually expand till it fills the small tube. Without increasing the amount of water—its *mass*—we have increased its *volume*. On cooling the water, it will contract to its original volume. Explain these results.

Probably the most satisfactory explanation to be found will be that the water is made up of extremely minute particles of water which were driven farther apart by the heat, thus causing the water to rise in the tube to find more space. As the water lost the heat which had expanded it, the particles came as closely together again as they had been at first. The invisible particles which were driven apart by the heat are called *molecules*.

The force which enables molecules to cling to each other until a greater force separates them is called *cohesion*. If the molecules which attract each other belong to different bodies, as when water sticks to glass, this force is usually called *adhesion*.

Heat a little ice, until it liquefies, in a test tube. Fill one end of a double egg-cup with a mixture of snow and salt. Boil the water in the test tube. A visible vapour will appear at the mouth. Hold the egg-cup so that its empty half will receive this vapour. Water will collect on the inside of the cup, and fall in drops into a dish set below. Continue till the water in the tube has disappeared. Pour the water out of the dish into another test tube and push it down into a deep dish filled with a mixture consisting of salt with about twice its weight of snow or pounded ice. In a minute or two, the water will be converted into ice again. It will be concluded that there must have been water in an invisible state in the bubbles while the water was boiling, and that when they rose and burst this invisible water filled the upper part of the tube; and further that the loss of heat transformed this invisible water into visible drops. Water in the invisible form is called *steam*.

The water existed in three different states: First in the *solid* state (ice), then in the *liquid* state, next in the *gaseous* state (steam). Although it is usually called water only in the liquid state we must infer that it is the same substance throughout these changes—that it is composed of molecules of water throughout all its changes. The heat loosens the molecules from each other in changing ice into water; drives them apart in changing liquid water into steam; while loss of heat results in the molecules returning to their original arrangement.

Picture out for yourself a brook as it would appear if its molecules were magnified to the size of peas. Describe your picture.

The change of a solid into a liquid is called *liquefaction* or fusion; of a liquid into a gas, *evaporation;* of a gas into a liquid, *condensation;* of a liquid into a solid, *solidification.* Evaporation and condensation constitute *distillation.* The experiments just described illustrate all these processes. The water which fell into the dish was *distilled water.* Distil some water containing salt in solution, and account for the difference in taste between the distilled water and the solution.

Fill a bottle having a small neck with water. Cork it tightly and set it out of doors on a cold winter night. Account for the effect upon the bottle. Does the ice differ from the water which froze in weight or in volume, or in both? Account for the floating of ice upon water.

Examine a thermometer, and study its action. Learn the freezing and boiling points. What temperature is meant by "blood heat?"

Drop two or three crystals of chlorate of potash into a test tube containing a little water. When the crystals have dissolved compare the taste of the solution with that of chlorate of potash. You will infer that the water simply loosened the molecules of chlorate of potash, and that they are now mixed with those of the water throughout. To establish this evaporate the water. What substance remains in the bottom of the tube?

Put a small teaspoonful of chlorate of potash into a test tube, followed by one-fifth of its bulk of dry black oxide of manganese, and shake them till thoroughly mixed.

Cut off a piece of glass tubing, $\frac{1}{4}$ inch bore, with the aid of a file; heat it two inches from the end in the flame of the spirit lamp, and when soft enough bend it slightly at that point. Round the sharp edges of the ends by holding them in the outside of the flame until they become red hot. Select a good cork which will fit the test tube tightly when half way in; with a round file make a hole through it, into which fit the end of the glass tube which is farther from the bend. Fill with water a pickle bottle and two smaller bottles with wide mouths, and invert them in a pan of water or a pneumatic trough. Insert the cork tightly into the test tube by *twisting* it in, and connect the bent glass delivery tube with a piece of rubber tubing of fitting size. While one pupil heats the mixture in the tube with the spirit lamp, let another collect in the bottles over water the gas which escapes. As the smaller bottles fill, remove them, mouth down, in a dish. Leave some water in the dish so that the gas cannot mingle with the air. Take away the tube before the pickle bottle is quite full of the gas. Note the large volume of gas obtained from the small amount of solid matter.

Twist one end of a piece of flexible brass wire around a small piece of soft charcoal. Push a piece of glass under the mouth of one of the small bottles of gas, and keeping the glass pressed against its mouth, turn the bottle up. Heat the charcoal until it begins to glow and plunge it into the gas. The effect at first will be very brilliant, but soon the charcoal will cease to burn. Remove the wire and close the bottle quickly with a damp slip of glass.

Invert in the same way another bottle of the gas; pour a little lime-water into it, cover its mouth with the hand and shake the lime-water through the gas. (For the method of preparing lime-water see page 39.) Now pour lime-water into the gas in which the charcoal was burned. Note the difference in the visible effects.

Take a coil of fine iron wire, having a thread which has been dipped in sulphur attached to the lower end, and fastened to a piece of card-board at the upper end; ignite the sulphur with a match, and then lower the wire into the gas in the pickle bottle. The wire should burn with brilliant sparks.

The teacher may now tell the pupils that this gas, in which charcoal and iron burn, is called *oxygen*. They will infer that the gas remaining in the bottle after the charcoal ceased to burn, which would not allow the remainder of the charcoal to burn, and which had such a remarkable effect on the lime-water, must be a different gas from oxygen.

The question now is to find what the oxygen came out of.

Fill with water the test tube containing the residue of the mixture from which oxygen was obtained. In a few hours pour the contents into a filter paper fitted into a funnel. The *filtrate*, i. e., the liquid which passes through the filter paper, will be found to have a saline taste, showing that something from the tube is dissolved in it. Pour enough of it into a flat dish to cover the bottom to a depth of ¼ of an inch. Set the solution in a warm place where it will be undisturbed, and with it a solution of chlorate of potash in a similar dish.

In a day or two, the water in both dishes will have evaporated. The chlorate of potash and the substance which gave taste to the filtrate will then be found crystallized on the bottom of the dishes. But the crystals will differ distinctly in form.

In the filter when dry will be found an insoluble black powder exactly like the black oxide of manganese which was mixed with the chlorate of potash. (To show that this powder is the same as at first it may be used a second time in the preparation of oxygen.) Draw the logical conclusion as to the source from which the oxygen came.

The pupils will now see that chlorate of potash must be made up of oxygen and the saline substance from the filtrate which is now crystallized in the dish. They must also conclude that a little oxygen is present in every molecule of chlorate of potash, and hence that the heat broke up these molecules, and drove the oxygen out of them. The crystals from the filtrate must be made up of molecules which differ from the molecules of chlorate of potash in containing less oxygen or none.

Since the molecules of chlorate of potash contain more than one substance, it is called a *compound substance;* but oxygen, since no one has been able to break it up into two different substances, is called a *simple substance* or chemical *element.* The molecules of the saline substance remaining after the oxygen has been driven out of the chlorate of potash have been found to consist of two elements, potassium and chlorine, which the pupils have not seen. Molecules, then, can be broken up into smaller parts. Each of the indivisible parts of a molecule is called an *atom.* (Gr. *a*, not; *temno*, I cut.) The force which brings and binds together the atoms of a molecule is called *chemical affinity.*

The *chemical names* of compound substances depend upon the elements of which they are made up. The names of compounds consisting of two elements, i. e. binary compounds, are distinguished by the affix *ide;* the names of those which contain three elements, called *ternary* compounds, take the affix *ate.* Since these ternary compounds usually contain oxygen, *ate* may be taken to indicate the presence of that element. Since chlorate of potash consists of potassium, chlorine, and oxygen, it may also be called *potassium chlorate;* while the binary compound, left with the oxide of manganese after the oxygen is expelled, is called *potassium chloride.*

Our next undertaking is to find what gas, so different from oxygen in its properties, remained in the bottle after the charcoal ceased to burn.

Pure charcoal is a simple substance—it is the element *carbon.* Now, since oxygen is also an element, the new gas could not have been formed by either of them breaking up. The conclusion is that this gas must be a compound substance formed by the *union* of carbon and oxygen. Its molecule has been found to consist of one atom of carbon and two atoms of oxygen. Its exact chemical name is *carbon dioxide*, but it is commonly called *carbonic acid gas.*

Just as the charcoal in burning was uniting with the oxygen around it, so, we must think, the iron in burning was combining with oxygen. As fast as this oxide of iron was produced, it was seen dropping through the water to the bottom of the pickle bottle, where it may yet be found in the form of solid black globules. This is the *black oxide of iron.* Since it is attractable by the magnet, it is also called *magnetic iron oxide.*

Shake up some lime-water in a bottle of air. Then burn the charred end of a stick in the air above the lime-water. In a minute or two, cover the mouth of the bottle tightly with the hand, and shake again. If properly done, the same effect will be produced on the lime-water as when it was shaken in carbon dioxide.

The pupils will infer that the charcoal must have been uniting with oxygen while burning in the air, and further, that there must therefore be oxygen in the air.

Hold a piece of sulphur near the nose, no smell is perceptible. Ignite the sulphur in an iron spoon; a strong smell is observable. Account for this.

It will be concluded that when substances burn in the air, they are uniting with the oxygen present there, and forming oxides, i. e. undergoing *oxidation*, just as they do when burning in pure oxygen.

Arrange on the desks, in boxes or dishes, specimens of the commoner solid *elements*, such as iron, sulphur, carbon, tin, zinc, copper, aluminum, and lead. Explain that none of these substances have ever been decomposed. Guide the pupils in comparing them in color, lustre, hardness, malleability, fusibility, etc.

Make a smooth ball from the dry pith of the stalk of the elder or the sunflower. Suspend it by a silk thread from some support. Hold a piece of amber or a rubber comb near it. No visible action takes place.

Rub the comb or amber with a piece of flannel. Bring it near the ball. The ball is at first attracted, and then repelled. Bring the rubbed side of the flannel near the ball which the comb or amber repels. It is now attracted.

The new power developed in these bodies by the friction is called *electricity*—that of the amber and comb, and of the ball which they touched *negative* electricity—that of the flannel rubber, *positive* electricity.

Rub a glass rod with silk. It will then attract a ball which a rubbed comb will repel, but the rubbed side of the silk will attract a ball which the glass repels. Was the glass positively electrified, or negatively?—the silk?

Electrify a pith-ball negatively by touching it with a rubbed comb. The comb then repels it. Touch the ball with the finger; the ball will then attract it. Electrify a ball positively and proceed in the same manner. Explain the facts.

The finger is said to *conduct* the electricity from the balls. Try pieces of unrubbed sealing wax and rubber. They leave the ball in the same electrical state as before they touched it. They are *bad conductors* of electricity.

Try the solid elements under examination, and classify them as good or bad conductors of electricity. Pulverize a little of each of them, and bring electrified bodies near the powder. Record the effect.

Hold the ends of a glass rod, or tube, and of a copper wire of about the same diameter in the flame so that the heat comes equally upon them. They should be grasped by the fingers at equal distances from the flame. Drop the one which first becomes uncomfortably hot, and continue to hold the other as long as prudence permits. Account for the difference. The one is said to be a *good*, the other a *bad* conductor of heat. By the aid of similar experiments, classify the elements on the desk as good or bad conductors of heat.

It will be found that those which are good conductors of electricity are also good conductors of heat, and that, although they differ in color, they all have the same kind of lustre. These elements are called *metals*, and their lustre the *metallic* lustre. The other elements before us are called *non-metals*. Oxygen, then, is a non-metal. Classify mercury as a metal or a non-metal.

Bring a magnet, first one end of it and then the other, near the powder of each of the elements on the desk. The powder may be conveniently placed on a slip of glass. Note the effect and explain it as far as you can. Classify such as are attractable by the magnet, as *magnetic* substances, the others as *unmagnetic*.

Hold a piece of each element above the desk and then take the hand away. They all move toward the earth. Call attention to the fact that they would move toward the earth if dropped twelve hours later, although the direction would be contrary. Account for this as far as you can.

The power by which the earth attracts bodies is called the force of *gravity*. The *amount* of force with which the earth attracts a body is called its *weight*.

Find the weight of a bottle of water. Fill the same bottle with kerosene oil and find its weight. Also find the weight of the same bottle full of sand. Deduct the weight of the bottle in each case. We now have the weights of equal volumes of the three substances. Divide the weight of the oil and the sand respectively by the weight of the water. The one quotient is called the *specific gravity* of the oil, the other of the sand. The water used as the standard should be artificially distilled, but rain-water will answer the purpose.

Collect two bottles of oxygen by the method before described. Prepare carbon dioxide in one of them by burning a piece of charcoal in the oxygen. Shake a *little* water through the gas, keeping the hand closely pressed upon the mouth of the bottle.

Twist one end of a wire around a piece of crayon, and ignite a piece of sulphur placed in a cavity at the end of the crayon. Lower the burning sulphur into the remaining bottle of oxygen. As soon as active combustion ceases, remove the crayon, and pour a small quantity of water in with the strong-smelling gaseous oxide of sulphur (sulphur dioxide), and shake thoroughly as described before. The liquid now in the bottle in which the sulphur was burned will have a distinctly sour taste, that in which the carbon was burned should be very slightly sour.

Dip blue litmus paper, or pour a solution of blue litmus powder, into each bottle. The color will be changed to red in both cases.

These substances with the sour taste which turned blue litmus red are called *acids*. Each of them is composed of an oxide united with water. The one which is made up of carbon dioxide and water is named *carbonic acid*, and the other for a similar reason is named *sulphurous acid*. There is another acid consisting of the elements of *sulphur trioxide* and of water, which is called *sulphuric acid*. The affix *ic* here denotes a greater amount of oxygen than *ous* does.

Examine a piece of magnesium wire or ribbon. Note its lustre and find whether it is a good conductor of heat and electricity. You will conclude that it is a metal. Ignite it with a match or in the flame of the lamp. The white product, which might be mistaken for ash, is *magnesium oxide*. Dampen this oxide with a little water on a piece of red litmus paper. Note the effect on the litmus.

