SCIENCE IN THE SCHOOL

A COURSE OF EXPERIMENTAL SCIENCE AND NATURE-STUDY

WITH TEACHING HINTS

BY

W. J. GIBSON, M.A.

EDINBURGH
H. & J. PILLANS & WILSON, 86 HANOVER STREET

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W. J. GIBSON, M.A.

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"I should look upon the day when every schoolmaster throughout this land was a centre of genuine, however rudimentary, scientific knowledge, as an epoch in the history of the country."—HUXLEY'S *Lay Sermons.*

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INTRODUCTORY NOTE.

The Scheme of Work and Notes here given were first printed for the purpose of affording the Students of the Teachers' Science Class recently held here a connected outline of the work done by them, and of such extensions of it as they might be disposed to undertake, by themselves or with their classes, on the same lines. It has been suggested to me that though the Notes are only of a tentative and suggestive character, they might find a wider circle of readers among teachers and students in training who are interested in the school teaching of science: hence this reprint.

The course in Experimental Science outlined in pages 6 to 44 makes little claim to originality; it follows in the main the tradition common to the laboratories. But the proofs have been read by one or two expert friends who have kindly allowed the work to benefit by their suggestions, although they are in no wise responsible for the defects that still remain.

The special feature of the course, which may perhaps justify its publication, is the attempt made in the last forty pages to connect with the experimental work of the laboratory a simple regional survey of the school district. In showing how this can be worked out it has been necessary to deal with a particular district, and the details given relate to Lewis; but similar methods can be applied whatever the district. The simple tables of classification given are such as may serve for school use, and the extracts from the students' notebooks printed in the Appendix may be found suggestive by teachers carrying out class excursions.

Should this booklet contribute, however slightly, to help forward the present movement among teachers to bring their pupils into direct contact with nature, I shall be pleased.

W. J. G.

STORNOWAY, 1*st September* 1905.

SUMMARY.

FOREWORD.

TO stir up the pupil's interest in the common things around him and his own relation to them, to train him to habits of exact observation, and to cultivate his power of expressing clearly and accurately what he sees—these are some of the chief aims of nature-study and science instruction in schools. The pupil's means of expressing what he sees will be made as wide as possible, and will include not only oral and written language, but drawing and modelling. The science work in the school laboratory involves in addition a training in careful manipulation, with the accompanying ingenuity which copes with foreseen and unforeseen difficulties of conditions. Above all, the work, both in laboratory and field, gradually strengthens in the pupil the power of independent thought, the ability to reason from cause to effect, and that attitude of mind, an important equipment for future life, which leads to the ready recognition and honest rejection of plausible fallacies.

As a final result of his school training the pupil should have laid the foundations at least of an intelligent knowledge of living things, and of their relation to one another and to their surroundings, and should have become acquainted with the methods by which such questions are investigated. But this involves a preliminary study of matter and of the forces acting upon it; in other words, before biological study can be successfully attempted some knowledge of physics and chemistry is necessary. The amount need not be very great, but the method of acquiring it must be sound. Further, to obtain any proper appreciation of physical and chemical changes, fairly accurate quantitative work is essential, and this involves, though only as a means to an end, a preliminary training in the making of exact measurements. A knowledge of the methods of measuring extension (length, area, volume), mass, density, time, circular movement, degree of heat, and the like, and practice in using the instruments of precision by which these are reckoned make a necessary first claim on the young student.

The science course seems naturally then to embrace

(1) Exercises in preliminary measurements, including a ready use of the balance,

(2) Experimental work in physics, at least to such extent as will make possible what follows, viz., an intelligent study of the meteorological phenomena, and of

(3) The chemistry of air and water.

With this physical and chemical knowledge the student is ready to attempt

(4) A series of observations on some living thing, preferably plant as well as animal—its life-processes and its relation to other living things and to its surroundings generally. This work clears the way in the student's mind for some understanding of his own life-processes and relation to his environment, and may be profitably followed by

(5) A simple regional survey of his own district, in which its detailed geography in the widest sense will receive his attention. In studying the build and surface of the neighbourhood he makes some acquaintance with geology and applies his laboratory work in meteorology; the variety of its flora and fauna shows him the need for scientific classification, and gives him an opportunity of becoming acquainted, in outline at least, with the ascending ladder of plant and animal life. Lastly, the study of even a small district shows him how man, in his distribution and his industries, is related to his surroundings and influenced by them.

With regard to a course of this kind, certain questions arise. Does the width of the course not encourage superficiality? Would it not produce better and more thorough work to take one science, such as chemistry or botany, and devote all the time available to it rather than to a general course of science? Doubtless, by doing so, much more knowledge would be obtained of the branch studied, but the acquirement of knowledge is not the first consideration in the school study of science; rather is it the development of faculty—the power to observe, to experiment, and to reason from these. The width of the course, too, is necessary. For at least three different kinds of observations and experiments are required, if the training is to be of a fairly representative character:—

(1) those that at the end of the investigation leave unchanged, as regards constitution, the materials used (Physics);

(2) those that result in a change in the composition of the materials employed (Chemistry);

(3) those that involve physical and chemical changes, but these occurring under the influence of the vital forces (Biology).

Further, though the student has not gone far in each branch, he is understood to have done thoroughly and by the best method what he has attempted, and he leaves school in the position to specialise in any branch as his needs dictate or his tastes induce, without finding that he has to unlearn anything or to alter his methods, and all the better equipped by his general training for intelligent specialised study.

Another question is as to the time available in an ordinary school course; for it has been assumed above that every pupil in school should receive some training in Nature-Study, and that all who complete a Secondary Curriculum should pass through a fairly extensive course in Experimental Science and Nature-Study. Can the present crowded curriculum afford the time? I think so, though every teacher knows how great the difficulties are. The method, however, is of more importance than the amount. In the Infant and Junior Classes two or three lesson-periods per week can quite well be spared for Nature-Study, and in Secondary Classes, if the Regional Survey be omitted, such a course as that indicated in these Notes will not take more than five hundred hours' work from boys and girls who begin it at the age of twelve or thirteen, and distribute the work over four or five years. The best results can be obtained only when the Nature-Study of the junior classes is arranged to lead up to the more definite science instruction of the older pupils. Most of the preliminary exercises in measurements also can be overtaken in the classes preparatory to the secondary stage.

Other subjects of the curriculum, as Arithmetic, Composition, Drawing, Handwork, Mathematics, and Geography should be correlated as closely as possible all through the school course with the Nature-Study. These subjects and the science-study will alike gain by the union: children are too apt to keep their different branches of knowledge shut away from one another in watertight compartments.

With regard to the application to school work of the course here outlined, no part of it should be regarded as binding either as to matter or order; but the selection should be such as suits the needs and powers of the class, and whatever order is adopted should be coherent and logical. The smaller print interspersed throughout the notes contains suggestions as to methods of working or teaching, and cautions and hints of various kinds, some of which you will notice have been derived from our general class experience in working through the course.

I hope we all realise that there is no such thing as finality in method. If our teaching is to be effective our methods must always remain flexible and progressive: dogmatic attachment to the letter kills the spirit.

PRELIMINARY MEASUREMENTS.

A. EXTENSION.

(a) Length.

The need for a standard. The units of length—yard and metre—and their sub-divisions. The two methods of sub-division compared as regards their usefulness. What are the advantages of each? Yard, foot, and inch may be made familiar to children from a very early age. The metre may be introduced much earlier in a school course than is at present usual. When the units are known much practice should follow, the child first estimating the distance with the eye and writing down his result, then measuring and entering measured distance under estimated distance, thus:

Estimated distance	=	inches.	
Measured distance	=	inches.	
Difference = error of estimate	=	inches =	%.

The importance of taking several measurements will be apparent to them, and older pupils will accustom themselves to give the mean of several measurements, thus:—

1st Measurement	=	cms.
2nd Measurement	=	cms.
3rd Measurement	=	cms.
Sum	=	cms.
Mean of 3 measurements	=	cms.

No attempt to give a figure alone, without denomination, for a result should ever be let pass: pupils must realise from the first that the denomination is of more importance than the figures.

A good exercise for a class is to make their own units from laths, strips of paper, or pieces of string, using the class standard unit to settle the marking.

One or two simple experiments will show them the necessity for holding the rule in correct manner and placing the eye in the right position when reading the measurement.