This substance changes the color of litmus, which has been reddened by an acid, back to blue, and is called a *base*. It is composed of the elements of magnesium oxide and of water. Why did we not get an acid as we did when the oxides of carbon and sulphur were mixed with water? The difference must be due to the fact that the element we began with in the last case is a metal, whereas carbon and sulphur are non-metals. Notice that the acids contain a non-metal other than oxygen, while the base contains a metal.

Make a weak solution of hydrochloric acid in water. Note its taste and its effect on litmus. Put granulated zinc, or little pieces of sheet zinc bent so that they do not lie too closely together, into an ignition tube or large test tube until the metal occupies nearly one-third of the tube. Fill the spaces between the pieces with water. Make arrangements for collecting two bottles of gas, as in the preparation of oxygen. Pour hydrochloric acid into the tube until the liquid reaches half an inch above the metal. An active effervescence should set in at once. Insert a cork, with delivery tube, and collect two small *wide-mouthed* bottles full of the gas.

Should the gas cease to flow before the bottles are filled, or at any time before the completion of the experiments upon it, the cork may be taken out of the tube, part of the liquid poured off the zinc, and more acid added.

Take the rubber delivery tube out of the water, and hold it upward in the mouth of a *small wide-mouthed* bottle or thick tumbler held mouth downward in the air. In about a minute remove the bottle from the tube, and while its mouth is still turned downward, plunge a lighted match up into it. The gas will burn, probably with a slight explosion. If the bottle be turned up as soon as the match enters the gas, the flame may be seen. Hold the tube for a longer time in the mouth of the bottle; the gas, when ignited, will burn quietly, showing that the explosion was due to the combustible gas being mixed with air. This combustible gas is called hydrogen.

What was really happening when the hydrogen was burning? The presumption is that it was uniting with the oxygen of the air. Let us try to find what its oxide is like.

Insert a piece of glass tubing, drawn out at one end till the bore is quite small, into the free end of the rubber tube. Ignite the gas as it issues from the smaller end of the tube. Hold the flame in the mouth of a clean dry bottle held mouth downward. A colorless liquid will collect like dew on the inside of the bottle. This liquid condenses just as water does, and upon examination it will be found to be really water. Water, then, is a compound substance consisting of hydrogen and oxygen. It is an oxide of hydrogen, and may be called *hydric oxide.*

Turn the mouth of one of the bottles of hydrogen first collected, up under the mouth of a smaller wide-mouthed bottle full of air. It will be found on applying a match to the mouth of the smaller bottle that the hydrogen has risen through the air and displaced it. Account for the fact.

Raise the other bottle of hydrogen, pass a lighted taper or candle up into it for a short distance, and steadily lower it again until well out of the bottle. The candle flame will be extinguished as soon as it enters the hydrogen, but will take fire again in coming out. This may be repeated several times with the same bottle of hydrogen. Explain the observed facts.

We must now find whence the hydrogen came. Being a simple substance, it could not have been formed by the union of other substances. No gas was evolved when we mixed hydrochloric acid with water, nor when we put water on zinc. The hydrogen, then, resulted from the zinc coming in contact with the acid. Hence, since zinc is a simple substance, the hydrogen must have come out of the acid.

But the zinc, although insoluble in water, has been disappearing. What is becoming of it? The only explanation we can find is that it takes the place in the acid which had been occupied by the hydrogen, uniting with that part of the acid with which the hydrogen had been united, and thus setting the hydrogen free.

Hydrochloric acid, or hydric chloride, as it may be called, is known to be a compound of hydrogen and chlorine. If our explanation is correct, there should be a compound of zinc and chlorine in the tube. We cannot see any new substance there, but we may taste it by touching the water in which it is dissolved to the tongue. When the water is evaporated we obtain it in the solid state. This newly-formed compound—*zinc chloride*—is called a salt.

Zinc is not the only metal which has the power of taking the place of the hydrogen of an acid. Try iron filings instead of zinc with hydrochloric acid. What salt can be tasted in the water?

Since these two salts are obtained by the aid of hydrochloric acid, differing from it in composition only in containing a metal instead of hydrogen, they are called salts of hydrochloric acid. From the metals they contain, the one may be called a salt of iron, the other a zinc salt.

Care should be taken in experimenting with hydrogen to use only small quantities and wide-mouthed bottles. There is then no danger from the slight explosions which may occur on account of an admixture of air.

Dissolve a little caustic soda in water. Taste the solution, and test it with litmus paper. Caustic soda is a soluble base, and like other bases must contain a metal or its equivalent. The metal in caustic soda is called sodium.

Mix hydrochloric acid with the solution of caustic soda until the mixture has neither a pungent nor a sour taste, and will neither turn blue litmus paper red nor red to blue, i. e., until it is *neutral* to litmus.

There is now dissolved in the water a substance which tastes like common salt. To make sure that it is salt, set aside some of the solution in a flat dish until the water has evaporated. The taste of the residue and the form of its crystals will leave no doubt that it is common salt. But no salt was put into the mixture. How shall we account for its production? We recollect that in the preparation of hydrogen the metals used took the place of the hydrogen in the acid. The conclusion is that in this case the metal sodium of the base acted in the same way—that it replaced the hydrogen in the acid, forming by its union with chlorine another salt, sodium chloride. If this reasoning be correct, we have discovered the composition of common salt, and know its chemical name.

Taste a weak solution of aqua ammoniæ, and test it with litmus paper. You will conclude that it is a base.

Make a mixture of the base aqua ammoniæ with hydrochloric acid. When the solution has been made neutral to litmus, put a few drops of it on a slip of glass and hold the glass slantingly. As the water evaporates, crystals will form on the glass. These are the crystals of another salt, ammonium chloride, often called sal ammoniac.

Why is not the displaced hydrogen set free when a base and an acid are mixed as well as when a metal and an acid are brought in contact with one another?

Let us now try to find out, as far as our means will permit, the composition of the minerals we examined some time ago.

We have learned that heat tends to break up compounds, and that when some substances are treated with acids, chemical changes set in. Let us take advantage of these facts in endeavoring to find the composition of limestone.

Put a small handful of bits of marble, chalk, or ordinary limestone into a bottle. The bottle should have a mouth large enough to receive a cork, with two tubes through it—a small one, reaching only through the cork, to be connected with a rubber delivery tube, and a larger one, through which, by means of a funnel, acid is to be poured. This tube should reach down nearly to the limestone in the bottle. Pour water down the larger tube until it covers the limestone and reaches a short distance up the tube.

Add enough hydrochloric acid to produce a lively effervescence, and collect over water a bottle of the gas which is evolved. Then put the end of the delivery tube into the mouth of a bottle of air standing mouth upward. Add acid whenever necessary to keep up effervescence in the generating bottle. In two or three minutes, the flame of a burning match will be promptly extinguished when held in the mouth of the receiving bottle, but the gas itself does not take fire. This gas then is neither combustible nor a supporter of ordinary combustion. What does the fact that it sank through and replaced the air show?

Empty it upon a candle flame. Account for the result?

Leave an open bottle of this heavy gas sitting on the table for a short time. Then plunge a lighted match into it. If the flame be extinguished, try again a few minutes later. Explain the result.

Push a glass slip under the mouth of the first bottle, turn its mouth upward, pour in lime-water, and shake the gas and lime-water together. This gas produces the same visible effect upon lime-water that carbon dioxide did. Since it resembles carbon dioxide in being incombustible and a non-supporter of combustion, we conclude with certainty that it is the same gas which we obtained by burning charcoal in oxygen.

Whence did the carbon dioxide come? Since neither the water nor the acid put into the generating bottle contain its elements, the inference is that it came out of the limestone.

Repeat the experiment of heating a thin slice of limestone in a wire coil, and dampen the residue on red litmus paper. It acts like a base, and has a pungent taste.

How shall we account for the formation of this base? We prepared our first base by treating the oxide of a metal with water. Our explanation, then, is that the residue which remains after heating the calcite is the oxide of a metal. It is evidently not a metal, as it does not possess metallic lustre or the other distinctive properties of metals. This oxide is called *quicklime*, or simply *lime*. And lime has been found to consist of oxygen and a beautiful metal called calcium; hence, lime may be called *calcium oxide*.

On each desk place a small lump of lime. Since it is the oxide of a metal, with water it should form a base. Let us try it. Slowly pour upon the lime as much water as it will absorb, turning it over as this is done. Curiously enough, the cold water seems to make it hot. Light a match in the crumbling mass. The lime is now said to be *water-slaked*. Rub some of it on dampened red litmus paper. It acts like a base. Taste it.

Put the water-slaked lime, or caustic lime, as it is called, into large bottles, until each is about one-third full. Fill them up with water, and shake. When the water has become clear again, try red litmus paper in it. The effect will convince you that a part of the caustic lime has been dissolved in the water. This solution of caustic lime in water is called *lime-water*. Cork the bottles and set them aside.

Put a larger lump of unslaked lime in one pan of a balance, and weights enough to equal it in the other pan. Slake this lump of lime in a dish, and when the resulting caustic lime has become cool and perfectly dry, put it into the same pan of the balance in which it was before it was slaked. Does it weigh more or less than the original lime? You will be forced to conclude that, although the lime is perfectly dry, the increase in weight must be due to the water having united with the lime. This is another example of chemical union.

The heat which was evolved while the lime was being slaked was doubtless due to the coming together of the atoms.

The base, caustic lime, consists, then, of the metal calcium, hydrogen, and oxygen, and may be called calcium hydrate.

We have found that the lime which remains after heating limestone contains a metal (calcium, we were told) and oxygen. We had previously found that limestone contains carbon dioxide. Therefore limestone must contain the elements of both lime and carbon dioxide, viz., calcium, carbon, and oxygen. We see now what happens to calcite when it is heated, and why chemists call it *carbonate of lime* or *calcium carbonate.*

Call attention to the fact that although limestone contains the black element carbon yet, when pure, it is either colorless or white.

Since magnetite is attractable by the magnet, we may be quite sure that it contains iron. Its hardness, blackness, and brittleness show that it is not pure iron.

We remember that it resembles the black globules of oxide of iron which were produced by burning iron wire in oxygen, and, indeed, the composition is the same.

Heat a thin fragment of hematite in a wire coil. It becomes dark and magnetic like magnetite. Hematite is evidently another oxide of iron. It is called from the color of its powder *red oxide of iron.*

Heat some grains of limonite in a closed tube. It yields water and becomes reddish. Heat a slice of it more strongly in a wire coil. It becomes dark and magnetic. We must think that limonite is a compound of red oxide of iron with water. From its yellow streak it is called *yellow oxide of iron.*

Heat powdered pyrite in a closed tube. A yellow deposit appears on the inside of the tube. Open the tube and continue heating. What do you now smell? What was the yellow solid which was at first deposited? Heat a bit of pyrite in a wire coil. It becomes magnetic. What have we established concerning its composition? Its chemical name is *sulphide of iron.*

Heat a slice of clay iron stone (impure siderite) in a wire coil, and test the residue with the magnet.

Put a teaspoonful of fragments of siderite into a test tube. Cover with water, add hydrochloric acid, and insert a cork fitted with a delivery tube. Apply heat, and pass, by means of a rubber tube, the gas which is evolved into lime-water.

Account for the effect. Infer the composition of siderite. What is its chemical name?

Heat gypsum in a closed tube until the water is expelled. The residue can be shown to consist of the metal calcium — the metal of which lime is the oxide — together with sulphur and oxygen. Hence, gypsum is known as hydrous (Gr. *hudor*, water) calcium sulphate or sulphate of lime. We have not the means, however, to demonstrate its composition.

These are the only minerals we have studied yet which hydrochloric acid, or the heat of the spirit lamp without a blow-pipe, will readily decompose. It will be interesting to know, however, some things which have been found out about the composition of the others.

Quartz is the oxide of an element, *silicon*, which resembles carbon. Hence, quartz may be called *oxide of silicon*, or briefly *silica*. Since it is the oxide of a non-metal, it might be expected that with water it would form an acid. Water, however, under ordinary conditions, as can be easily shown by experiment, does not even dissolve it. But by indirect processes their elements can be got to unite, thus forming *silicic acid*. The salts of this acid are called *silicates*, since they contain a metal with silicon and oxygen.

Feldspar, mica, and hornblende are silicates. Each of them contains aluminum, the most abundant of the metals, and one or two other metals besides.

Rock salt is chemically the same as table salt, as can be inferred from comparison.

All the minerals we have considered are compounds — either salts or oxides — except graphite. Although this mineral has a metallic lustre, it is only a form of the non-metal carbon. Note how it differs in its properties from charcoal.

SECTION C: THE PRINCIPAL CONSTITUENTS OF THE SOLID EARTH.

Rocks.—Visit the sea-shore or the banks of a river, brook, or lake. Seek out a bed of *gravel.* You will find in it several minerals you know, and others of which you are ignorant. The pieces of quartz and other minerals will sometimes be colored red or yellow. These colors are generally due to an admixture of red or of yellow oxide of iron. Gravel, it is plain, is not a mineral, but a mixture of various minerals. It is a *rock.*

Visit a bed of *sand.* You will find that it, too, is a mixture of several minerals. Quartz, opaque or transparent, will probably be the most abundant, but others will be found in greater or less amount.

Examine *clay* next. Take a lump of stiff clay to the school-house, and cover it with water. When thoroughly soaked, stir it through the water. Pour off the water above the clay as soon as it becomes clear. When the remaining water has evaporated sufficiently to allow the clay to be handled, it will be found to be quite *plastic.* Mould pieces of it into a variety of small models.

Put water into a saucer just made from damp clay. If the water does not pass through the clay, empty it out, and set the saucer and other clay models in a dry place.

When dried, the clay will be found to have become quite *rigid*, though still *soft*. Bake the clay models in an oven or in a metal vessel set on a stove. The heated clay will be both rigid and *hard*. The baking may be done at home by the pupils.

These experiments illustrate the most important properties of clay, and show its fitness for the manufacture of bricks and earthenware.

But is clay a single mineral, or a mixture of minerals? Heat thoroughly a little piece of ordinary clay in a wire coil. Note the change of color. Hold a magnet first near some particles of clay which have not been heated; then near some broken from the heated piece. The latter will be attracted. Explain the facts.

Ordinary clays usually owe their color to the presence of iron compounds. But they consist mainly of silicates of alumina. Pure white clay is aluminum silicate. We cannot see the different minerals which make up our common clays on account of the fineness of the particles.

The masses of mineral matter which make up the solid earth are called *rocks*, no matter how loose or finely pulverized they may be. Each pupil should take to the field a knife or file, and the party should have a bottle of hydrochloric acid to aid in determining the minerals which the rocks contain.

Find a bed of gravel which is now accumulating. Such beds occur only where there is flowing water. Examine the pebbles. They are of various sizes, but all are more or less smooth and rounded. Seek for an explanation. You will conclude that these are results due to the pebbles being rubbed together as the water carried them along to the heap of gravel, and rolled them over one another after they got there.

Visit also growing deposits of sand and clay. They will be found only where there is water. The grains of sand are water-worn like the pebbles in the gravel.

Gravel, sand, and clay are evidently formed through the agency of water. They are *water-formed* or *aqueous* (Lat. *aqua*, water) *rocks*. But why are they mainly laid down in separate places? Upon investigation you will find that the gravel is deposited where the water is not moving with sufficient force to push along the pebbles, but is moving rapidly enough to carry along particles of sand and clay. Similarly, the sand settles where the water is moving too fast to allow the clay to settle. The clay sinks at last in still water.

Search for beds of gravel, sand, and clay at a distance from water. You will often find them far above the present level of the waters, even on the tops of high hills. What does this teach? It shows that once these places were covered by water, swiftly flowing, gently flowing, or quite still, according to the character of the deposit.

You will be sure in the course of your exploration to come upon a rock which looks like consolidated gravel, the pebbles being held in place by the finer material of the rock. This is *conglomerate* or *pudding-stone*. The rounded pebbles tell you that it is a water-formed rock. But it must have been loose gravel once, else the pebbles could never have been worn and rounded as they are. Try to find out how it was consolidated.

Rocks will also be found which are evidently made up mostly of grains of sand all cohering together. These are *sandstones*.

Shale is consolidated clay. Account for the consolidation of the clay and sand.

Sometimes in steep banks you will see aqueous rocks lying one above the other in layers or strata (sing. stratum). Account for this arrangement. Which of the layers was the oldest, that is, which was first deposited? Why did the one cease to be deposited and the other begin? It will be seen that the arrangement of the rocks one above the other is a means of determining their relative ages.

There may be no granite rocks *in situ* in your neighborhood, but you will at least be able to find boulders which have been brought from some district farther north where granite abounds. How were these boulders transported? They are too large and heavy to have been brought by water. The only explanation we can think of is that our country was once covered with glaciers, and that these boulders were borne by the ice as it slowly moved southward, as similar boulders are now being transported in the mountains of Switzerland and Alaska.

Break up some pieces of granite. You will find, upon testing the minerals it contains, that it is a mixture of feldspar, quartz, and mica, varying, however, in relative amount in different specimens. The hard glassy-looking mineral is evidently rock-crystal. The less hard one, which has glistening cleavage planes, and is nearly white, or more or less strongly tinged with red oxide of iron, is feldspar. The dark soft mineral which cleaves into thin elastic sheets is black mica. You will be struck by the fact that these minerals show no signs of having been water-worn except, perhaps, at the surface of the rock. The pieces are angular, and are evidently imperfect crystals—having crowded upon each other during their formation, and thus interfered with each other's development.

But how were the minerals liquefied or softened sufficiently to enable the molecules to group themselves into crystals? It must have been through the action of heat and, perhaps, heated water. The granite may once have been a bed of sand or pebbles. In that case it is a *metamorphic* (Gr. *meta*, change; *morphe*, form) rock. When an aqueous rock has been hardened and crystallized to a greater or less degree through the influence of heat, it is called a metamorphic rock.

The granite, however, may never have been an aqueous rock. Its material may have been ejected in a liquid state from the interior of the earth. In that case it is an *igneous* (Lat. *ignis*, fire) rock. Quite likely you will not be able to decide whether your specimens are metamorphic or igneous.

Examine the weathered surface of a granite boulder. Does the weather have any visible effect on either of its minerals? Scrape off some of the soft friable substance produced by the decomposition of the feldspar.

We were once told that feldspar is a silicate containing two metals, that is, a double silicate. The soft residue is a single silicate — the only metal in it being aluminum. The metal potassium, in combination of course with other elements, has been washed away.

Pulverize a little of the decomposed feldspar and heat it for several minutes in a closed tube. You have been told that the feldspar *loses* something by weathering; this experiment shows you what it *gains*.

The chemical name, then, of the substance we have just been heating is *hydrous aluminum silicate*. You will have noticed its resemblance to white clay. And, indeed, it is the same. It contributes largely to the formation of beds of clay. Other double silicates besides feldspar decompose in a similar manner.

Slate is one of the commonest of metamorphic rocks. Its composition and fineness of grain go to show that it was once clay. Its stratification, and the remains of animals and plants frequently found between its layers, demonstrate its aqueous origin. Relics of ancient life, found in rocks, are called *fossils*.

You will find that the thin even sheets into which slate cleaves are not, as you will probably suppose at first, different layers deposited by water. Note that the lines of cleavage are, generally speaking, crosswise to the layers of bedding. And, further, the fossils do not rest upon the cleavage surfaces, as they would do if these were the layers of deposition. This slaty cleavage did not exist in the clay at first, as it is not found in modern clays.

Much as heat converts clay into hard and rigid bricks and earthenware, so long continued pressure, accompanied by a moderate heat, has changed the original clay into slate. Often, too, crystals, more or less distinct, have been produced. The cause of slaty cleavage is more difficult to understand. Perhaps, however, the teacher will be able to show experimentally that steady pressure upon a body composed of particles of unequal diameters tends to arrange the particles with their longer diameters at right angles to the direction of the pressure.

The slate rocks, originally deposited in horizontal layers in still waters, as clay is being deposited at the present time, have often been tilted and curved by disturbances in the earth's crust. Frequently, also, seams and veins, filled with quartz, calcite, or some other mineral, which has filtered into them, cross the beds.

About the sites of old volcanoes and where there have been fissures in the earth's crust, you will find rocks which were never, so far as we know, deposited by water, but which were produced by the solidification and crystallization of molten matter from the depths of the earth. One of the commonest of these rocks is *basalt*, usually known as *trap*. A piece of massive trap might be taken for a fragment of sandstone. The little grains composing it, however, are crystalline and not water-worn. It is heavier, too, and harder to break than sandstone. You will sometimes find light basaltic rock containing many cavities formed by the expansion of the gases present in it when in the melted state. The rounded cavities are frequently filled with minerals which look like pebbles. Upon breaking them, however, you will find that they are composed of crystalline minerals which have filtered in from the surrounding rock. This variety of trap is called *amygdaloid* (Lat. *amygdalum*, an almond). Account for the name.

We have divided rocks into three classes: 1st, Aqueous Rocks, the materials of which were brought together by water, and which, although often consolidated by pressure since their deposition, have not been altered perceptibly by heat; 2nd, Metamorphic Rocks, originally deposited by water, but afterward altered by pressure and *heat;* and 3rd, Igneous Rocks, the solidified products of volcanic and fissure eruptions.

Along the lower course of a stream, beds of clay, sand, and gravel are found. Follow the stream upward and you will find, near its mouth, the source of the deposits — the older rocks from which the materials for the deposits have been taken. They may be older aqueous rocks, or they may be the fragments at the base of a promontory of igneous rock. Upon reflection it will become evident that the first aqueous rocks were composed of materials derived from igneous rocks — that these fire-formed rocks must have constituted the foundation upon which the water did its work. Does it follow that all the igneous rocks are older than any of the aqueous rocks? Remember that volcanic action in the earth has not ceased.

Try to find, by actual study of the rocks in localities where the fragments lie close to the masses from which they were broken, the principal agencies in their disintegration.

In the finer-grained water-formed rocks, you have sometimes met with the remains of plants and animals. If you closely observe how stems, leaves, shells, etc., are now being buried in the accumulating mud-beds of sea-shore and river, you will be able to picture out the conditions which existed long ago when the plants and animals, of which fossils are the relics, were buried in the stony graves in which they have lain for long ages.

Do not suppose that the stony fossil stem has been produced by the conversion of wood into stone. That could not have been, for the stone is not composed of the same elements as wood and other vegetable matters. But as the plant gradually decayed, stony particles took the place of the vegetable matter. There is but little of the original material of the plant left. Some of the carbon usually remains, enough to blacken the outside of the fossil.

The hard parts of animals — their bones or shells — persist in their fossil remains. Touch a clam or oyster shell with hydrochloric acid. Scratch it with a knife. Examine the shells in a piece of fossiliferous limestone in the same way. What do you infer?

Limestones may be found which are made up almost entirely of fossil shells. When fossils are not to be found, the limestones have probably undergone alteration. Limestones, then, are aqueous rocks which accumulated in waters abounding in corals, shell fish, and other animals with hard parts containing much carbonate of lime. They thus differ from the other water-formed rocks with which we have met in deriving their material immediately from animals.

Soils.—The loose earth through which the roots of plants spread, and from which they absorb a part of the plant-food, is called the *soil.*

Procure about a quart of ordinary soil. If there are lumps in it, break them up thoroughly. Separate the pebbles and little stones from it by means of a wire sieve.

Put the soil which passes through the sieve into a small pail half full of water. Stir the soil through the water, then allow it to come to rest. Empty the muddy water into a large pail. Pour fresh water upon the residue, and proceed as before. Continue to pour the water off until it is no longer rendered muddy by the residue of the soil in the small pail. Examine the sediment. What name may be given to it?

Set the large pail aside until the water no longer looks muddy. Pour off the clear water, and leave the pail in a dry room until the remainder of the water has evaporated. Examine the residue in the large pail. What name may you give it?

If the two residues be nearly equal in weight the soil was a *loam.* If the part in the small pail considerably exceed the other, the soil was a sandy loam; but if the contrary be the case, it was a *clay loam.*

It should be noted, however, that the fertility of a loam depends largely on the amount of decaying organic matter mixed with the sand and clay.

Heat a little red earth in a wire coil; also a bit of yellow earth. Note the change of color. Test them with the magnet. Explain the facts.

Procure a lump of black earth, such as is usually known as black mud. Some may suppose that, since the red and yellow colors of soils are due to the red and yellow oxides of iron, that the blackness in this case is owing to the presence of the black oxide of iron. Since the latter is magnetic, the magnet will at once decide the question.

Heat a small piece of this black soil in a wire coil until only a light ashy-looking residue is left. It is evident that the black substance so largely present in this soil is combustible. What must it be? After further examination and discussion, the conclusion will certainly be reached that it is carbon.

But whence came the carbon? We know that when a piece of wood is held in a flame the charred end is composed mostly of carbon which remains behind after the other elements of the wood are mostly expelled.

Visit any boggy place within reach. It will be noticed on the way that plants which decay above ground in dry places disappear without leaving behind any black residue; but in boggy ground, where the oxygen of the air is mostly excluded by water, a large part of the carbon of decaying plants remains behind. Soils containing a large proportion of this carbonaceous matter are *peaty* soils.

Examine also the vegetable mould in the forest produced by the decay of fallen leaves.

An excursion is now in order for the purpose of examining the character and depth of the soils in the neighbourhood.

Spots will be found where there is no soil at all — nothing but bare solid rock; others where the soil is very shallow — only a few inches deep. Upon inquiring of those who have dry cellars and wells, you will be able to decide whether the soil is always underlaid by solid rock.

Examine the *alluvial* soil of an intervale and compare it with the soil of the adjoining uplands. Account for the difference.

Visit places where rocks are plainly crumbling away and forming soil.

Find whether upland soils are usually or always formed from the underlying rocks. Account for the fact when decided. Do not forget the glacial boulders in attempting an explanation.

Coal.—Our studies of peaty soils will enable the pupils to understand how *peat* is formed in bogs.

It should be shown by means of fossils from the rocks underlying the coal beds that plants grew in their vicinity previous to their formation. These rocks, as well as those overlying the coal are water-formed rocks.

Such considerations as these will lead the pupils to think it highly probable that coal-beds were once accumulations of decaying vegetable matter in swampy lands which have since been buried beneath sediments deposited by overflowing waters.

SECTION D: THE PROPERTIES AND COMPOSITION OF THE AIR.

Fit a cork, which has a bent delivery tube passing through it, into a test tube full of air. Hold the apparatus so that the end of the delivery tube will be under water, and heat the confined air. Part of the air will be forced from the tube, and will ascend in bubbles through the water. Account for this. How, besides in temperature, does the air in the tube now differ from the air which was there at first?

Hold your hand in the air two or three inches above the flame of a lamp. Then hold a bit of down or fine cotton-wool in the same place, and suddenly release it. If carefully done, it will rise vertically for several feet. Explain its ascent. Account for winds on the same principle.

Confine a portion of air by corking a tube tightly at both ends. Hold one end against a firm surface, and push in the cork at the other end with a blunt rod. Although the air cannot escape from the tube, the cork can easily be driven in, thus diminishing the volume of the air without lessening its mass. This experiment shows that air is highly *compressible*. On removing the rod, the cork, if no air has escaped around it, will be driven back nearly to its original position. Since the air was not able to push the cork out at first, we must conclude that the compression endowed it with more ability to do work — more *energy*.

Hold the tube horizontally, leaving the farther end free, and push the nearer cork in quickly. Explain the result.

Place a piece of paper over the mouth of a tumbler of water. Keeping the paper in its place, invert the tumbler. Something pushes or pulls upon the paper with sufficient force to hold up the water in opposition to gravity. Show by experiment that the paper is not held up by adhesion. Something presses *upward*, then against the paper. What can it be? There is nothing touching the lower side of the paper except the air. It must be the air, then, that pushes against the paper.

Stand a small tube, which is open at both ends, with the lower end in water. Then, pressing the thumb against the upper end, raise the tube. Some water is maintained in the tube without the intervention of paper. Lift the thumb. The water drops out of the tube. Explain.

By using a bent tube, it may be shown that the air exerts pressure laterally.