1. Measure a metre in inches.
2. Measure a yard in centimetres.
3. Measure an inch in centimetres.
4. Measure your own height—Metric and English.
5. Measure length of span.
6. Measure circumference of wrist.
7. Make any other measurements of interest to the pupils.

Heights for members of class should be tabulated, the mean for the class found, and each student should compare his with the mean. In school each pupil could measure his height at intervals and prepare curve of his year's growth. His rate of increase could be compared with the mean for class. The curve of height could be compared with that for some other personal measurement, *e.g.*, chest girth.

Some standard measurements should be firmly fixed in the mind of the pupil, *e.g.*, he should measure and remember his own height, length of step (which by pacing can be used as a fairly accurate measure of distance), length of classroom, area of playground, the length of some neighbouring street, or distance between two well-known points. The height of the nearest tower or steeple should be used by the teacher as a standard of moderate heights and that of the nearest hill or mountain as a standard for geographical purposes. The height of Ben Nevis or Everest in feet does not convey any clear conception to the ordinary child; but if you can tell a Lewis boy that it would take eleven Cleishams (a mountain he can see from his own home) piled one on top of the other, to equal Everest, he has some real, if vague, notion of the height.

These measurement exercises afford an opportunity for the pupils to realise the limits of accuracy. An important conception for them is the idea of two limiting values—that one can say with absolute accuracy that a certain length lies between, say, 14·5 cms. and 14·6 cms., and that a finer scale may enable us to say that it lies between 14·57 cms. and 14·58 cms. When observed or measured quantities are being dealt with, the teacher has to discourage all unwarranted pretensions to accuracy, *e.g.*, do not let a class learn that the height of Everest is 29,002 ft. The 2 ft. is ridiculous; it pretends that the height of Everest, correct to something like ·007 per cent. is known!

Children are particularly prone to this pseudo-accuracy when their result is obtained through an arithmetical operation, *e.g.*, when finding the ratio of the circumference of a circle to the diameter they will go on dividing to the fourth or fifth decimal place, although their original accuracy of measurement may be such that the second decimal figure of the ratio is uncertain.

8. Make a scale to show inches and tenths, and one to show inches and sixteenths.

A series of scales of various kinds should be made as required for the geometrical drawing of the class. It will be found convenient before beginning the drawing to make the scale on a strip of paper or cardboard, and then to use it directly. In such a scale as that above, the zero mark should be at the second inch division from the left end. The inch to the left of the zero is the one on which the sub-divisions into 10ths or 16ths should be shown.

9. Measurement of straight lines, using rule and dividers.

10. Devices for measuring small lengths—diagonal scale, vernier, sliding gauge, micrometer screw. Make a line 4·27 inches, one 10·68 cms. long, etc., using diagonal scale.

The principle of the vernier will be best understood by making one, on a strip of cardboard or paper, to be used with the ordinary ruler. Similarly for diagonal scales, prefer to use those made by the pupils themselves. Before using the micrometer screw a series of exercises might be given on a common screw-nail. How much does its point move forward for four turns, for two turns, for one, for a half-turn, for a quarter-turn? What is the pitch of the screw supplied? The pupil will now be able to appreciate the micrometer screw and its use. The general principle here and in future experiments should be that a boy is not to use a piece of apparatus while ignorant of its construction.

11. Measurement of curved lines—using thread, dividers, tracing-wheel, pins and thread.

12. Measure diameter of a penny, of a halfpenny.

It will be noticed that the latter measurement will furnish conveniently one of the units in the English system.

13. Measure diameter of a cylinder by various methods, including the use of the callipers.

The use of accurately squared blocks of wood placed one on each side of the cylinder, as an aid in finding the diameter, will be apparent.

14. Measure diameter of sphere.

15. (*a*) Use triangle of millimetre paper (a readily made form of diagonal scale) to find internal diameter of piece of glass tubing.
(*b*) Take a tapering peg of soft wood and pare it down until the smaller end enters the tube. Press it carefully home, turning it round until it fits accurately the end of the tube. Take it out and measure with the micrometer screw the diameter of the compressed part.

Check-measurements by different methods should be used in this way wherever possible.

16. Measure diameter and circumference of circle, using for the latter (*a*) thread, (*b*) strip of paper, (*c*) rolling, (*d*) rolling with dot on margin, (*e*) any other method. Find ratio of circumference to diameter in each of the cases. Generalise.

A modification of (*c*) recently suggested gives good results. It is as follows:—On tracing-paper describe a circle using as fine a line as possible. Draw a straight line on a sheet of paper. Near one end mark a point. At any point on the circumference of the circle described on the tracing-paper make a mark. Place the tracing-paper over the straight line, making the two marks coincide. Press the point of a needle slightly through the point on the circumference of the circle, and using the needle-point as a pivot slightly turn the tracing-paper with the other hand so that a minute arc of the circumference may lie along the straight line. The tracing-paper should now be held steady with one hand while the needle-point is transferred to the new point in which circumference and line cut each other. Slightly turn the tracing-paper round this as the new pivot, and continue similarly until the point marked on the circumference again comes over the line. The distance between this and the point originally marked on the straight line gives the circumference

The ratio of the circumference to the diameter is so important that all the methods of measuring it known to the teacher should be employed; and various sizes of circles should be taken, small ones drawn on paper, and large ones with chalk and string on the classroom floor. Very large ones marked out on the playground by means of a peg and rope may be measured by the pupils, their feet being used as the unit of measurement. Results should be tabulated and the children given time to see for themselves that whatever the size of circle, whatever the unit, or the method, the ratio is always the same, the variations arising only from the amount of accuracy that can be applied in any particular case. It is only after this has been done, and they have found out for themselves that the best measurements give a value for π of 3·14. . . . that they should learn that its value, correct to the fourth place, as estimated by the most careful methods, has been found to be 3·1416. One will not omit at an early stage such questions as:—Is π a length? What is it then?

Circular Measure.—The trigonometrical definition of an angle is much better for school purposes than Euclid's, and even young children should become familiar with the idea that an angle ROP is "the amount of turning about the point O which the line OP has gone through in turning from the position of the fixed line OR into the position OP." The natural starting-point for measuring angles is one complete revolution. Describe a circle, draw one diameter, and through its middle point another straight line to divide into equal parts the two semicircles. Cut out one of the quadrants, and by superposition check the equality of the four. What amount of turning does a radius pass through in describing one of these quadrants? Having got the right angle it may be sub-divided into thirds, and each of these bisected to give sixths. With a very large quadrant this sixth may be divided by trial into fifteen equal parts, and so a practical conception of the degree as the unit of angular measure is obtained. The use of the radian as unit will follow. These exercises will naturally be taken as part of the work in mathematics. The construction and use of the protractor will now be understood. From cardboard or stiff paper various forms of protractor can be made—

the circular, semicircular, and quadrantal. Practice with the protractor, both in measuring and making angles, will follow, *e.g.*—

Measure the three angles of several triangles. What is the sum for each? Check this by clipping off and piecing together the three corners. Set off angles of 32°, 126°, 210°, 320°, 530°, 3π radians, etc.

(b) **Area.**

1. By counting squares find area of rectangle. Connect the area with length of two adjacent sides.

Perhaps the easiest way to arrive at this with young children is by arranging the length an exact number of inches and breadth another exact number, marking the inch divisions on the four sides and getting the children to rule straight lines to connect opposite points. This gives a network of inch-squares. If the pupil has started the exercise with a clear idea of what a square inch is, he can arrive at the area by counting the inch-squares. After he has worked out several rectangles of different dimensions the relation between the length and breadth and the area will strike him.

Establish (2) and (3) experimentally by cutting and piecing:—

2. The relation of the area of any parallelogram to that of the rectangle on same base. Hence method for calculating area of a parallelogram.
3. The relation of the area of a triangle to the area of rectangle on same base. Hence method for calculating area of any triangle.

The method of clipping out figures, superposing them, cutting them and piecing them together in various ways, is a helpful mode of investigation in the teaching of elementary geometry.

4. How will area of trapezoid be obtained?
5. How will area of any polygon be obtained?
6. Area of Circle. Describe circle on squared paper. Count number of small squares in area.
   Find ratio of this area to that of square on radius.
   Hence method of finding area of any circle.