What else does the air press against besides the things we have noticed? How do you know? What compresses the air in the room and pushes it against the surfaces with which it is in contact? It must be the upper air, pressing downward with all its weight, which compresses the lower air and gives it this energy; just as in a former experiment, the pressure of the air in a closed tube increased its *expansive force.*

If the school possesses a pound of mercury and a glass tube about three feet long, the pressure of the air per square inch may be calculated, and the principle of the barometer explained.

The Constituents of the Air.—Repeat the experiments and arguments by which we were formerly led to conclude that there is oxygen in the air.

Show that the air cannot be entirely composed of oxygen. It is our business then to find what other gas or gases are present in it. How shall we begin?

Let us remove the oxygen from a confined portion of air, and try to find what the residue is. We know that when substances burn in the air, they combine with its oxygen. We may remove the oxygen, then, from some air by burning something in it. Let us try alcohol.

We have been burning alcohol in a spirit lamp. The oxides produced by its combustion are invisible to us, but we may catch them in a bottle.

Hold the wide mouth of a bottle rather closely over the flame. Drops of water will condense on the inside of the bottle. In about a minute, close the mouth of the bottle with a slip of glass and invert it.

As soon as the mouth of the bottle is cool enough, pour in a little lime-water and shake it through the gases in the closed bottle. A striking change takes place in the lime-water. By argument based on these experiments show what two oxides are produced by the combustion of alcohol, and demonstrate the presence of two elements in it. Besides these, alcohol has been found to contain some oxygen, but not nearly enough to oxidize the two other elements in its molecule.

Wrap a bit of cotton around the end of a brass wire, into a loose ball as large as a grape. Bend the wire into a shape resembling that of the radical sign in algebra, but rounded at the angles. Saturate the cotton with alcohol. Hold the wire so that the bend below the cotton rests upon the bottom of a small pan containing lime-water to the depth of three inches. Ignite the alcohol in the cotton with a match; then quickly lower a wide-mouthed bottle over the cotton until its mouth rests upon the bottom of the pan. The lime-water will rise in the bottle.

The part of the wire bearing the cotton should reach more than halfway up the bottle. There must be enough lime-water in the dish, otherwise air will be forced into the bottle from the outside after the alcohol has ceased to burn. This would spoil the experiment.

Raise the bottle a little, but not till its mouth is out of the lime-water, and draw out of it the wire and cotton. Then put one hand into the water and slide the *palm* under the mouth of the bottle. Turn the bottle up and shake it thoroughly, keeping the hand constantly pressed upon its mouth.

Plunge a lighted match or stick into the gas which now remains over the lime-water. If the experiment has been properly done, the flame will be immediately extinguished. The gas itself does not take fire. What gas previously prepared does this agree with so far? How shall we determine whether it is that gas or not? By finding whether it will have the same effect on lime-water.

Repeat the preceding experiment with the exception of putting a burning stick into the gas. Instead, as soon as it has been shaken through the lime-water, still keeping the hand tightly over it, lower the bottle into a deep pan or pail full of water. Remove the hand, and tip the mouth of the bottle containing the gas under the mouth of a much smaller bottle which has been filled with water and inverted in the vessel. The gas will rise into the smaller bottle, displacing the water. Turn the bottle up in the usual way. Remove the hand, pour in lime-water, and shake it through the gas. The water should remain clear.

Show that this gas differs from any before prepared. Its name is *nitrogen*. Show that there is nitrogen in the air. Explain why lime-water was used in the preceding experiment rather than pure water.

Phosphorus may be used instead of alcohol in this experiment, but it is so inflammable and poisonous that the latter is to be preferred in the common schools. However, by using phosphorus it is easy to show that about four-fifths of the air is nitrogen, and about one-fifth oxygen. Directions for performing the experiment with phosphorus may be found in any text-book on chemistry.

Leave some clear lime-water standing in a bottle tightly closed, and beside it some more in an open dish. In a few days a scum will have formed upon the surface of the water in the latter dish. Break a little piece of it away from the rest. It sinks through the water. Skim off the rest of it, and remove the water which adheres to it. Touch it with hydrochloric acid. This substance displays the distinctive properties of a mineral well known to us. What is it?

If it is carbonate of lime, the gas evolved must be carbon dioxide. This may be established by treating a considerable quantity of the scum with hydrochloric acid in a test tube provided with a delivery tube. The gas, when passed into lime-water, will produce the same effect as carbon dioxide.

Whence came the carbon dioxide? It is not present in water or hydrochloric acid; neither did it come from the caustic lime dissolved in the water, for, as we remember, that is a compound of lime (calcium oxide) and water. Hence it must have come from the air. But why did it leave the air and become part of this scum? We can only explain this by supposing that the lime has a stronger affinity for carbon dioxide than for the water with which it is combined in the caustic lime (calcium hydrate) in the lime-water. The lime then, we believe, gave up the water and united with carbon dioxide out of the air, thus forming a compound of calcium, carbon, and oxygen (calcium carbonate).

The teacher must be careful to keep the distinction clear between the water which is *combined* with the lime to form caustic lime, and the water in which the caustic lime is *dissolved* to form lime-water. The latter is only a *mixture*, not a compound of caustic lime and water.

By shaking lime-water through a bottle of air it can be shown that there is but a small amount of carbon dioxide present there. Give the argument.

Pass carbon dioxide, obtained from carbonate of lime in the manner described in Section B., into a small bottle of lime-water. Take the delivery tube out of the water as soon as the substance which forms in the water has made it opaque.

Allow this newly formed solid to settle until the water has become quite clear. Prove the elementary composition of this solid.

Shake the solid through the water, and pass in more carbon dioxide. In a short time the water will become clear again although the solid does not settle to the bottom. Account for this. You will probably conclude that the carbon dioxide has made the opaque body more soluble in water. This will explain its disappearance from sight.

Bring a cold glass vessel into a warm room. Drops of water collect on the outside of it. The water could not come out of the glass. Whence did it come? Give other proofs that there is invisible water vapour (steam) in the air.

We have now shown that the air contains nitrogen, oxygen, carbonic acid gas, and water — two elements and two compounds. Besides these, it has been shown to contain a very small amount of ammonia and of oxides of nitrogen. Ammonia is a compound of nitrogen and hydrogen. It may be smelled as it issues from a bottle of aqua ammoniæ, or in the air of a stable before it has been cleaned out in the morning.

Show that there is little if any hydrogen in the air.

SECTION E: THE CONSTITUENTS OF THE WATERS OF THE EARTH, AND SOME OF THEIR PROPERTIES.

Water, we already know, is by far the most abundant constituent of our seas, lakes, and rivers.

Allow some sea-water, if obtainable, to evaporate, or boil it in a test tube until the water disappears. Of what does the residue mainly consist?

Scratch a piece of coral, or the shell of an oyster or mussel, with a knife, and then touch it with hydrochloric acid. Collect some of the gas, in the manner described for calcite, and allow it to pass through lime-water.

Heat a sliver of this shell or coral, and note the effect of the dampened residue upon red litmus paper.

Touch the bone of a sea-fish with hydrochloric acid. The mineral part of the bone is evidently different from that of the shell and coral. It consists mainly of a salt called, from its composition, *calcium phosphate* or *phosphate of lime.*

Touch a fresh-water shell and the bone of a fresh-water fish with hydrochloric acid.

Examine the deposit on the inside of a kettle or boiler which has been in use for some time.

These experiments will show that not only sea-water, but fresh water, holds in solution various saline matters. Indeed, we might be sure without examination that the rains would dissolve out of the soil and rocks such compounds as are soluble in rain-water, and carry them into the rivers and seas.

But how shall we explain the fact that shells and bones remain for a very long time undissolved in the waters? We once showed that carbonic acid gas in water has the power of making carbonate of lime soluble. And since rain-water contains a considerable amount of carbon dioxide taken from the air, it is a better solvent than waters which contain a less amount of the gas.

Similarly, it has been found that carbon dioxide renders phosphate of lime soluble in water.

Take a sip of rain-water and of water artificially distilled. Are they more or less palatable than ordinary spring or river water? Account for the difference.

CHAPTER II.

THE ORGANIC WORLD.

DIVISION I.—PLANTS.

SECTION A: THE DEVELOPMENT OF THE PLANT—ROOT, STEM, AND LEAVES.

Collect a number of large seeds. Select some which contain albumen, as those of the ash and of Indian corn; some which have no albumen, as those of the maple, the bean, and the pea; some whose embryos have fleshy cotyledons, as beans, peas, and apple-seeds; some whose embryos have one cotyledon, as those of the Indian corn; others with dicotyledonous embryos; and seeds with polycotyledonous embryos, as those of the white pine and most other members of the Pine Family.

Plant a sufficient number of each kind of seeds in boxes in a moderately warm room, and water them regularly, but not too frequently. As soon as each kind begins to germinate, dissect some seeds (previously soaked, if too hard) of that kind, comparing its parts with those of the germinating plantlet.

The pupils will learn what parts grow larger in germination, what parts become smaller—they will note the uses of the different parts—and then the teacher will give them their names. Make drawings of the embryo, giving the names of its parts—the radicle, the seed-leaves or cotyledons, and the plumule if apparent.

Leave at least as many young plants in the earth to continue their growth as there are pupils in the class.

Keep them in the school-room and let the children observe their growth from day to day, noting any interesting changes which are observable. Measure their height from time to time, and calculate the rate of increase. Why can we not see them grow?

Observe particularly the manner of growth, the formation of *nodes* and *internodes*, the growth of the leaves and their arrangement on the stem. Name the different parts of the leaves — the blade, the foot-stalk, the stipules, and notice which of them are sometimes wanting.

Observe and name the different shapes of the leaves, and distinguish between simple and compound leaves.

Watch the formation of *buds*, and their position — *axillary* or *terminal*. Compare those which are not intended to live through the winter with those which are, and account for the difference.

Require the pupils to make drawings illustrating all the important facts and new terms.

If the plants enumerated cannot all be had, or are not found sufficient to bring out all the necessary points, other seeds and growing plants may be brought in from the fields or gardens.

The propagation of plants by seeds is called *reproduction*.

SECTION B: THE DEVELOPMENT OF FLOWERING PLANTS CONTINUED — THE FLOWER, FRUIT, AND SEED.

In the early spring, bring to the school-room several young trees — birches, maples, apple-trees, etc., which bear living buds, but as yet no branches. Keep as much of the native earth about their roots as possible. Bring also branches of older trees or shrubs, including some with two *forms* of buds. Set the plants and branches in vessels of damp earth or sand. Watch the buds from day to day as they swell and lengthen out. Into what do the axillary buds on the young trees develop? — the terminal buds. These buds are called *leaf-buds.* Observe that leaf-buds develop not into leaves but into branches, or continuations of the stems, with ordinary or *foliage* leaves upon them.

Some of the buds on the branches from the older trees will develop into a kind of modified branches bearing several sets of modified leaves set closely together at the top of the branches, or branchlets. These are *flower-buds.* Each flower with its stalk constitutes a modified branch, the *flower-leaves* corresponding to the foliage leaves, but set much more closely together. Theoretically, then, every bud which develops at all becomes a branch of some kind (or a continuation of the stem, which is equivalent to a branch).

Distinguish and name the different sets of parts which make up a flower, using large flowers at first. Name the different sorts of flower-leaves — sepals, petals, stamens (filament and anther), carpels. Lead the pupils to see that the carpels are *ovule-bearing leaves*, and the stamens *pollen-bearing leaves.*

Investigate the history of the pollen after its discharge by the anther. It will be found that the stigma is specially fitted to retain it. After careful observations in the field, it will be concluded that insects and winds are the chief agents in conveying pollen from the anther to the stigma—that is, in effecting *pollination*.

Discover at least one plant in which pollination could not be effected by the wind; also, a flower in which it is impossible, or nearly so, for the pollen from its own anthers to reach its stigma.

Carefully exclude pollen from the stigmas of some large flowers. Keep a plant of the same species under similar conditions except those for preventing pollen from reaching the stigma. It will not be long until the use of the pollen becomes evident. The effect produced by the pollen upon the ovules is called *fertilization*.

Study the means by which *cross-fertilization* is secured in the common iris (blue-flag), and find what insect plays a prominent part in its pollination.

Follow the history of the flower on, either in the fields or by bringing specimens into the school-room from time to time. The maple, cherry, apple, strawberry, tomato, and Indian corn will present an instructive variety. Notice what parts of the flower perish, and what parts continue to live and grow.

When growth has ceased, we have the full-grown *fruit*. The plants mentioned above furnish examples of some of the principal kinds of fruit—the *achene*, *pome*, *berry*, *stone-fruit*, *grain*, and *key-fruit*. The fruit may be defined as the ripened pistil together with any part of the flower which may adhere to it.

Prove that the little seed-like bodies on the outside of the juicy receptacle of the strawberry are not seeds but the true fruits.

Finally, open the ripened ovary (*the seed-vessel*), take out the seeds, open one of them, and examine the embryo within.

We have now followed the life-history of the plant from embryo to embryo.

SECTION C: ANNUALS, BIENNIALS, AND PERENNIALS, HERBS, SHRUBS, AND TREES.

Collect several wild and several cultivated plants which grow from the seed, blossom, and die, all in one year, These are *annuals* (Lat. *annus*, a year). Learn the names of those you find.

Set out in a box or bed a cabbage, turnip, carrot, beet, parsnip, and onion which were grown from the seed last year. Sow near them some seeds of each plant. Should the seeds of any of them fail to germinate, young plants grown from the seed can be obtained from gardeners or farmers, and be planted in boxes or pots in the school-room. Compare the growth and development of the first year with that of the second year. Notice the change in the bulb of the onion, the thick leaves of the cabbage-head, and the fleshy roots of the other plants as the growth of the second year proceeds. Draw the inference as to the use of these parts.

Such of the plants as die outright on ripening their seed at the end of their second year's growth are called biennials (Lat. *bis*, twice; *annus*, a year). Plants which continue to live and grow for more than two years are called perennials (Lat. *per*, through; *annus*, a year).

Distinguish between *herbs*, *shrubs*, and *trees*. Discover and name some annual, some biennial, and some perennial herbs. Find how our native perennial herbs provide against the cold of winter, what parts of them die in the autumn, and what parts retain their vitality through the winter.