In practice it is necessary to count squares for a quadrant only of the circle. The difficulty lies in counting the broken squares. These may be pieced together by eye to form whole ones, or another method is to reckon all over a half as complete squares and to neglect all less than a half. Both methods should be tried and the results compared. Children find it convenient to dot or stroke each portion as it is counted to prevent its being reckoned a second time. The results may be entered thus:—

Number of small squares in area of circle - - =
Number of small squares in area of square on radius =
Ratio of 1st to 2nd - - - - =

If the results obtained by the class be tabulated on the blackboard the pupils will readily suggest that this is a ratio with which they are already familiar. They have now found a formula by which the area of any circle may be calculated when once the radius, or, in practice, half the diameter, has been found. This formula is so important that the young investigators must be left with no doubt as to the correctness of their own generalisation. (7) and (8) will help to make them sure of this.

7. Divide a circle into a number of small triangles by drawing diameters. Cut out these in opposite pairs and paste them on paper to form a parallelogram. Measure area of parallelogram produced. Compare result with that obtained by calculation when the formula discovered in (6) is used.

   What measurement in the circle corresponds to the height, and what to the length of the parallelogram?

The result may be arranged thus:—

$$\begin{aligned} \text{Area of circle} &= \tfrac{1}{2}\ \text{circumference} \times \text{radius}. \\ \text{But circumference} &= \pi \times \text{diameter}. \\ &= \pi \times 2r \\ \therefore\quad \text{Area of circle} &= \frac{\pi \times 2r}{2} \times r = \pi r^2, \end{aligned}$$

which is the same result as that obtained by the methods under (6). In treating the built-up figure as a parallelogram what error is involved? Would the error be less or more by making the sections very small?

8. Describe two equal circles on the same piece of cardboard. Circumscribe square about one of them. Cut out portion equal to πr^2 (say $3\frac{1}{7}\ r^2$) as follows, (see Fig. 8):—Divide RO into 7 equal parts. Let OS be one of these: draw SX parallel to side of square. Cut out and weigh portion shown by shading. Cut out and weigh the other circle. Compare the weights. Is there any likely source of error in the material used?

9. What method would give approximate area of ellipse? Prove correctness of your method by weighing.

10. Area of irregular figures—
    - (*a*) by tracing figure on squared paper and counting squares;
    - (*b*) by tracing figure to scale on cardboard and weighing it and a rectangle of the same cardboard.

Further exercises in measuring irregular figures may be found, if desired, in some of the other methods employed for the same purpose, *e.g.*,

- (*c*) by finding the mean ordinate;
- (*d*) by Simpson's Rule;
- (*e*) by the use of the planimeter.

11. Find area of Lewis from ordnance survey map by methods (*a*) and (*b*) above.

(c) Volume.

1. Make paper models of cubic inch and cubic centimetre.
2. Build up a rectangular solid as follows:—Lay side by side a row of ten wooden cubes, each a cubic centimetre in volume. How many cubic centimetres does this row contain? To this add nine wooden rods, each ten centimetres long and one square centimetre in section. How many cubic centimetres does this slab contain? On it place nine slabs each 10 cms. in length and in breadth, and 1 cm. thick. What is the length, breadth, and thickness of the cube thus built up? How many cubic cms. does it contain? Hence establish general method of estimating volume of rectangular solids from three dimensions or from area of end and length.
3. Calculate volume of each of the rectangular solids supplied. Immerse each in water and find volume of water displaced.
4. Will the method discovered in (2) serve for finding volume of a cylinder?
5. Check volume of cylinder found in this way by measuring water displaced by cylinder.
6. Find, by measuring area of end and height, the internal volume of a hollow cylinder.
7. Check by measuring water the cylinder can contain.
8. Exercises in measuring volume of liquids. The English imperial pint. How many cubic inches of water in a pint? The litre. How many cubic cms in a litre? Find the equivalent of a litre in pints. Of a pint in decimals of a litre. Estimate by eye the quantity of water contained in a vessel. Check by measurement.
9. The use of graduated vessels for measuring volumes of liquid. The pipette and burette.

The need to keep the eye on a level with the mark in reading should be insisted on. In reading height of a liquid like water take the mark at the lowermost point of the curve; with a liquid like mercury that at the highest point of the curve. Why?

There is apt to be a good deal of confusion in the minds of pupils as to the burette, *e.g.*, they occasionally read the cubic cms. of volume as if they were cms. of height, instead of being thin cylinders of liquid of one cubic cm., each with its thickness depending inversely on the diameter of the burette tube.

10. Paste a strip of gummed paper longitudinally on a test-tube. By means of a burette graduate it to read cubic cms., and along the same strip mark in cms. a scale of vertical heights.

11. Do the same with a wider tube. What is the difference between the cubic cm. marks on this and those on the narrower tube of (10)? Inference?
12. From the given glass tube make and graduate a pipette.
13. Measure mean length of a given test-tube. By using burette or pipette find its internal volume. From these two measurements calculate diameter. Check your result by direct measurement of diameter.
14. A piece of copper wire is supplied. Measure length. Find volume by dropping it into burette. Hence calculate diameter of wire. Check result by measurement with micrometer screw.
15. A small piece of sheet copper is supplied. Find area. Find volume by burette. (What precaution is necessary in folding up the copper?) Hence calculate thickness. Check result by micrometer gauge.
16. Calculate length of wire spiral supplied, by measuring diameter of wire and finding volume by burette.

A variety of other similar exercises in mensuration may be given, the calculation part supplying material for the arithmetic lesson.

17. A square pyramid and a square prism of the same base and height are supplied. Calculate volume of prism. Find volume of pyramid by displacement. Find ratio of the volumes. Hence establish method for calculating volume of pyramids. If prism and pyramid are made of same material establish the correctness of the method by weighing.
18. Find by a similar method the ratio of the volume of a cone to that of a cylinder of the same base and height. Hence the general method of calculating volume of a cone.
19. Find the total surface of the square prism, square pyramid, cylinder, and cone, supplied.

If more difficult exercises of this kind are required they may be found in the investigation of surface and volume of the sphere and of solid rings.

20. Find by the method of displacement the volume of the irregular solids supplied.

B. MASS.

"*The balance is to be regarded as an instrument of moral culture, to be treated with utmost care and reverence.*"—Dr Henry E. Armstrong, F.R.S.

Some easily investigated property of matter is required, so that we may have a simple means of measuring the mass. Preliminary exercises in lifting various bodies and estimating the relative muscular strain involved in holding them up will call attention to the gravitation-pull on a body as a practical means of determining its mass. But weight (*i.e.*, gravitational pull) and mass (*i.e.*, quantity of matter) are not strictly the same. The amount of gravitational pull on a body as measured by a spring-balance is not quite the same near the poles as at the equator, but we cannot think of the quantity of matter in the body as having been altered by such a change of position.

1. What is the relative quantity of matter in two cubes of the same metal, each of one centimetre edge, as compared with that in one such cube?

   Take a piece of thin rubber cord and fasten a piece of string to each end. Suspend it, by one of the strings, from a nail driven into a strip of wood. To the other end attach a small tray such as can be made from a canister lid. Make an ink mark across the rubber cord near its lower end, close to the string, and a corresponding mark at the same level on the strip of wood. Place one of the metal cubes in the tray. Mark the level on the wood at which the ink mark on the cord now stands. Remove the cube and put into the tray the other cube which was equal in volume. Note where the mark now stands.

One method of finding equality of mass has now been discovered. Equal masses will stretch the cord to the same extent.

2. Place in the tray enough shot to stretch the cord to the same mark.

We have now got the same mass of lead as we had of the metal of which the cube was made, but have we the same volume?
This can be found out by applying the method of displacement.

Equal volumes of the same substance have now been found to have the same mass. Some unit of mass is required. The English standard unit is that of a certain mass of platinum and is known as the pound. The metric standard is also that of a certain other mass of platinum and is known as the kilogramme. The thousandth part of the kilogramme is the gramme, which is a convenient laboratory standard.

3. Take a piece of thin rubber cord and suspend it as in (1). Measure length of rubber cord between the two strings. Add successively loads of 5, 10, 15, 20, 25, 30, 35, 40, 45, and 50 gms., measuring the length of the cord in each case and enter up as follows:—

Load in gms.	Length of cord	Increase of length.

   Plot curve to show relation between weights and increments in length of cord.*

If thick rubber cord be used, a series of heavier weights will be taken.

* For Curve-Plotting see page 19.

4. Support a metre-stick at its centre on one of its flat sides. On one arm at 40 cms. from the point of support place one of the metal cubes formerly used. Start the other equal cube at the centre and move it outward on the other arm until it just balances the first. At what distance is it from the centre? Inference? Place the two cubes at 30 cms. from centre on opposite arms, at 25 cms., at 20 cms. Result? Is your first inference correct?

A convenient method, then, of finding equality of mass is by counterpoising.

The beam balance is seen from (4) to be a device for measuring the equality of the gravitation-pull on the two masses which are being compared.

Pupils should have an opportunity of understanding the main points of construction in a good balance. The agate bearings should be shown, and the pupils themselves will probably be able to suggest the object they serve. This preliminary consideration of the instrument need not take long, and will enlighten its users as to its delicacy, precision, and fineness of construction. The increased respect and care for the balances which may result is a development for which there is but too much need in the attitude of beginners.

Points to be attended to in using the balance :—

(*a*) The floor of the balance and the scale pans should be clear of dirt and perfectly clean. Dusting should be done by means of a large camel-hair brush.

(*b*) Level the base by means of the levelling screws.

(*c*) Raise the beam by turning the handle, and note whether the oscillations of the pointer are the same on the two sides of the zero of the index. The beam should be raised completely.

(*d*) Lower the beam again to its support. This must always be done before anything is placed in or taken from either pan.

(*e*) The substance to be weighed is not placed on the scale-pan itself, but is weighed in a watch-glass, porcelain basin, crucible, or whatever is convenient. This should be placed on the left hand scale of the balance. Avoid all moisture about the balance or case. If relative densities are being found, the outside of the vessel should be dry, and there should be no spilling of the water contained in it. If vessels are to be weighed that have been heated, they must be first cooled in a desiccator, and then transferred direct.

(*f*) The weights are to be placed in the right-hand pan. They are always to be lifted by means of the forceps, and are never to be touched with the fingers. They should always be either in the scale-pan or in the proper compartments of their box.

(*g*) Begin with a weight which is too heavy; then use lower weights of same denomination in succession, until you obtain a weight that is somewhat too small; then those of the next lower denomination in descending order.

(*h*) The weighing is complete when the pointer makes equal swings right and left.

(*i*) The weights should then be entered in the note-book from their empty places in the box, and this entry checked carefully with the actual weights as these are removed from the scale-pan. The entry in the note-book should not only show the weights used, but also what is being weighed, and the date should be added.

5. Find the weight of an ounce in grammes.
6. Compare weight of 3 pennies with that of 5 halfpennies.

Density.—What is the relation between mass and volume for the same substance, the conditions remaining the same? The density of a substance will be given by the mass of unit volume of the substance. Does the density of the same kind of matter vary when the conditions are unchanged? Have different substances the same or different densities

7. Weigh 3 pennies. Find by measurement the volume of the pennies. Any source of error in this measurement? Hence calculate the weight of a cubic centimetre (unit volume) of the bronze.
8. In a similar manner find weight of unit volume of the alloy of which our silver coinage is made.
9. Weigh a small dry beaker. Into it run from the burette 50 c.c. of water. Weigh. Hence calculate weight of one c.c. (unit volume) of water.

   (*a*) Use distilled water.
   (*b*) Use cold tap water, noting temperature during experiment.
   (*c*) Use warm tap water, noting temperature.
   (*d*) Use sea water.

Different pupils can try different waters, several trying each. Results can then be collected and tabulated, and conclusions drawn.

10. In the same way determine density (*i.e.*, weight of unit volume) of alcohol. To get very exact volumes, use the relative density bottle.
11. Determine density of (*a*) turpentine, (*b*) olive oil, (*c*) acetic acid, (*d*) petroleum.

Caution.—Do not let substances dealt with smear the fingers. Some persons, for example, have skins very sensitive to the action of turpentine.

Do you find that the density for the same substance is always the same?

12. Determine density of milk.

Do different samples of milk give the same density? If you find variations in the destiny, what do you suppose is the cause of these?

13. You are given a specimen of alcohol which is suspected of having been adulterated with water. Use the density test to settle the question.
14. You are supplied with small cubes of various metals, each of 1 cm. edge. Find the weight of each.

Tabulate the results of the foregoing experiments thus:—

Substance.	Weight of 1 c.c. in gms.	Relative density to that of pure water.
Alcohol - - -		
Turpentine - -		
Olive oil - - -		
Petroleum - - -		
Water (warm, tap) -		
,, (distilled) -		
,, (cold, tap) -		
,, (sea) - -		
Acetic acid - -		
Aluminium - -		
Zinc - - - -		
Iron - - - -		
Copper - - -		
Lead - - - -		

15. On each scale of the balance place a small dry beaker. Counterpoise them exactly. Pour alcohol into one of them until about half full. Pour water cautiously into the other, until they are exactly counterpoised

again. Then measure the volume of liquid in each. Of which is there most? Why? From this calculate the relative density of alcohol compared with that of water. Compare with that already obtained by direct weighing.

For further exercises in relative densities see Exps. 20 to 34, pp. 23 to 26.

C. TIME.

The notion of time arises from the observation that events succeed each other. A preliminary discussion with pupils will lead them to show the difficulty of obtaining a standard. They will, with questioning, suggest that the height to which the sun rises gives an indication of the season, that the changes of the moon give a shorter standard of time, and that the succession of day and night furnishes one of a still more convenient length.

1. Find the time from sunrise to sunset, and after an interval of a week or two repeat the experiment. Will the ordinary day serve as an exact standard?
2. Find similarly the time between sunset and sunset.
3. Set up a stick in the playground; measure the length and direction of the shadows at intervals during the day, trying not to miss the time when the shadow is shortest.
4. Observe the position of any well-marked constellation several times during an evening, noting its height above the horizon. Will such devices serve to measure the lapse of intervals of time shorter than a day? Will this measurement be approximate or exact?
5. Make a rough sun-dial by marking on ground position of shadow at the consecutive hours. Compare these with clock time after an interval of a few days.

The pupils by this time will have seen the need for a "mean solar day." How are the sub-divisions of this to be obtained? What simple forms of uniform movement can be used? Consider some of these, *e.g.*, the dripping of water, the running of sand, pulse-beats, the vibrations of a suspended bob.

6. Make a water-clock and graduate it by comparing with a watch. Does the rate of dropping remain the same as the vessel empties?
7. Take a piece of glass tubing $\frac{1}{2}''$ or more in diameter and about 6″ long. Draw it out in the middle in the flame to a fine bore. Stopper one end. Fill this end with fine, dry sand. Stopper the other end. Time it, adding or taking away sand until it runs out exactly

in half-minute, 1 cr 2 minutes, or other convenient interval.

8. Count your pulse-beats (*a*) sitting, (*b*) standing, (*c*) after vigorous movement.
9. The pendulum. Does the length of swing affect the number of beats per second ?

The pupils need to be paired for this, one taking the time, the other counting the beats. Count as the bob passes the middle point. Should the first one be counted as one? It is not necessary to count for the whole minute ; the beats may be counted for half-a-minute and doubled.

10. Does the weight of the bob affect the rate of vibration ?
11. Does the length of the string affect it ?
12. Count beats for ten or more different lengths of string measured in cms. Plot results on squared paper.*

If you are not sure of the exact form of the curve at any part of its course take such intermediate lengths of string as will supply the missing data. This pendulum curve makes a very good exercise for beginners in plotting and using curves. It yields useful exercises in interpolation. When the curve has been obtained such problems can be set as the following:—Find from the curve what should be the length of a pendulum beating 42 times per second ? 78 times ? How many times a minute will a pendulum 23 cms. long beat ? One 104 cms. long ? Each result is first read from the curve, and then checked by experiment. In this way confidence in the method of interpolation is established.

13. What length of pendulum will beat seconds ?

By this time the pupil will have confidence in the uniformity of rate of beat, and he has now a convenient means of measuring small intervals of time, as he has a unit which is $\frac{1}{24 \times 60 \times 60}$ or $\frac{1}{86,400}$ of the mean solar day.

Curve-Plotting and Statistical Geometry.