Learn to distinguish our principal forest trees and shrubs — the maples, cherries, birches, alders, the oak, the hazel, the ashes, the elm, the poplars, willows, pines, spruces, the hemlock, larch, or tamarack, and cedar, and in localities where they grow, the linden or basswood, the butternut, and the hornbeam. Note the time and order of their flowering; which of them blossom before their leaves appear; which of them have flowers with both stamens and pistils; which have on the same tree some flowers with stamens and no pistils (*staminate flowers*), and others with pistils but no stamens (*pistillate flowers*); and which bear the pistillate and the staminate flowers on different trees. Make a collection of their leaves and fruits. Compare them, and make illustrative drawings. Find which of them are deciduous and which are evergreen.

SECTION D: FORMS AND PROPERTIES OF ROOTS, STEMS, BUDS, AND BRANCHES.

Make a collection of plants illustrating fleshy and fibrous roots, and the principal modifications of stems and branches — as the *runners* of the strawberry; the *tendrils* of the grapevine, the Virginia creeper, or the squash; the *suckers* of the rose or the raspberry; the *rootstock* of the couch-grass; the *tuber* of the potato or of the spring beauty; the *bulbs* of the onion and lily; and the *thorns* of the hawthorn. Allow the pupils to identify each of these modifications as a stem, or branch of a stem, giving proofs. The clearest proof in most cases is that they bear leaves, which is a peculiarity of stems. Sometimes, however, the leaves are very small and scale-like, as in the case of the potato tuber. The position and origin of thorns show that they are branches, although other evidence may occasionally be found.

Propagation by Cuttings.—At any time when the leaves are off the trees, cut vigorous shoots from young branches of last year's growth. Among others, get some from the gooseberry, the currant, and the willow. Keep them in a damp cellar, or rolled in damp moss, until early spring. Then set them in prepared earth, well packed around them, leaving several buds above the ground. Keep the earth moderately moist, and free from weeds. Also bury in the earth short pieces of the underground stems of couch-grass, each piece having but one bud. If successful, you will find that little branches, or portions of branches, will develop roots, so that each will become a complete and independent plant with root, stem, and leaves. These experiments demonstrate the remarkable power of striking root which branches possess. We must show how this property may be taken advantage of in the propagation of plants.

Layering.—Bend a branch of a gooseberry or currant bush down to a little hollow in the earth, and make a notch partly through the wood with a knife at the place where it touches the ground. Pin the branch down with a hooked stick and cover the part near the notch with earth, leaving the end of the branch above ground. When it has taken root, sever it from the main plant and set it out in another place.

Grafting.—Melt together some resin, bees-wax, and tallow, using about one-third more resin than of either of the other ingredients. Tear a piece of calico into narrow strips. Roll them up and soak them thoroughly in the liquid mixture.

ROOT-GRAFTING.
a. The Stock. *b.* The Scion. *c.* The Union of Stock and Scion.

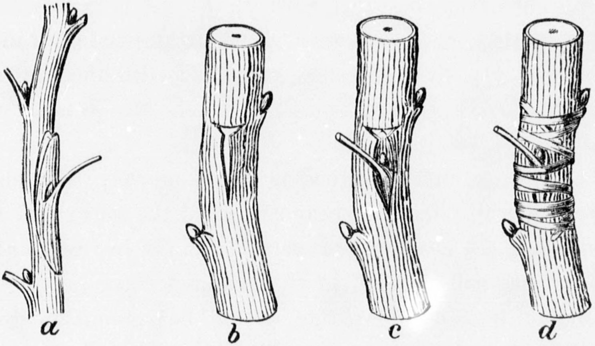
In autumn, after the fall of the leaf, or in winter, cut some short pieces of last season's growth, without flower-buds, but bearing leaf-buds, from the ends of the branches of a healthy apple-tree. Keep these shoots in a cool, moist place, with their cut ends in damp earth or moss. If the work is to be done in the school-room, we must bring in, when spring arrives, some young apple-trees about two years old, taken up root and all. With a very sharp knife, cut the stem off obliquely close to the root. Make the cut as smooth and even as possible. At the middle of the cut surface, by making a downward slit, produce a tongue of wood projecting upwards. Cut off obliquely the lower end of one of the shoots previously mentioned, and make in it a tongue projecting downwards, so that it will fit exactly upon the end of the root cut as described. Then fit them together tightly, taking care that the inner bark of the one is in close contact with that of the other, at least on one side. Finish by wrapping a strip of calico, saturated with the grafting mixture, firmly around the parts where the joining was made.

The process just described is called *grafting;* the plant upon which the shoot is grafted is called the *stock*; and the shoot itself the *scion.* If properly done, the two will unite, and growth will proceed in the ordinary way.

One or two of the plants should be set out in good earth in the school grounds. The others may be planted at home in the garden by the children, to be afterward transferred to the orchard.

If it is not convenient to do the work in the school-room, the grafting may be done in the orchard upon an older tree. Cut off the ends of some of the lower branches, and graft upon them shoots from other trees. If the teacher should be conscious of a lack of skill, a lesson from some one who has a practical knowledge of grafting will overcome the difficulty.

Budding.—If a single bud be cut smoothly from the new wood in the summer, before the tree has completed its growth for the year, it will, if inserted under the bark of another tree of the same kind, grow out and become a branch. A portion of bark and a very little wood at the base of the bud should be cut out with the bud. A cross-shaped incision is made in the bark so that it can be raised to receive the bud beneath it. A piece of tape, soaked in the grafting mixture, is then tightly wound about it.



BUDDING.

a. Removal of bud. *b.* Method of slitting the bark. *c.* The bud inserted. *d.* The same tied up.

Find why the different varieties of orchard fruits are usually propagated by grafting or budding.

Encourage the children to experiment further in this line and report their failures and successes.

Transplanting Trees.—No school, in country or city, should allow arbor day to pass without planting one or more trees. If there is no room in the school grounds for more trees, city schools may find vacant spaces in the public parks and along the streets; country schools, by the roadside near the school, or before the house of a poor or infirm resident of the district. In the country, too, the children should be encouraged to plant trees about their homes.

But the trees must be taken up and planted in an intelligent manner, and be cared for and protected afterward, else only disappointment will follow. The proper time to transplant trees is just before the buds begin to swell. In selecting trees for transplanting, prefer those which grow at some distance from others. They will bear the change to an exposed situation better than those which have been growing in the dense shade.

Small thrifty trees will bear transplanting better than larger ones and will soon surpass them in size.

Great care should be taken not to destroy the fibrous roots. As soon as the tree is out of the earth its roots should be dipped in, or daubed with, rich mud, or covered with very damp earth. It is important that the rootlets be kept moist until the tree is set out.

The ground into which the tree is set should be well spaded. Sift loose rich earth about the roots when the young tree has been set in place. Shake the tree up and down a little as the roots become covered to assist in working the earth into all the cavities. Finally press the earth down, but not too compactly, to the level of the surrounding soil. A pail of water thrown on the earth before the last is put in will aid in bringing the fine soil close to the rootlets.

If the soil be clayey, the tree must not be planted deep, as water would collect and stagnate around it. In the case of very clayey soil, a little drain filled with sand or sandy earth should be digged to carry off the surplus water.

In most cases, unless the tree is quite small, the ends of the branches should be lopped off in order to balance the loss of roots. In doing this the future symmetry of the tree should be kept in view.

Sometimes it would be better to saw off the top of the main stem, and cut off all the branches quite short. It is well to cover the wounds with paint or tar.

The earth around the tree should be covered, especially if the season be dry, with a mulching of straw, decaying chips, or other loose material. The trees will need to be watered in case of a drought.

In the country, if not protected from cattle by a fence, each tree must be separately guarded by stakes or palings set around it and joined by cross-pieces.

SECTION E: STRUCTURAL RELATIONS AND CLASSIFICATION OF PLANTS.

Collect a set of plants, in bloom at the same time, illustrating the various degrees and forms of cohesion and adhesion in the flower. The buttercup, plum, apple, adder's tongue, trillium, dwarf raspberry, fly-honeysuckle, and dandelion will make a good set, but a closely related plant may be substituted for either of them.

First examine the flowers for examples of union between the parts of the same circle, i. e., for *cohesion*. In the buttercup no cohesion will be found; but in the others the parts of the calyx are more or less united, the lower part, as far as the cohesion extends, forming the *tube* of the calyx, and the upper part the *limb*. The number of lobes or teeth in the limb indicate the number of sepals except in the florets of the dandelion in which the limb of the calyx is made up of numerous bristles so that we can only infer the number of parts of which the calyx is formed, from the number which make up the stamens and corolla. Among the flowers will be found cases in which the petals are distinct, and in which they are more or less united; cases of distinct stamens, and of stamens united by their anthers; of distinct carpels, and of carpels coherent.

Next look for examples of union between different circles, i. e., for *adhesion*. Here you will find the calyx quite free from all the other circles; there you will find it adhering to—combined with—the ovary. Sometimes the corolla will be free from the other parts of the flower, and only attached to—*inserted on*—the receptacle; sometimes it will be *inserted on* the calyx tube. Again, in the dandelion it is seemingly inserted on the top of the ovary. Stamens will be found inserted on the receptacle, on the calyx, and on the corolla.

In this way, the pupils will be led to see that flowers differ widely in the degree and manner of the union between their parts—in the way they are put together—that is, in their *structure*.

Compare the flowers as to the *number* of parts in the different circles of the same flower, and in the corresponding circles of different flowers. Also compare the veining of their leaves, and sections of their stems. Draw any general conclusions which seems to be justified by the facts.

If this work be done after the summer vacation, a different, but equally suitable, set of plants can be found.

Let the pupils find two or three plants in the field whose flowers resemble those of the buttercup in having neither cohesion nor adhesion, and in possessing several carpels and numerous stamens.

Seek for resemblances in other parts as well as in the flowers—in the form of the leaves; in the stipules, if present; in the taste of the juice, and in the fruit.

On account of these resemblances, especially in the structure of the flowers, these plants are considered to be nearly enough related to belong to one *Family* or *Order*. It is called the *Crowfoot* or *Buttercup Family*. Find the origin of both names.

The features, in which the plants of this family agree with each other, but differ from the members of other families, constitute the *characteristics* of the Crowfoot Family. Enumerate and record these characteristics. Make out tabular descriptions of at least three plants of this family, displaying clearly to the eye their common features, and at the same time their individual differences.

Do not require of the children, at this stage, the use of the technical terms used by botanists for expressing the lack of cohesion and adhesion, and the different modes of them. Encourage a clear statement of the facts by the use of ordinary language.

The pupils should make drawings of the plants to accompany their written descriptions. These drawings should exhibit the plant as a whole, and also sections of liffer-

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THE HAREBELL.
a. Section of Flower.

the flower and fruit. The plant may be drawn either as it appears in life, or after it has been dried under pressure. Small plants may be dried in old books. Larger ones should be placed between thick sheets of drying paper, or several thicknesses of old newspapers. Pressure is applied by laying a board on the top bearing a number of bricks or stones. The paper should be changed every day at first; less frequently afterward. If carefully done, the leaves and flowers will retain their natural colors.

In the manner previously described, the pupils should make out for themselves the characteristics of the Rose and Lily Families, with descriptions and drawings.

Make out the structure of the flower in the blue-flag or iris and in the lady's slipper or some other member of the Orchis Family, noting the structural differences between them and the Lily Family.

In examining plants, if the seed be so small that the parts of the embryo cannot be made out distinctly, its general form and the number of cotyledons can be learned by allowing the seed to germinate.

SECTION F: STRUCTURAL RELATIONS AND CLASSIFICATION OF PLANTS—CONTINUED.

During the next season make out, as before, the characteristics of the Cress, Aster, Buckwheat, Willow, Pine, and Grass Families, with accompanying drawings and descriptions.

In selecting representatives of the preceding families, always include one or more cultivated plants if possible.

Make out, at least, the family relations of the cabbage, turnip, beet, carrot, radish, apple, cherry, strawberry, plum, raspberry, currant, bean, clover, onion, oat, wheat, and timothy. The pupils will be pleased when they discover that those cultivated plants, which are mostly descendants of immigrants from the Old World, have near relations among the native American plants which grow and propagate their species without man's care.

In the spring-time, watch the curious way in which the leaves—*fronds*—of ferns unfold. Nothing but the leaves rise above the ground. The stem and root must be beneath its surface in our ferns. Dig some up and examine them. If they grow at a long distance from the school take up two or three kinds, with a good share of their native soil, and set them in boxes in the school-room. Allow them enough water and not too much light.

Follow the growth of the reproductive organs on the back of the fronds.

Compare the ferns with representatives of some of the other families of flowering plants—the Club-mosses, Mosses, Horsetails, Lichens, and Mushrooms or Fungi. Note such differences as will enable the pupils to refer ordinary flowerless plants to their proper families.

In autumn, collect a quantity of the ripe spores of ferns or of club-mosses. Demonstrate, by imitating the natural conditions as closely as possible in the school-room, that they possess vitality and the power of growth. The spores may be sown upon pieces of brick placed in a saucer containing water. The brick will absorb water to keep the spores sufficiently moist. Cover the saucer with a glass jar, and keep it where the temperature will be as even as possible and the light not too strong.

If time and opportunity permit, a small area of damp earth may be prepared in a suitable place, and then be sown with spores. The spot should be protected so that rains will not wash the spores away. The sowers may succeed in growing new plants.

The pupils are now able to arrange all the plants they have met with in two divisions which will include the whole, viz., plants which bear flowers and seeds (each of which contains, when mature, an embryo); and plants which do not bear flowers or seeds, but reproduce themselves by means of minute reproductive bodies called spores. These great divisions of plants are called *Series*—the former the *Flowering Series*, the latter the *Flowerless Series*.

Similarly, divide the Flowering Series into two *Classes*—the Exogenous Class or Dicotyledons, and the Endogenous Class or Monocotyledons. Inquire into the appropriateness of these terms. Enumerate and record the features common to all plants of each class. These are *Class* characteristics. Refer the families of flowering plants whose characteristics have been made out to one or the other of these classes, giving the reasons. Consider whether part of a family ever belongs to one class, and the other species of the family to another class.