Pupils should get frequent practice in expressing graphically the observed results of experiments, as in the case of the pendulum observations (page 18). Squared paper should be constantly resorted to as a means of illustrating statistics of all kinds. Historical and geographical facts, as well as the more obviously suitable ones belonging to arithmetic and mathematics generally, are frequently rendered clearer and gain much in interest by such treatment. Whenever two variable quantities —population and time, prices and sizes, ages and insurance premium,

* For Curve-Plotting see below.

or whatever other form the statistics may take—which depend in some way on each other, occur, they are best investigated by the plotting of curves. Children should become so familiar with the method of plotting that they will of themselves have recourse to squared paper as a means of clearing up a subject. The chief difficulty with beginners is in the determination of the scale, and at first they require a good deal of help in this matter.

The following are suggested as typical exercises, but the pupils' work in Mathematics and Arithmetic will furnish abundant examples of the use that can be made of squared paper and of the graphs described on it.

1. Curves to show readings of barometer and thermometer.
2. Curves to exhibit any set of statistics, *e.g.*, the population of Lewis since 1851. Account historically for any irregularities in the curve.
3. Determine intermediate values from such a curve, and predict the population for a coming year.
4. Plot a curve from which cms. can be read in inches, and inches in cms. Curve to read sq. ins. in sq. cms.
5. Curve to show the relation of numbers to their squares. Include negative numbers. Interpolation exercises.
6. Curve to show the relation between the lengths of the string of a pendulum and the number of vibrations per minute. Exercises in interpolation.
7. The curve of a given equation.
8. Solution of simultaneous equations by means of curves.
9. Graphs as a means of exhibiting a railway time-table.
10. School statistics of various kinds.

Interesting suggestions on curve-plotting will be found in Lecture III. of Prof. Perry's "Practical Mathematics." (Published by the Board of Education, and obtainable through Oliver & Boyd, Edinburgh, price 6d.)

The three fundamental units—those of Length, Time, and Mass—in two different systems have now been considered. Some of these have been fixed upon arbitrarily, but most of them are connected with certain natural measurements—the metre, for example, is intended to be the 10,000,000th part of a quadrant of the earth's circumference, a gramme is the weight of a cubic cm. of pure water at a temperature of 4° C., and a second is the 86,400th part of the mean solar day.

Other units are derived from these fundamental units. Velocity, derived from length and time—1 foot or 1 cm. per second; acceleration—1 foot per second per second; units of force—the dyne (metrical unit), the force which acting for one second on 1 gramme of matter will communicate a velocity of 1 cm. per second; the poundal (British unit), the force which acting on one pound for one second will communicate a velocity of 1 foot per second. If a pound be let fall for one second it will be found to have a velocity of 32·2 feet per second; the force that has been acting has therefore been one of 32·2 poundals. Make and graduate a spiral spring to read the pulling force of gravity in poundals.

The experimental study of dynamics, *i.e.*, of force, if taken up, would naturally come in at this stage, preceding the work of the next section on the physics of air and water.

PHYSICS OF AIR AND WATER.

1. Note proofs that the air is something.

2. Glass globe with stop-cock supplied. Screw to air-pump. Exhaust and close stop-cock. Weigh. Admit air and weigh again.

3. Over mouth of a thistle funnel tie piece of rubber film, such as is used for toy balloons. The tying behind the lip should be such as makes an air-tight junction. Blow into funnel. Sketch and account for change.

Suck air out. Sketch and account for change.

Keeping finger on end of tube turn funnel about in various directions. Is there any change in shape of rubber? Inference?

4. Fill tumbler with water: place piece of stiff paper on top of tumbler: invert: take away hand: account for what happens.

5. Dip end of long glass tube into water. Suck gently at other end. What happens? Why? Try the same experiment using mercury. What difference do you notice? How do you account for it? Do not let the fluids experimented with reach the mouth.

6. Fill a tube about 33 inches long, closed at one end, with mercury. With finger on open end invert in cup of mercury. Remove finger when open end is under surface of mercury in cup. Note what occurs, and account for it.

7. Place tube at various slopes and note results.

8. Use same tube: attach to open end, by means of a piece of rubber tubing about 4 inches long, a piece of glass tubing about 6 inches long and open at both ends. Tie rubber tubing to both tubes. With closed end down, fill tube with mercury until it reaches the attached end of the short glass tube.

(*a*) Arrange the apparatus as in Fig. 9: note result.
(*b*) Blow into open end: note result in long tube.
(*c*) Suck part of air cautiously from open end: note as before.

Account for the changes noticed.

9. Use this apparatus as a barometer by affixing to any upright, and fixing beside it a yard stick as shown in Fig. 9. The stick should show inches and tenths, but a long strip of paper

can be used instead of the stick, and could show on one edge inches and on the other cms. What will have to be subtracted from the height of the column as measured, to get the height of the column supported by the pressure of the air?

10. Make barometer readings three times a day for a fortnight, and plot curve on squared paper. (Outdoor readings of thermometer may be taken at same time.) Note any connection you observe between rise and fall of barometer and changes in the weather.

11. Take glass tube of 7 inches length: bend into **V** shape at 3 inches from one end. Fill and invert short end in basin of water.

(*a*) Take finger away from each end.
(*b*) What effect is produced by moving the outlet end upwards and downwards?
(*c*) Take out, fill again and try long leg in and short one out.
(*d*) When the siphon has run out as much water as it will, pour in water gradually into the basin again until full. Note in each case what occurs, and try to account for it.

The following variation of the siphon experiment gives a good opportunity of studying its working and finding an explanation of its action. Fit a flask with a two-holed stopper provided with two tubes, a short one drawn out to a point which projects within the flask, and a longer one, the inner end of which just passes through the stopper. If the flask be filled with water and inverted over a vessel of water, into which the shorter tube dips, the whole acts as an ordinary siphon; but when air is made to occupy the greater part of the flask, and the water-level inside is below the pointed end of the tube inside, a fountain-jet is obtained, and the vacuum can be estimated by stopping the end of the outlet tube. In making the shorter tube, draw out the point as straight as possible. The most effective size of orifice will be found by a few trials.

12. Study the action
(*a*) of a common syringe,
(*b*) of a pump,
(*c*) of a force pump. Make sketches.

13. The action of the air pump.

14. Put alarm clock under receiver, timed to go off after air has been exhausted. Inference from result?

15. Given a glass tube 33 inches long closed at one end, a quantity of mercury, a cup, balance and metric weights, and a rule marked with millimetres

(*a*) Devise a method of measuring the amount of pressure of air on each square centimetre of surface.

(*b*) Hence calculate pressure on each square inch.

(*c*) Measure by any method you can devise, the total surface of one of your hands, and calculate the air pressure it sustains.

(*d*) Why is the pressure not felt as such?

16. Tie tightly the mouth of a child's toy balloon, slightly inflated. Place under receiver of air-pump. What occurs when the pump is worked? How do you account for it?

17. What effect is produced on the volume of a quantity of enclosed air when the pressure is increased? Bend a glass tube so that it may have a long and a short arm. Close the end of the short arm. Support in an upright position and pour in enough mercury to close the bend. Manipulate it until the mercury stands at same level in the two tubes. What is enclosed in the shorter tube? What pressure is it under? By adding mercury to the longer tube, what is the effect on the pressure? Is all the mercury in the longer tube effective for pressure? Measure height of effective column. What is the increase of pressure? What effect has this had on the volume of enclosed air? Note quantitative results of a series of experiments.

18. Fill with water, to about three-fourths, a narrow, straight glass cylinder, such as the graduated ones used for measuring. Into this invert an almost empty small glass phial containing just enough water to make it almost ready to sink. A few trials will give the correct amount. Pressing the lips on the mouth of the cylinder, blow strongly. What occurs, and why? The same principle is applied in the "Cartesian diver."

19. By means of a U tube determine the pressure of the gas supplied to the laboratory.

20. Bend a glass tube, 20 to 25 cms. long, into a U shape, making the bent part as even as possible. Support it vertically. Pour in a little mercury. Into one leg pour a little alcohol; into the other leg pour water. Add the water cautiously until the mercury is exactly in the middle of the bend, or if there is more of it, until the ends of the mercury are at the same level in the two arms of the tube. Now measure the length of each of the columns. Which is longer? Why? From this calculate the relative density of alcohol. Compare with result already found by direct weighing.

Notice that your U tube is in reality a kind of inverted form of beam-balance, the mercury index acting as the beam.

21. Use the U tube to determine the relative densities of the other liquids already experimented with, and compare the results with those previously obtained by direct weighing.

22. Attach two pieces of glass tube to a three-way joint, and to

its free end a rubber tube provided with a spring clip. Let the open ends of the two tubes dip into separate beakers, one containing alcohol and the other water. Suck cautiously until the two liquids have risen some distance in their tubes; then close clip. Measure height of the two columns. Which is higher? Why? Hence calculate the relative density of alcohol. Compare with previous results. The apparatus used in this experiment is known as Hare's.

23. Using Hare's apparatus determine relative densities of the other liquids previously experimented on.

24. Weigh one of the small metal cubes of 1 cm. edge supplied. Suspend it from the hook of the beam by a silk fibre, arranging under it a small beaker of water at such a height that the cube, hanging from its fibre, is entirely immersed in the water, even when the beam swings. What is the weight now?

Weight in air	=	gms.
Weight in water	=	gms.
Difference	=	gms.

25. Do the same with the cubes of other metals. Compare the differences found in each case. Is it such as indicates a cause common to all the weighings? What has been common to all the cases? Think over it and work out an explanation, then test it by taking a larger cube of a substance not already weighed. Weigh it in air and in water. Does the result support your theory?

26. What happens when a body lighter than its own bulk of water is immersed in water? What happens when a body heavier than its own bulk of water is immersed? What force is acting on both bodies to pull them down? Which to thrust them up? On what property of a liquid will its upthrust depend? Fill a burette with alcohol. Float a cylinder of wood—an unsharpened lead pencil will serve—upright in it. What proportion of its length is immersed?

27. Perform the same experiment in water. What proportion of the length is now immersed? Why more in the one case than the other? Could you from these two experiments, without any weighing, determine the relative density of alcohol?

28. Determine the weight of the pencil by finding its displacement of water in the burette.

29. Determine its relative density by using the burette. What would be the weight of unit volume of the pencil, if it were of the same substance throughout?

30. Take the thistle-funnel with rubber film, used in Exp. 3, and cut off the stem about an inch below the funnel. To this

short stem attach a length of stout rubber tubing. Into a piece of straight glass tubing of fine bore introduce a small length of mercury or coloured water to serve as an index. Attach this to the free end of the rubber tubing. Note the effect on the index of applying a slight pressure to the rubber film.

Immerse the film in a cylinder of water (1) the film being just covered; (2) submerged at a depth of 2 cms., 4 cms., 6 cms., 8, 10, etc. Note the effect on the index at each depth, and find an answer to the following questions:—

(*a*) Is the pressure of the water always the same at the same depth?

(*b*) Does the width of the vessel containing the water affect it?

(*c*) Is the pressure of the water at the same depth the same in all directions?

In turning the funnel about to test this, will you keep the top of the rim, the centre of the film, or the bottom of the rim at the level in question?

The principle discovered in Exps. 24 and 25 that "a body immersed in a liquid loses that portion of its weight which is equal to the weight of the liquid displaced" or "the vertical thrust of a liquid on an immersed body is equal to the weight of the liquid displaced," was first found out by Archimedes. It may be made use of in a variety of ways, and chiefly for determining (1) the relative density of substances that are insoluble in water; (2) the exact volume of irregular solids when the substance of which they are composed is insoluble in water; and (3) the density of liquids.

31. Determine the relative density of the quartz composing the pebble supplied.

Enter results as follows:—

	Weight of pebble in water	=	gms.
	Weight of pebble in air	=	gms.
Difference =	weight of water displaced	=	gms.

$$\therefore \text{ Relative density of quartz} = \frac{\text{(mass of pebble)}}{\text{(mass of equal vol. of water)}} =$$

What is the upthrust of the water on the pebble?

What is the weight of a cubic centimetre of quartz?

What is the volume of the pebble?

32. Cut a strip of cardboard to fit vertically into a test-tube. Mark on the strip cms. and millimetres. Trim the zero end so that when inserted into the tube it may be half way down hemispherical end of the tube. Why? Load the tube by putting into it enough fine shot to make it float vertically in water with a few centimetres of the tube clear above the surface. Note the

mark to which it sinks. The tube forms a hydrometer which can be used to determine the density of liquids.

It will be noticed that a hydrometer of this kind varies as to the amount of its immersion according to the liquid, but its weight is kept constant. Compare it with a Nicholson's hydrometer, which is always immersed to the same extent by varying its weight. A simple and accurate Nicholson's Hydrometer can be readily constructed with some copper wire, a couple of pipe heads, and a ping-pong ball.

33. Determine the density of the given liquid :—
   (*a*) by weighing a measured volume,
   (*b*) by weighing in it and in water one of the small metal cubes used in Exp. 24 (page 24),
   (*c*) by using the hydrometer made above,
   (*d*) by using Nicholson's hydrometer.

34. How would you determine the relative density of (*a*) a cork ; (*b*) a piece of loaf sugar ; (*c*) a specimen of powdered chalk ? Try the methods you suggest.

35. **Filtration.**—Take some muddy surface water. Let sit for a time. Note what occurs. Stir up the sediment again and run the whole several times through filter paper. Has pure water now been obtained ? Take a portion of it and evaporate to dryness. Any solid residue ? Can you obtain pure water by filtration ?

36. Refer back to Exp. 9 (page 16) on density of sea water. Why is it more dense than ordinary water ?

Measure out into a weighed evaporating basin about 20 c.c. of sea water. Weigh. Evaporate to dryness on a sand bath. Cool in desiccator and weigh. What is the percentage of solid matter in solution in sea water ? Enter results as follows :—

Weight of evaporating basin and water	=	gms.
Weight of basin	=	gms.
Difference = weight of sea water taken	=	gms.
Weight of basin and contents after evaporation	=	gms.
Weight of basin	=	gms.
Difference = weight of solid matter	=	gms.

∴ Percentage of solid matter in solution in sea water

$$= \frac{\text{(weight of solid matter)} \times 100}{\text{(weight of sea water taken)}} =$$

37. Place a few crystals of sulphate of copper in a weighed porcelain crucible. Heat very gently in the oven for a short time to drive off any adherent moisture. Weigh. Heat strongly over the flame for a considerable time. Cool and weigh. Heat again and repeat until on weighing there is no further loss of weight shown. Calculate the loss as a percentage of the original weight. What other change has taken place ? Moisten the sulphate with

water, and let stand for a time. Result? What had been driven off?

38. Determine in the same way the percentage of water of crystallisation in a sample of borax or of washing soda.

39. **Deliquescence.**—Weigh out a small quantity of fresh calcium chloride in a small porcelain basin or crucible. Let stand for several days, note any change of appearance, and weigh again. What has caused the change?

40. **Distillation.**—Half fill a flask with sea water. Lead a delivery-tube from the stopper into a small empty flask held sideways. See that the inner end of the delivery-tube is clear of the water in the flask. Heat the water to boiling. When steam begins to come over into the empty flask, keep the flask cool by turning it and laving it with cold water. Continue the process until 40 or 50 c.c. of distilled water has been obtained. Let it cool. Compare with the sea water and with tap water. Note particularly the colour and the taste of the three. Close the flask of distilled water with a new cork. Shake up vigorously for a time and taste again. If there is a difference how do you account for it? Did the shaking add anything to the water?

41. By boiling tap water expel the air dissolved in it. Devise some means of collecting the expelled air, and adopt any means you can for testing whether it has the properties of ordinary air.

42. **The solvent power of water.**—Take 50 c.c. of water. Add salt, a little pinch at a time, shaking after each addition. Keep on adding as long as any salt will dissolve. If some undissolved salt is left it can be removed by filtering. Evaporate the solution to dryness, and find what weight of salt has been dissolved. How many gms. of salt dissolved by 100 gms. of water?

43. Perform the same experiment heating the water to boiling.

44. Similar experiments may be performed on such substances as magnesium chloride, magnesium sulphate, potassium chlorate, and barium sulphate. A series of experiments may be taken to show for a substance its solubility for every 10° rise of temperature. All numerical results obtained should now be expressed as gms. of substance soluble in 100 c.c. (*i.e.* 100 gms.) of water at 20°, 30°, 40° C., etc., and the curves should be plotted together on one sheet of squared paper, the temperatures being set out along the horizontal, and weight dissolved along the vertical, axis.