Divide the Exogens into two groups—*Sub-classes*—*Covered-Seeded* plants and *Naked-Seeded* plants, and write out the characteristics of each sub-class.

Arrange the families of Exogens with which you are acquainted under one or the other of the above sub-classes.

The pupils are to work out the above classification themselves. A set of specimens illustrating these natural divisions of plants should be arranged before them while thus engaged.

Description of Red Clover.—The main root is large, firm, and tough. Its principal divisions are long and fleshy, with fibrous branches extending a great way in various directions.

The stem is exogenous, contains only a small amount of wood, and is slightly hairy.

The leaves are net-veined, compound, alternate. The blade is composed of three oval leaflets, each of which has a pale spot on its upper surface. Each leaf has a pair of broad stipules which adhere to the foot-stalk except at the tips.

The flowers grow in dense roundish clusters, or *heads*. They are pleasantly sweet-scented. Each flower is on a little receptacle of its own.

The lower part of the calyx forms a narrow cup, which is hairy at the mouth. The cup bears five slender teeth, which show that the calyx is composed of five sepals united at the base.

The corolla is composed of five petals of different sizes and shapes. It is of a purplish color. The upper petal is the largest. There are two smaller petals at the sides, and between them two small petals are united at one edge. All the petals are united below in a long, slender tube. Upon splitting this tube, without pulling it out of the calyx, two slender thread-like parts will be found inside of it. When traced downward, one of them will be found to end in the small, green ovary, and is therefore the style. When traced upward, the other will be found to bear an anther on the top, and is therefore a filament. Nine other stamens show their anthers, but their filaments unite in the long tube, which seems to consist of the filaments of nine stamens and the lower parts of the petals, grown together. This tube, when pulled out, is seen to have been fastened to the base of the calyx-tube. We might have thought it grew from the receptacle had we not noticed that the flower closely resembles, in structure, those of the Pea and Bean. And since there is nothing to show that the pistil has more than one carpel, we conclude that, like the pistils of its near relatives, it is formed from only one ovule-bearing leaf.

The fruit is very small, and remains hidden within the calyx. It seems most often to contain only one seed. The seed contains nothing but an embryo, which has two cotyledons.

We do not know yet how long the Red Clover lives, but I shall raise some plants from the seeds, and count the years until they die.

NOTE.—The above description will show that a plant may be described with exactness, including the structure of the flower, without the use of any of the more difficult technical terms employed in text-books on Botany.

SECTION G: THE COMPOSITION OF PLANTS.

We know something about the composition of the earth, the ocean, and the air. To discover what plants are chiefly composed of is our next undertaking.

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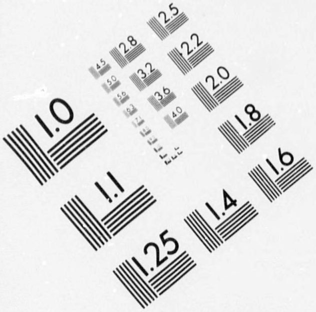
Place in the bottom of separate test tubes a little cotton fibre, a bit of white linen, and a piece of the pith of a sunflower, and cover them with water. Note the effect, if any; then pour off the water and cover them with alcohol. Empty the alcohol, and cover them with hydrochloric acid.

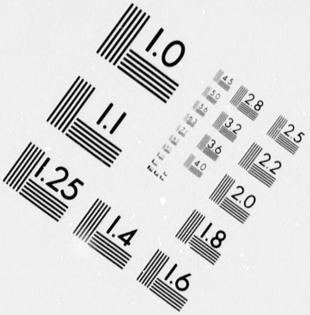
Slowly heat a dry piece of each of the substances above mentioned in a test tube closed by the finger. Clear drops of water collect on the inside of the tube, while a black mass of charcoal remains in the bottom.

Each of these substances, then, must contain carbon and the elements of water—hydrogen and oxygen. This means that the molecule of each contains one or more atoms of carbon, hydrogen, and oxygen, respectively. The wood of plants is mainly composed of a substance called *cellulose*, consisting of these three elements. Cotton and linen fibre and dry sunflower pith are nearly pure cellulose.

With a knife or grater, reduce a small potato to a fine pulp. Place the pulp in the middle of a piece of *thin* cotton, and draw together the edges so as to form a little bag with the pulp in the bottom. Take a saucer of water, and by alternate dipping and squeezing, without using much force, try to get out of the pulp anything soluble which it may contain, or anything which is in a sufficiently fine state of division to pass through the meshes of the cotton.

When this has been well done, stir the water, and pour it, and everything which it contains, into a slender bottle





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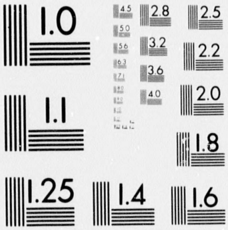

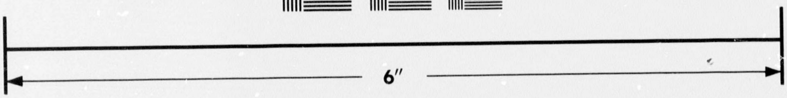

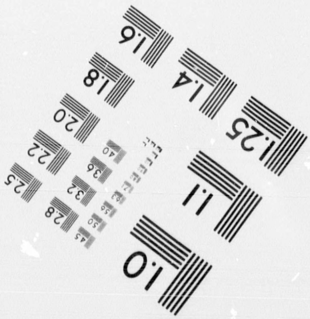

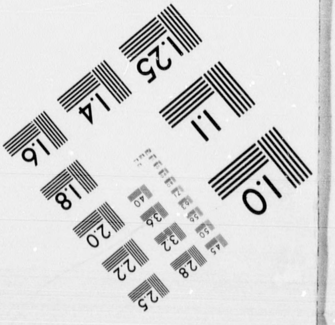

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or into test tubes. Soon a white solid substance will have settled to the bottom. This is evidently insoluble in cold water.

Pour off the liquid over it into test tubes. Boil a little of this white substance with fresh water, in a test tube. Mix with water a small portion of the jelly-like mass which results. Put in two or three drops of tincture of iodine—a solution of iodine in alcohol. A new and bright color should appear.

Treat a bit of starch in a similar way with cold and hot water, and tincture of iodine. Facts will justify the inference that the white solid which came out of the potato is *starch.* How, being insoluble, did it pass through the cotton? It is *granular*—made up of little grains small enough to make their way through the meshes.

Heat slowly a piece of thoroughly dry starch in a closed tube. What collects above the starch on the inside, and what is the dark substance which remains in the bottom? You will conclude that each molecule of starch contains one or more atoms of carbon, of hydrogen, and of oxygen.

Cellulose and starch are ternary compounds; they are called, from their elementary composition, *carbohydrates*—the first part of the word denoting carbon, the middle part hydrogen, and the termination *ate* oxygen.

Warm with the flame of the spirit lamp, in a test tube, some of the liquid which was poured from over the starch. Before the water has begun to boil, a substance, which evidently was dissolved in the cold water, will solidify in the warm water. This substance, so plainly different from starch in its properties, must also have come out of the potato. It is known as albumen (Lat. *albus*, white), although, from the presence of foreign substances, it does not appear to be quite white.

Mix wheat flour with enough water to make a lump of stiff dough as large as a small apple.

Put this dough into a thin cotton bag. Dip it in water and squeeze it repeatedly in the same manner as the potato pulp. Stir the water and pour it into a test tube. Identify the substance which settles to the bottom. Spread the bag open, and examine the part of the flour which did not pass through into the water. Although it is insoluble like the substance which passed out, it differs from it in being sticky, and in admitting of being drawn out into strings which contract when they break. This substance is called *glutin* or *vegetable fibrin.* These names, it will be noticed, were suggested by its properties. Upon slowly heating dry albumen and gluten, it will be found that they both contain carbon. We shall not be able to show experimentally what other elements are in them. They have, however, been found to contain (besides carbon) hydrogen, oxygen, nitrogen, and a little sulphur, i. e., the elements of the carbohydrates and two more. They are called *albuminoids*, *nitrogenous substances*, or *proteids.* Note the suitability of the first two names; that of the third is not so apparent in the present state of our knowledge.

Call attention to the fact that sugar is another substance found in plants. Treat a little sugar with hot and cold water. Heat a few grains of it slowly in a closed tube. What elements must be in it? It is plainly another carbohydrate.

The pupils will be able to mention substances found in plants which differ in some of their properties from any we have examined. Indeed, there are many other vegetable substances—some carbohydrates, some albuminoids, some oils, some acids, etc.; but those we have considered make up the greater part of most plants.

Hold a green leaf by one edge, keeping the farther part in the flame of a spirit lamp, and carefully observe the visible changes. The part of the leaf exposed to the fire first dries, then blackens, and lastly whitens. Do your best to burn the white film which remains. This incombustible material, or *inorganic* matter, is the *ash* of the plant. Burn other portions of plants in the same way.

Procure some ash from a stove. Mix the ash with water. A part of it settles to the bottom. Dip a piece of red litmus paper into the water above it. The effect shows that part of the ash is soluble in water, and also that this soluble part contains a metal.

The ashes of plants have been found, by analysis, to consist mainly of the salts and oxides of various metals. Hence we speak of the ash as *saline* matter.

But what became of the carbohydrates, albuminoids, oils, etc., when the plants were exposed to the fire. They must have been consumed. These combustible substances are called *organic* matter. What was the black substance which was the last to burn? Which is greater in amount in the plant—the organic matter or the ash?

SECTION II: THE FOOD OF PLANTS AND ITS ASSIMILATION.

Upon inquiry, your pupils will tell you that a full-grown plant has much more matter in it than when it began its existence, and that this matter must have been obtained from its surroundings — from its *environment*.

They will also notice that the soil and air, with the water which falls from the air, constitute the whole material surroundings of the plant. They will tell you that the organic substances in the plant — the starch, sugar, cellulose, albumen, gluten, etc. — are not found either in the air, water, or soil. It must be that the substances which the plant took in — its *food* — underwent chemical changes within the plant by which these organic compounds were produced. The changes which the plant food undergoes are denoted collectively by the term *assimilation*, since by them substances which differ from those in the plant are transformed into substances which are *similar* to them.

The pupils can easily be led to see that the food of the plant must contain the elements of starch, sugar, cellulose, and the other organic compounds which are the products of assimilation.

Examine a young plant — root, stem, and leaves. No openings can be seen through which the smallest particle of solid matter could enter. It is evident that a plant can only take in — absorb — liquid or gaseous matter.

Let us try to find out some of the substances which plants absorb. To make starch and the other carbohydrates the substances taken in must contain their elements — carbon, hydrogen, and oxygen. They cannot take in carbon by itself since it is quite insoluble. But the air contains carbon dioxide, a gaseous compound of carbon. Hydrogen is not, by itself, a constituent of either the soil or air. Water, however, which contains hydrogen and oxygen, is present in both the liquid and gaseous states.

These two compounds, carbon dioxide and water, contain, taken together, the same elements as starch. And further, water contains hydrogen and oxygen in the proportions in which they exist in starch. We remember that when starch was heated in a closed tube its hydrogen and oxygen immediately began to pass off together in the form of water, leaving carbon behind.

It is probable, then, that the plant absorbs carbon dioxide and water, and out of their elements forms the carbohydrates. Let us put this supposition to the test of experiment.

Twist the end of a small wire around a short piece of a taper. Fill a pan with water to the depth of about three inches. Set a pickle bottle, or other wide-mouthed bottle, with its mouth down into the water, and let it stand thus on the bottom of the pan. Bend the wire in the manner described for the preparation of nitrogen by the combustion of alcohol. Rest the bends below the end which bears the taper, on the bottom of the pan. The taper should reach a short distance above the water. Light the taper, and set the bottle mouth downward over it. As the taper burns, water will rise into the bottle. When combustion has ceased, quickly raise the bottle, and as soon as the water which has risen into it drops out, place the palm of the hand closely over the mouth of the bottle and turn its mouth upward. Remove the hand, pour in lime-water until the bottle is one-fourth full; close it tightly again and shake the lime-water through the gases.

The effect will show that carbon dioxide was produced by the combustion of the taper, which means that the taper contains carbon which united with the oxygen of the air in the bottle. The air, then, now contains little oxygen, but, instead, much carbon dioxide.

Burn the taper in two other bottles as before; but this time leave the bottles standing with their mouths under water. Get the taper out of the bottle by raising the latter in the water and drawing the taper out by the wire. Be careful not to raise the mouth of the bottle out of the water.

Prepare another bottle in the same way, and after removing the taper, push up into it, without raising its mouth above the surface of the water, a sprig of mint, or some other plant, with rootlets attached. Most of the leaves should reach above the water, and the roots should be immersed in the water. The plant may be as tall as the bottle.

It will be well to prepare three other bottles, using another pan, in the same way. Take two plants of one species, and two of another.

Set two of the bottles containing plants of the same species in a place where they will receive plenty of sunlight. Set the other two in a totally dark, but not a cold place, as in a trunk or close box. Let all the bottles remain with their mouths under water for six or eight days, then push a slip of glass under a bottle which had no plant in it, and turn its mouth upward. Lower into it by a wire a burning taper. It will be at once extinguished. Shake up lime-water in it, and in the other bottle which was left without a plant. The effect on the lime-water will be the same as in the bottle in which the taper had just been burned. Explain the results.

Remove the plant, without allowing air to enter, out of one of the bottles which was left exposed to the light. Then slip the hand under the mouth of the bottle and invert it, allowing the water in it to fall to the bottom of the bottle. Quickly lower a lighted taper into it by means of a wire. The taper should continue to burn for some time. Remove the plant in the same way from the companion bottle; but raise it above the water before placing the hand upon its mouth that any water which is in it may fall out. Then shake through it some lime-water. The water should remain clear. Account, as far as you are able, for these results.

Since the carbon dioxide remained in the bottles which contained no plants, and disappeared from those in which plants had been placed, we must conclude that, in the latter case, the plants absorbed that gas. And since there was oxygen enough in the latter case to enable a taper to burn, although all, or nearly all of it, had been previously removed by the combustion of the taper, we are led to conclude that the plant gave out oxygen.