45. When a solid is dissolved in a liquid is the volume of the liquid increased? Take one of the substances that you have found readily soluble, and by using a long, narrow tube in which to make the solution, seek an answer to this question.

46. Take a long tube, close one end with a stopper. Support it vertically and about half fill it with brine; to this add gently,

by means of a pipette or otherwise, so as not to mix the two liquids, a quantity of water sufficient almost to fill the tube. Mark with gummed paper the level at which the liquid stands. Close with the thumb the top of the tube, and, holding it in front of a light, invert so that the two liquids may mix. In doing this observe the liquid carefully. Turn it back to its old position and note the level at which it now stands.

47. Perform a similar experiment, putting water in the lower half of the tube and alcohol above. Observe as before. What explanation can you offer of the results of this and the previous experiment?

If time be available this would be a convenient point for performing a series of experiments dealing with capillarity, the surface-tension of liquids, and the diffusion of different liquids when in contact with each other. One of the latter is dealt with here as having a bearing on the later study of the physiology of a growing plant.

48. Take a thistle funnel. Tie firmly over the mouth of it a piece of bladder to make it watertight. Pour in through the tube enough treacle or syrup to fill the thistle portion. Mark with gummed paper the height at which the syrup stands. Support the funnel in water, the bladder and thistle part being immersed, but the level of the syrup being higher than that of the water. Which is the denser liquid—water or syrup? Let stand for several days, observing at intervals the level of the syrup. What happens?

49. Make a mixture of alcohol and water. Determine the density of this liquid. Into a thistle funnel prepared as in the previous experiment pour enough of the liquid to stand well up in the tube, and mark its level. Support in water as before, leave for several days, and observe any change of level. Then determine density of liquid remaining in the funnel. What has happened?

The action observed in this and the previous experiment is known generally as *osmosis*, movement of the liquid inwards being *endosmosis*, as in (48); and outwards, *exosmosis*, as in (49).

Effects of Heat.

1. Through a rubber stopper pass one end of a long, straight glass tube. Dip the free end of the tube deeply into coloured water, and while holding it in this position fit stopper and tube tightly into a small inverted flask. Support the flask and tube vertically, by means of a retort-stand and clamp, in such a position that the open end of the tube dips into the coloured water, a portion of which also fills part of the stem of the tube. Warm

the flask slightly by holding the hand on it. What occurs, and why? Try heating the flask very carefully by allowing the flame to play on it momentarily. Observe and record as before.

2. Does expansion also take place when a liquid is heated? Fill the same flask quite full of coloured water. Fit the stopper and tube into the flask in such a way that the liquid may rise a little in the tube, and bubbles of air may not lodge under the stopper. Support the flask on wire-gauze on the retort-stand, mark the level of the liquid in the tube by a piece of gummed paper, and heat the flask by the flame. At intervals note the level of the liquid.

3. Does a solid expand when heated? Gravesande's ring may be used, or a much simpler piece of apparatus devised from a thick wire, fastened vertically, the lower end to a fixed nail or binding-screw, and the upper end to the short arm of a long lath pivoted near one end. The swing of the long arm will magnify any change in the length of the wire. The wire may be heated by moving up and down in contact with it a sponge, saturated with burning spirit, and held by a long wire fastened to a piece of wood for a handle.

Caution.—Avoid drops from the burning spirit. From the foregoing experiments compare generally the amount of expansion produced in gases, liquids, and solids, by heating.

4. **Degree of heat.**—Take three vessels. Into one put cold water, into another lukewarm water, and into the third warm water. Can you distinguish them by putting your hand into each? Now place one hand in the cold water and the other in the warm water and keep them there for some time. Then simultaneously transfer them to the lukewarm water. What information is afforded by the feeling of each hand as to the degree of heat of the lukewarm water? Is sensation a satisfactory means of determining degree of heat?

Some form of heat-measurer (thermometer) is wanted that will indicate readily the degree of heat possessed by bodies. Previous experiments have shown that the greater the degree of heat the greater was the expansion in the case of gases, liquids, and solids. Will an air thermometer, a liquid thermometer, or a solid thermometer be most suitable? Why?

If time is available the making and graduating of a mercury thermometer is an interesting exercise, and will afford an opportunity of discussing the different methods of graduation.

Does the liquid alone expand in heating, or is there expansion also of the containing glass? Is any allowance made for this? If not, why?

5. **Conduction of heat.**—Compare wood, iron, copper as conductors of heat, devising your own experiments.

6. Almost fill a test-tube with water. Holding the tube by the bottom, slant it and let the flame play on the upper part of the tube, but not above the water-level. Can you hold it in your hand until the water boils? Is water a good or a bad conductor of heat?

7. How near can you hold your finger to the side of the bunsen flame without inconvenience? Is air a good or a bad conductor?

8. Make a wide spiral of copper wire, and holding it vertically lower it over the flame of a candle until the lower part touches the wick. What happens, and why?

9. Bring a piece of wire gauze, held horizontally, down over the flame of a Bunsen burner. What happens? Turn off the gas, hold the gauze about an inch above the nozzle, turn on the gas, and light it above the gauze. What happens? Account for it.

This is the principle applied in the miner's safety-lamp invented by Davy.

10. If water is a bad conductor how is the water in a vessel warmed when heat is applied below? Fill a beaker with water, adding some substance, such as litmus or bran, whose fine particles may be suspended in the water. Heat the beaker by a burner placed below and watch the movement of the particles as the water becomes heated.

11. Hold the hand some distance above a flame. What is felt?

The distinction between the conduction by which heat is transmitted in solids and the convection by which it is transmitted in gases and liquids will now be understood.

12. Stand a burning candle in a saucer and set over it a lamp chimney. Add enough water to the saucer to seal the lower end of the chimney. What happens? Why?

13. Down the middle of the upper part of the chimney place a strip of tight-fitting cardboard to divide the upper half of the chimney into two compartments. Place the chimney thus prepared over the flame as before. How do you account for the difference observed? By means of the smoke from smouldering brown paper test your explanation.

This would be an appropriate point for the discussion of the ventilation and warming of rooms, with such illustrative experiments as the ingenuity of the pupils may suggest. In connection with warming by open fires, a ground plan and an elevation of the room might be drawn, and on the drawings the temperatures actually observed at different points of the room noted. Arrows might be added to indicate the presence and direction of the air-currents detected by the use of smoke, as in (13).

14. **Hope's Experiment.**—Using Hope's apparatus apply a freezing mixture to the middle of a column of water, and take readings of the top and bottom thermometers every minute or two minutes. Plot the curves for the two thermometers, using minutes (time) for the one ordinate, and degrees (temperature) for the other. What have you learned from the experiment?

15. Break some ice small, place in a beaker and heat gradually, taking temperatures every minute or two minutes. Keep the thermometer in the liquid. Continue heating until all the ice is melted, and then continue until the water begins to boil. Note the temperature of the steam. Plot the results on squared paper. Note the various things you have learned from the experiment.

16. What are the three states of matter? What is the agent you have used in converting the one into the other? What is the melting point of ice? Find the melting point of butter. Of paraffin wax.

An interesting exercise for girls would be to find the melting points of the various kinds of fats.

17. Does the pressure affect the melting point for solids? Does it affect the vaporisation point of a liquid?

Boil water in a flask. Transfer the flask immediately to the receiver of the air pump, and exhaust. Observation?

18. Take a strong round-bottomed flask; half fill with water, and boil for some time. Remove flame and immediately close the flask with a tight rubber stopper. Invert it over a basin and carefully pour cold water over it by means of a sponge. What occurs? How do you account for the result observed in this and the previous experiment?

19. **Tension of Aqueous Vapour.**—Take two similar barometer tubes, fill with mercury and invert over mercury. Introduce into one of the tubes a few drops of water. What effect has this on the level of the mercury? Why? Has the introduction of a few drops of alcohol the same effect? What effect has the warming of the liquids on the vapour tension? What effect has cooling?