Fill a bottle, in which a number of fresh leaves have been placed, with rain-water or water from a stream, which, since carbon dioxide is soluble in water, must have taken in some of that gas from the air. Invert the bottle with its mouth down in a saucer of water, and expose it to direct sunlight. Bubbles of gas will collect upon the leaves and will readily ascend in small bubbles to the surface. What gas is it?

Prepare another bottle similarly, using water from which the carbon dioxide has been expelled by boiling. No bubbles of oxygen will be given off from the leaves.

When the leaves, then, can get no carbonic acid gas they cease to give off oxygen.

It seems that the oxygen which is evolved from a plant comes from the carbonic acid gas which it absorbs; that is, the plant decomposes carbon dioxide and gives off its oxygen, retaining the carbon. By careful manipulation, the oxygen from the leaves may be emptied upward into a vial or small test tube. If a hardwood splinter, with a glowing tip, be plunged into it, active combustion will set in.

A leafy water-plant immersed in rain-water in an inverted test tube, will give off oxygen rapidly when held in the light.

Examine the gas now in the bottles which were set away in darkness. Find whether a taper will burn in one of them. Shake lime-water through the other. Account for the difference between these results and those obtained in the bottles left under the influence of sunlight.

Set a young cabbage, bean, or other plant, in a bottle, with its roots immersed in a solution of red ink or aniline dye. Account for the effects observable in the plant on the following day.

Allow the earth about the roots of two potted plants to become very dry. Water the leaves of one of them regularly for several days without wetting the earth. Apply the water to the earth about the roots of the other plant. What inferences may be drawn?

Stand a plant with only its roots in water. Set another top downward in a bottle. Put water enough into the bottle to cover the top and upper leaves, leaving the rest of the plant, including the root, immersed in air. Notice which of the leaves wither first, and draw the obvious inferences.

We have established pretty conclusively, by experiments and arguments, that plants absorb carbon dioxide out of the air by their leaves; that they absorb water by their roots, and but little, if any, by their leaves; that they take in by their roots substances dissolved in water; and that they exhale oxygen from their leaves. We have also found that the absorption of carbon dioxide and exhalation of oxygen only go on under the action of light.

It is now reasonably clear that the plant makes starch and the other carbohydrates out of carbonic acid gas and water. But these two substances contain more oxygen than is necessary for that purpose, since they *both* contain it, while in starch there is only enough oxygen to form water with the hydrogen. That is, there is sufficient hydrogen and oxygen in the water alone for the making of starch, and only the carbon of the carbon dioxide is required. *Its* oxygen is exhaled by the plant.

But the albuminoids contain two elements, nitrogen and sulphur, neither of which are present in carbon dioxide or water.

Now, so far as we know, the plant cannot build up *elements* into compounds. The food of plants consists of compounds, most of which the plant decomposes and builds up again into others more complex.

Although there is an abundance of nitrogen in the air it is of no direct use to the plant. Plants derive their supply of nitrogen mainly from the ammonia and oxides of nitrogen in the air, and salts of nitric acid — nitrates — present in the soil in small amount. The sulphur required for the production of albuminoids is supplied by the soluble sulphates. The most important of these is sulphate of lime (gypsum), which is slightly soluble, and is present in fine particles in most soils. These sulphates must be decomposed in the plant in order that their sulphur may be worked into the forming albuminoids.

Fill a small wide-mouthed bottle nearly to the neck with water. Make a hole through its cork just large enough to receive the stem of a plant of suitable size. Split the cork from one side into the hole, and push the stem of the plant through the cleft into the hole made to receive it. Close the cleft and lower the root of the plant into the water. Fit the cork tightly into the neck of the bottle. Turn a glass jar, or a larger bottle mouth downward over the bottle containing the plant. What collects on the inside of the larger bottle. Whence does it come? Explain the facts and reconcile them with what we had previously learned about the use of water as food for plants.

The pupils are familiar with the main facts of respiration in animals. They inhale oxygen and exhale carbon dioxide produced by the oxidation going on in nearly all parts of the body.

It can be demonstrated that a similar process, which may be termed *vegetable respiration*, goes on in plants. They absorb oxygen, which promotes oxidation in the plant, slightly raising its temperature; and carbon dioxide, produced by the oxidation of carbon in the plant, is exhaled.

It will be remembered here that plants absorb carbon dioxide, decompose it in assimilation, and give off its oxygen. But this process ceases in darkness, whereas respiration continues through the night. It is plain, however, that plants absorb more carbon dioxide for assimilation than they exhale as a product of respiration.

Explain why the presence of plants in a bedroom *may* be injurious to health.

CHAPTER III.

THE ORGANIC WORLD.

DIVISION II.—ANIMALS.

SECTION A: THE DEVELOPMENT AND LIFE HISTORY OF AN ANIMAL.

We have followed a plant from its beginning as an embryo through the successive stages of its existence. In a similar manner we propose to trace the life history of an animal. Of all kinds of animals, an insect will best suit our purpose. Its development is easily followed, and since its life is usually brief we shall not be wearied by waiting.

Caterpillars of various kinds are easily obtained. They may be brought to the school in bottles with some leaves from the plant on which they were found. This will probably be the plant—or one of the plants—upon which they feed.

A breeding cage may be made from a wooden box, each side of which is about a foot square.

Set the box with the open end in a vertical position. Cut a hole about four inches square in the side which is then uppermost. Cover the open end with wire netting or gauze, and nail a strip of wood, about three inches wide, at the bottom. Put in enough sandy earth to cover the bottom to the depth of three inches, and put in some dry twigs.

The caterpillars kept in this cage must be provided from time to time with fresh leaves from their food-plants. The earth should be kept slightly moist.

If properly cared for some of the caterpillars will shortly begin to make a little case, called a *cocoon*, in which to stay during the next stage in their development. If the insect constructs its cocoon above ground, it will be easy to watch its progress. Find where the caterpillar gets the material of which its cocoon is made.

Examine the contents of some of the cocoons. Compare the new form which the insect has assumed with that of the caterpillar.

Some caterpillars do not make a cocoon, but attach themselves to a stick or other support, and there undergo the change to the pupa state in open sight. In this inactive state the insect remains often for only two or three weeks, sometimes until the following spring. Then its final transformation into the winged state takes place.

If these winged insects be kept in the case for a while, and provided with suitable food, they may be induced to lay eggs.

We have now seen the four principal stages in the development of an insect. You will understand, however, that the *egg*, which has been mentioned last, is really the first state. The second form of an insect, of which the caterpillars are examples, is called the *larva* (plural, *larvæ*). The term *caterpillar*, strictly, is only applied to the larvæ of butterflies and moths. The larvæ of flies are called *maggots*, and those of beetles *grubs*.

The form into which the larva changes is called the *pupa* (plural, *pupæ*) or *chrysalis*.

The fourth state, in which the insect is usually provided with wings, is the *imago*.

If unsuccessful in carrying any one species through all these transformations, the whole history of the typical insect must be learned by piecing together the partial histories of two or more.

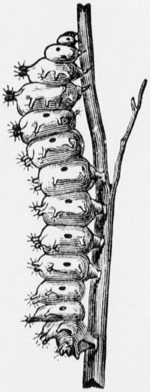
If it is desired to keep one species by itself, it may be kept in a pasteboard box, having a glass cover, and small holes in the sides for ventilation. A glass jar with a piece of gauze placed over the mouth also answers well. The bottom of the box or jar should be kept covered with damp earth.

In which of its stages does an insect partake of food? In which does it eat most greedily? In which does it grow? In what ways does it obtain its food in different stages? How does the food of the same insect vary in its different stages? What differing habits sometimes make an insect harmful to man in one of its states and useful in another? How many legs and wings has an insect in the imago state? Compare the eyes of an insect with human eyes. Find the row of little holes on each side of the body of an insect, which are the openings to its breathing organs. Allow the pupils to find, by individual observation, the answers to the preceding questions.

In country and village schools, at least, the life history of several species of insects may be traced. Four are selected as examples, the first for its size and beauty, the others rather on account of their fondness for human food-plants.

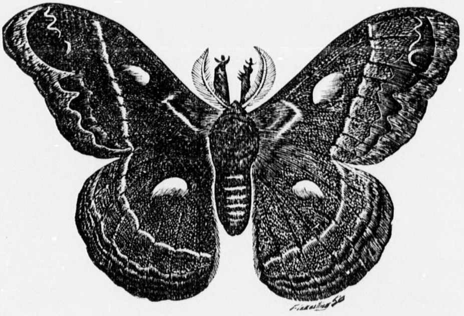
In the autumn, there may be found feeding on the leaves of the apple-tree a large green caterpillar, three or four inches long when full-grown, having its back set with warts or tubercles, some red, some yellow. If it cannot be found on the apple, it may be looked for on the plum, cherry, alder, and lilac. This is the larva of the *Emperor Moth.*

THE COCOON OF THE EMPEROR MOTH.



THE LARVA OF THE EMPEROR MOTH.

Place several of these caterpillars in the breeding cage, and supply them with leaves. Soon they will begin to build cocoons. The cocoon is double, of a brownish or grayish color, about three inches long, and an inch broad at the widest part. The space between the outer and the inner cocoon is occupied by fibres of silk. If you should not succeed in securing any of the caterpillars, the cocoons may be found upon the trees at any time during the winter or early spring. The chrysalis may be taken out of one of them for examination. The cocoons should be kept out of doors, or in a shed, during the winter. When winter is over, they should be brought into the schoolroom and placed in a breeding cage. About the last of May, the imago will come forth in all its beauty. Let the pupils watch its exit from the cocoon and the expansion of its wings. It is now a magnificent creature with wings extending, when spread out, six or seven inches from tip to tip. Note the colors and arrangement of the wings.



IMAGO OF EMPEROR MOTH.

This insect is closely related to the silk-worm moth, from whose cocoon is obtained the silk of commerce.

On visiting the garden, some morning in June, you will find the tops of certain young plants—cabbages, beans, or onions perhaps—lying on the ground looking as if they had been cut off near its surface. Slowly scrape away the earth about the stump and you will find the culprit—a greasy-looking, brownish or grayish caterpillar. It coils itself up as soon as it is disturbed. It is known as a *Cut-worm*, for a reason now plain to you. Leave it lying on the surface of the ground, but keep your eye on it. Notice the course it pursues when it sets out to escape. Before it has entirely disappeared, take it again; and, with some of its kind, put it into a glass jar which has a little earth in the bottom.

Provide them with leaves from their food-plants. After a while they will cease to eat. Upon examining the earth in the bottom of the bottle, you will find that they have made cells for themselves, in which they have become transformed into pupæ. Take one of the pupæ by the head and note the behaviour of the other end. Leave the others undisturbed in their cells.

In a few weeks the imagos will appear. Note the distinctive characteristics of these moths, so that you will know them from others when you see them out of doors, or when they fly into the house at night attracted by the light. Find whether cut-worms ever destroy weeds. When do they do their work?

The *Potato Beetle*, improperly called a bug, is easily followed through all its transformations. The imagos may be seen upon the potato plant early in June. They deposit their yellow eggs in clusters on the under side of the leaves. The larva is yellowish in color, and has a row of black dots on each side. If allowed to live, it will descend into the earth to become a pupa. Put some well-grown larvæ into a bottle partly filled with earth, and feed them with potato

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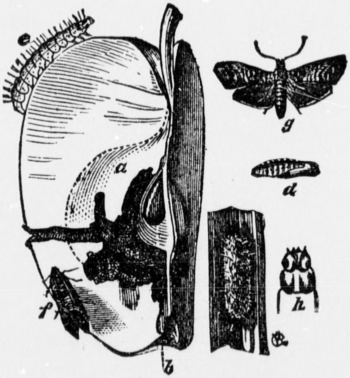
leaves until they pupate. Take some of the pupæ out of the earth. Notice whether the transformation is more or less marked than in the case of a butterfly or moth. Leave some of them in a bottle until they become perfect beetles.

Trace the life history of the insect whose larva is so destructive to apples by eating holes through them. Find where the larva enters the apple, and where it makes its exit. In autumn, before the apples are ripe, procure some fruit infested by these larvæ. Put a number of the apples into a box or jar along with some bits of wood. Examine the cocoons when finished, and then set them away in a cool place till spring.



This cut shows the transformations of the Codling Moth, its cocoon, and its burrowings in the apple.

The beautiful little moths which emerge from the cocoons will enable you to identify those of the same species which you will find flying about the apple trees, if you visit them at night with the lamp about the time the blossoms are opening in the spring. Find where, upon the young apple, this insect, the *Codling Moth*, deposits its egg. Also discover where they make their cocoons, and remain during the winter.

The honey-bee, the ant, and the mosquito, afford interesting subjects for study.

SECTION B: THE ADAPTATION OF FORM TO FUNCTION IN ANIMALS.

The domestic animals offer the best opportunity of studying the admirable correspondence of form to function in organized beings. Our observations will include the horse, cow, sheep, pig; the hen, turkey, goose, duck; the cat and dog.

Below will be found a list of topics and questions indicating the extent and character of the investigations to be made.

THE DOMESTIC ANIMALS:

Their Food and Clothing.
How do they take their Food?
How do they procure Food when not provided by Man?
How do they feed their Young?
In what position do they Eat?
How do they Drink?
How do they get Up and lie Down?
Which of them spend most time in Eating?
Which of them Ruminate?
What is the Cud, and what is its Use?

Which of them can Swim, Climb Trees, Fly, Perch?
Compare the Teeth of those which subsist on Vegetable Food with the Teeth of those which feed on Animal Food, and account for the difference.
Which of them have both upper and lower Front Teeth?
Compare the Feet, Toes, Ears, Eyes, and Noses of each species with the Corresponding Organs of all the others.
Which of them have relatively much longer Necks than the others? Of what advantage is this to them?
Which of their Limbs correspond (are homologous) to Human Arms, Legs, Hands, and Feet?
How do they express Pleasure, Anger, Grief, Fear?
In what Position do they Rest and Sleep?
How do they call their Companions?
How do they Attack other Animals?
How do they Defend themselves against Attack?

In making the observations indicated above, encourage the children to note for themselves the adaptation of form to function, and that for every difference in the habits of animals there is a corresponding difference in form.

SECTION C: THE DISTINGUISHING CHARACTERISTICS AND HABITS OF THE COMMON WILD BIRDS.

The birds enumerated below are so common and easily distinguished that every child, both in country and city schools, may learn to recognize them. It will not be necessary to kill any of them in order to identify them. Patient observation will overcome all the difficulties, and at the same time call forth patience, tact, and keenness of sight and ear; not to speak of the direct and indirect moral effects.

If four or five birds are learnt each year, the list will be mastered before the pupil leaves the common school.

City schools may take advantage of natural history collections to supplement their more limited opportunities for field work.

Learn to recognize the different species in as many ways as possible—by their plumage, their songs, their modes of flight, etc.

Observe closely the nesting and feeding habits of each species, the difference (if any) in plumage between the males and females, and discover which are migratory, and which resident throughout the year.

1. The American Robin is so well known that no description is necessary.

Our Robin is a member of the Thrush Family, of which two or three other species are quite common.

The Swamp Robin, or Hermit Thrush, is much shyer than the common Robin, and does not frequent the open fields. Its under parts are mostly white, but the throat and breast are speckled with dusky spots.

The Robin of England—"Redbreast"—is quite a different bird from ours.

2. The Black-capped Chickadee lives with us throughout the year. It is a small bird, mostly ash-colored above, with the top of the head, the chin, and throat black. The Chickadees prefer to go in small companies. The usual note, *Chick-a-dee*, *dee*, *dee*, is quite familiar.

Find what it is looking for as it inspects the stems of trees so carefully. Is it doing good to itself alone, or to the

BLACK-CAPPED CHICKADEE.

trees also? Does it ever run about on the ground?

The Chickadee belongs to the Titmouse Family.

The Hudsonian Chickadee is less common with us than the Black-capped. It is brownish above, without any black on the head.

3. The Summer Warbler, or Golden Warbler, is abundant among the willows and low shrubbery along the banks of streams. It is common, too, in the trees and bushes about houses, and in the parks and streets in towns and villages. It is the yellowest bird we have. Its back is olive-yellow; under parts mostly golden-yellow, streaked with orange-brown on the breast and sides. The wings and tail are dusky, but there is no black about the bird.

We have several other species of the Warbler Family during the summer. They are all small birds, generally not more than five or six inches in length. As a rule, they spend most of their time in trees or shrubbery, attracting but little attention from man notwithstanding the bright colors which adorn most of them.

4. The Cedar Waxwing is a beautiful and gentle bird. Its plumage is very soft and smooth. The fore parts ot the body, both above and below, are of a brownish-ash color, which acquires a pale reddish cast towards the bill, and behind shades off into clear ash above and into yellow

below. The bill is black, and there is a black strip running back to the eyes. The wing is mostly blackish-ash. The tail is tipped with yellow. From its crested head, it is sometimes known among boys as the "Top-knot Bird."

Some of the wing feathers are frequently tipped with red waxy-looking appendages, not large enough, however, to be noticed unless the bird is quite close to the observer.

The Waxwings usually go in flocks. In the spring a company may sometimes be seen regaling themselves upon the old but juicy fruits of the mountain ash. Later, they frequent orchards, whence they are locally named "Apple-birds." They are said to destroy large numbers of canker-worms and other insect enemies of the apple. Spare them, then, even should they sometimes indulge in cherries and other small fruits.

5. The Purple Martin is about as long as the Waxwing. The male is blue-black in color, very lustrous. The wing is nearly as long as the body. The tail is forked. It resides while with us in "martin-houses" erected by man for its accommodation.

The Martin belongs to the Swallow Family.

We have four other species of swallows. The tail is usually plainly forked; their wings are always long and flight swift. The Cliff Swallow usually builds its mud nests under the eaves of barns, whence it is called the Eaves Swallow.

The Barn Swallow nests inside of barns, fastening its nest to a beam or rafter.

The Tree Swallow nests in holes in trees, fence-posts, etc. Its body is lustrous green above and white beneath.

High sandy banks may often be seen pierced with many rounded holes. These are the entrances to tunnels which lead to the nests of the Bank Swallow.

6. The Song Sparrow is one of the first feathered singers to arrive in the spring. Its silvery notes may be heard on sunny April mornings while the snow still covers the forest lands, and lies in patches in the open fields.

It is a grayish streaked bird, with usually a brownish blotch on the throat. There is no yellow about it, and but little white is shown. It is commonly called a "gray-bird;" but that name is applied, by those who are not close observers, to several species of sparrows.

The "gray-bird" which is most likely to be confounded with the Song Sparrow is the Vesper Sparrow or Grass Finch. It differs somewhat from the Song Sparrow in size, color, and song, but may be most readily distinguished by the two white feathers which show at the sides of its tail when it flies. Both species frequent fields and roadsides.

7. The Chipping Sparrow is a very small "gray-bird." Its crown is reddish-brown. The throat and belly are grayish-white without streaks or other markings. Its song is a mere chipping. It is very familiar in its habits, and will allow the observer to approach, as it hops about the roadside, near enough to see its brown cap.

The Savanna Sparrow is another "gray-bird" smaller than the Song Sparrow. It frequents intervales and low meadows. It has no brown cap; but a light streak over the eye, upon close approach, is seen to be yellow. It has a musical, but *very weak* song, by which it may be easily distinguished.

8. The White-throated Sparrow is familiarly known as Old Tom Peabody—a name suggested by the number and grouping of the syllables in its song. It is mostly grayish and reddish-brown above. The crown has two broad

black bands, separated and bordered by narrow white stripes. The throat is pure white, bounded by dark ash on the breast and sides of neck. The light line in front of each eye and on the edge of the wings is, upon close view, seen to be yellow.

9. The English Sparrow is another "gray bird"; at least, the female is. The black throat of the male distinguishes him at sight from the female. Unlike the native sparrows, they reside with us through all the seasons. They are very familiar, frequenting in flocks, yards, and gardens, and the streets in towns and villages.

10. The Purple Finch is much smaller than a robin, but slightly longer than the larger sparrows. Its prevailing color is rose-red above and in front below. The red deepens into crimson on the crown, and is striped with brown on the back.

The female and young are quite different in color, but they may be known by the company they keep. The Purple Finch is a fine singer.

AMERICAN GOLDFINCH.

The male of the Pine Grossbeak is also red, but is much larger than the Purple Finch. The Grossbeaks remain with us during the winter, and mostly go north in the spring, whereas the Purple Finches leave for the south before winter sets in.

11. The American Goldfinch is mostly yellow above and below. The crown is

black. The wings are black, with strips across them formed by the white tips of the shorter feathers.

The Goldfinch is frequently known as the "Thistle-bird" or "Wild Canary."

12. The slate-colored Junco resembles a sparrow in shape and size. It is of a dark ash color above, and on the throat and breast. The white of the under parts meets the dark color of the breast in a definite line. It shows two white tail-feathers when it flies.

Junco returns to us very early in the spring—usually near the first of April. It is often called the Blue-bird, but is very different from the true Blue-bird, which is rare with us, at least in most localities.

The Sparrows, Goldfinch, Purple Finch, and Junco belong to the Sparrow Family.

13. The Bobolink, in spring plumage, is mostly black. There is a cream-colored patch on the back of the neck. The shoulders, and the back near the tail, are grayish white. The tail-feathers have pointed tips. It is much smaller than a robin, but larger than a sparrow. (See illustration on next page.)

In this country, the Bobolink frequents intervales, low meadows, and river-islands. It belongs to the Black-bird Family.

Three other species of the Black-bird Family are quite common. The Red-winged Black-bird and the Rusty Black-bird are birds nearly equal in size to the Robin. The former has scarlet shoulders; the latter is black throughout in the spring, in autumn rusty-colored. The Crow Black-bird, or Purple Grackle, is considerably larger than a Robin. Its head and neck are blue, with a brilliant metallic lustre.

Bobolink, male and female.

14. The Common Crow will speak for itself.

15. The King-bird is blackish-ash above—darker behind and on the head. A bright red spot on the crown is seldom seen, being concealed by the dark feathers. The throat and under parts are white. The tail is tipped with white.

The King-bird is smaller than a robin, but a little larger than a bobolink. Observe its habits, and you will learn how it got its name. It belongs to the family of Flycatchers.

We have several other species of Flycatchers, most of them considerably smaller than the King-bird, and difficult to distinguish.

16. The Night-Hawk is a dark mottled bird with a conspicuous white mark on each wing. It is usually seen upon the wing—in the dusk of the evening, and on cloudy days. It is not a hawk—not a bird of prey at all. It belongs to the Goatsucker Family.

The Night-Hawk is closely related to the Whip-poor-will—a bird we seldom see, as it is strictly nocturnal in its habits.

17. The Chimney-Swift resembles a swallow so much in its form, voice, and mode of flight that it is commonly called the Chimney "Swallow." It is a brownish-black bird, with a short blunt tail by which it may be distinguished from a swallow. It builds its nest in chimneys. It is the only member of the Swift Family which visits us.

18. The Belted Kingfisher frequents lakes and wooded streams. It is as long, or slightly longer, than the Crow Black-bird. It is dull blue above, and has a band across the breast of the same color. The rest of the under parts is white. It has a long crest on the back of its head. Its bill is long and stout.

A fair knowledge of the eighteen birds described above may be taken as the minimum attainment. In favorable localities, something may be learned about the birds referred to in the small print—also about the Humming-bird, the Woodpeckers, Jays, Owls, Hawks, the Bittern, the Heron, Gulls, Snipes, etc.

OTHER ANIMALS.—Some acquaintance with our other native wild animals, inhabitants of land and of water, should be gained during natural history excursions.

CLASSIFICATION OF ANIMALS.—It is not possible for the children in attendance at the common schools to acquire a sufficiently extensive and exact knowledge of animals to enable them to make out a general classification of them. The teachers, however, should frequently call their attention to the more evident relationships among the animals they observe, and lead them to notice that some are more highly organized than others.

SECTION D: KINDNESS TO ANIMALS.

Happily, human life is now held sacred among us, and human suffering excites general sympathy; but we are still, speaking generally, careless of the lives and feelings of the lower animals. Soon, if man keeps up the needless slaughter which is now going on, scarcely a remnant will remain of the nobler wild animals of the earth, while its birds of song and bright plumage will be practically exterminated.

The gentler brute creatures have found in man not a benevolent lord, but a sanguinary tyrant. The only friend they can depend upon is God. "One of them shall not fall to the ground without your Father."

Much of the cruelty practised by children is due to thoughtlessness. In such cases the mild appeal of the teacher will at once prove effectual. Sometimes ignorance is the cause. For instance, snakes and salamanders are generally looked upon as venomous reptiles. None of our snakes, however, possess poison fangs. Salamanders are not lizards, as they are often called, but harmless relatives of the frog and toad.

But we may trace still more to *heredity*—to lamentable survivals from barbarous ages. Each of us can do something to hasten the time when men will cease to regard the pursuit and death of defenceless, terror-stricken animals as "sport," and when women will no longer wear as ornaments the remains of harmless birds. The gentle deer may yet roam our woodlands in peaceful security, and many sweet-voiced birds, in happy confidence, build their nests in the shrubs and trees about our homes.

BOOKS FOR TEACHERS.

In addition to the prescribed texts, teachers will find the books included in the following list very helpful in preparing themselves to deal with the Nature Lessons intelligently and effectively:

1. Common Minerals and Rocks, by W. O. Crosby. Paper, 25c.; cloth, 60c.

Gives a brief account of the agencies through which rocks are formed, describes the principal kinds of rocks, and the commoner minerals found in them.

2. Tables for the Determination of Common Minerals, by W. O. Crosby. Boston: J. Allen Crosby. Cloth, $1.25.

Contains, in a brief form, much useful information about minerals, and tables by which some two hundred minerals may be determined mostly by easy physical tests.

3. A First Book in Geology, by N. S. Shaler. Boston: D. C. Heath & Co. Boards, 70c.

A very plain and readable book, quite easily understood by beginners.

4. A Compend of Geology, by Joseph LeConte. New York: American Book Company. Cloth, $1.20.

A good book to get after reading No. 3. It uses more technical language, but is an excellent summary, and finely illustrated.

5. A Manual of Botany. Spotton's Botany, price $1, will answer very well.

6. Gray's Manual of Botany with Lessons, price $3, describes a greater number of plants, and the descriptions are more detailed.

7. Insects Injurious to Fruits, by William Saunders, Director of the Experimental Farms in Canada. Philadelphia: J. B. Lippincott & Co. Illustrated, $2.

Describes many of the commoner insects, and gives an account of their habits. An excellent work.

8. My Saturday Bird Class, by Margaret Miller. Boston: D. C. Heath & Co. Boards, 30c.

9. Some Canadian Birds, First Series, by Montague Chamberlain. Toronto: The Copp, Clark Co. Boards, 30c.

These two cheap little books would be very useful to any one beginning the study of birds. They contain descriptions and engravings of a good many of our commoner birds, including, however, some not found in the Maritime Provinces.

10. Handbook of Birds of Eastern North America, by Frank M. Chapman. New York: D. Appleton & Co. Cloth, $3.

Contains a very complete account of the birds of the eastern part of the Continent, with keys to aid in their identification. It is well illustrated.

11. A Popular Zoology, by Steele and Jenks. New York: American Book Company. Cloth, $1.50.

This book gives a general account of the Animal Kingdom. It contains much interesting information, and is profusely illustrated.

12. Hand-book of Zoology, by Sir J. W. Dawson. Montreal: Dawson Brothers. Cloth. This is a popular guide to Canadian Zoology. It is fully illustrated.

13. Lessons in Elementary Physics, by Balfour Stewart. Macmillan & Co. Illustrated, $1.50.

The author desires to convey his thanks to those friends who so efficiently aided him in the preparation of this volume. Both the author and publishers especially acknowledge their obligation to Mr. G. U. Hay, editor of *The Educational Review*, of St. John.