20. Have different liquids different boiling points?

21. Does the presence of solid matter in solution affect the boiling point? Use water with salt in solution.

Quantity of Heat.—Temperature indicates only intensity of heat, not quantity of heat. 1 gm. of water at 50° C. possesses a certain quantity of heat; 2 gms. of water at 50° C. has the same temperature, but does it possess the same quantity of heat? The unit for measurement of heat is the quantity of heat required to raise 1 gm. of water from 0° to 1° C.

22. Does water evaporate at ordinary temperatures?

Is there water vapour normally present in the air? How would you determine this experimentally?

23. A piece of seaweed furnishes a simple *hygrometer* for showing relative amount of moisture in the air. It should be kept in a perforated box outside the window, and should be weighed each day, and the curve plotted. Plot barometric, thermometric, and hygrometric curves on the same sheet. Any connection?

24. **Latent heat of water.**—In Exp. 15 it was found that heat added to melting ice did not raise its temperature as long as any part of the ice remained unmelted. What quantity of heat thus becomes latent in the case of water?

Take a weighed beaker of 300 to 400 c.c. capacity. About half fill the beaker with water which has been heated to a temperature of 40° to 50° C. Weigh. Support the beaker on slices of cork, and add quickly small pieces of ice, drying each with a cloth before dropping it in. Stir with thermometer and go on adding ice until, when melted, the water has a temperature of about 10° C. Weigh beaker and water again, and enter results as follows:—

	Weight of beaker and warm water	=	gms.
	Weight of beaker	=	gms.
∴	Difference = weight of water at T°	=	gms.
	Weight of beaker and water at T_1°, after adding ice	=	gms.
	Weight of beaker and water at first	=	gms.
∴	Difference = Weight of ice added	=	gms.

Hence calculate the number of units of heat lost by the known weight of warm water. This is evidently the quantity of heat required to melt the ice, and to raise it to T_1°. But the weight of water produced by the melting ice is known, therefore the number of units used in raising it from 0° to T_1° is known. Deducting this from the total heat used, the quantity required to melt the given weight of ice is known, and hence the quantity required to melt 1 gm. What then is the latent heat of water?

What do you think will happen to this latent heat when water is reconverted into ice?

25. **Latent heat of steam.**—It was found in Exp. 15 that when water was boiled the water and the steam when once raised to 100° remained at that temperature when the heating was continued. What quantity of heat thus becomes latent in the case of steam?

This can be determined by boiling water in a flask and leading the delivery-tube, when the steam is escaping freely, into a weighed quantity of water of known temperature in a beaker or calorimeter. Continue until the water reaches about 50° C. The quantity of water added as condensed steam will be given by the increase in weight of the beaker and contents. The temperature through which the water in the beaker has been raised is also known.

From these the number of units of heat given out by the steam which condenses to form 1 gm. of water in changing to the liquid state and falling to the observed temperature may be obtained.

To get accurate results some precautions are necessary. The beaker should be supported on slices of cork, and screened from the heat of the neighbouring flame and flask. The boiling-flask should not be more than half full.

The correction for heat lost by radiation from the beaker during the experiment may be made by noting the number of minutes during which the steam is passed, and the fall in temperature of the water in the beaker during the minute succeeding the close of the experiment; from this the average loss per minute may be calculated, and so the total quantity of heat lost. Is this accurate or approximate?

Steam which condenses in the delivery-tube must be prevented from entering the beaker. This may be done by making the outer leg of the delivery-tube in two pieces, passing into a wider tube stoppered at both ends. The portion leading to the beaker passes through the lower stopper to one side, and at least half way up the wide tube; the other passes through the upper stopper in the same way, and at least half way down the large tube. In this way the drip accumulates in the bottom of the wide tube. (See Fig. 10.) The apparatus should be fitted up in such a way that the condensing beaker or flask can be removed quickly at the end of the experiment.

26. When water evaporates what will be the effect on the temperature of the remaining water and of surrounding objects? Wet the finger and wave it in the air. Observation? Wet a small patch on a board. On the water place a watch glass, into which has been poured a few drops of ether. Evaporate the ether rapidly by blowing over it with bellows. What is the effect on the water beneath the watch glass?

The chills frequently produced when wet clothes are allowed to dry on the person form another illustration of the same principle.

27. Another illustration is afforded by Wollaston's cryophorus, a glass tube with bulbs attached containing only water and water vapour. Run all the water into the bulb of the shorter arm. Place the other bulb in a freezing mixture. Referring back to Exp. 19, what effect has this on the tension of the water vapour? What is the effect on the evaporation of the water? Observe the result that the consequent cooling has after a time on the unevaporated water.

CHEMISTRY OF AIR AND WATER.*

Air.

1. Burn phosphorus under inverted glass cylinder over water in plate. Observe exactly what happens.

The properties of the white solid formed are now to be studied.

2. Let sit for some time; slip disc under mouth of cylinder; invert. Test contents with lighted taper.

3. (*a*) Put strips of red and blue litmus paper into tap water; any change noticed?
   (*b*) The same into the water in cylinder.
   (*c*) The same into the water in plate.

Write down after each of these (1), (2), and (3)—
   (*a*) what you infer directly from the observations, and
   (*b*) what explanation you think might account for what you have observed.

4. Find internal volume of glass cylinder.
   (*a*) By measurement.
   (*b*) By filling with water.
   (*c*) Repeat Exp. 1; mark with gummed paper height to which water rises in jar. Measure the volume of water thus risen, and check this by measuring the volume of the part of the jar from the rim to the paper mark.
   (*d*) What proportion of the contained air has disappeared?

5. Try this experiment several times. Is there any variation in the volume of air that disappears? If so, how do you account for it?

6. (*a*) Try similar experiment with sulphur, igniting it with the gas flame.
   (*b*) Test residual air with taper, and water in cylinder and plate with red and blue litmus.
   (*c*) What volume of air has disappeared?

7. Similar experiments with a burning taper or candle. Will ignited phosphorus continue to burn in the residual air in which the candle has been extinguished?

8. Notice dry phosphorus in the dark. Can this glowing be a slow form of combustion? Support a piece of dry phosphorus,

* The various sheets giving the outline of the chemical portion of the course were not given out to the students in their present form until the meeting of the class after that at which the experiments had been performed and the results partially discussed.

about the size of a pea, on a wire in a test-tube of air inverted over water; let stand for a fortnight. (*a*) Any change observed? (*b*) If any air has disappeared, note volume. (*c*) How does the remaining air behave when a burning taper or burning phosphorus is put into it?

9. Perform similar experiment with some other substance that changes slowly in air, *e.g.*, iron. Dust iron filings round inside of test-tube. Invert over water and let stand for a fortnight. Note (*a*), (*b*), and (*c*) as in (8).

10. (*a*) Can the disappearance of the fumes from the phosphorus and sulphur be hastened by shaking?
  (*b*) What conclusion do you draw as to what becomes of the fumes when they disappear?
  (*c*) Have you any other evidence as to this?

11 Whence are the fumes derived? You have suggested that they are either (1) an emanation from the burning phosphorus, or (2) a substance produced by combination of phosphorus with the part of the air which has disappeared. This requires further investigation.

If (1) be correct what should be the effect on the weight of substance left? If (2), what should be the effect? Which of the substances produced would lend itself readily to weighing?

  (*a*) Dry a small quantity of iron filings in oven and weigh in a small crucible. Float this in water under an inverted glass cylinder, the internal volume of which has been estimated. Let stand for a fortnight.
  (*b*) Any change in volume of enclosed air, and if so, how much?
  (*c*) Test residual air.
  (*d*) Dry in oven and weigh crucible and contents. Increase or loss of weight? Inference?

12. What is the effect of heat on phosphorus, sulphur, salt, wood, coal, chalk, magnesium, paraffin, sodium, iron filings, mercury. Those not already investigated are to be heated over the gas flame in an iron spoon. Note in each case what happens, what is produced, and what is left behind.

13. Heat for some time, in the spoon, a little mercury. Note what is produced.

14. There is supplied to you a red powder produced when mercury is heated in air.
  (*a*) Heat some of this powder in a dry test-tube. Note changes.
  (*b*) When the heating has been going on for some time put into the tube a glowing (not burning) splint of wood. Note what happens. How do you account for it?

Refer back to the question which was being investigated in

Exp. 11, and consider the question again in the light of the result now obtained and that obtained in Exp. 11.

15. Collect a quantity of the gas given off by the red powder of mercury. If this be the active constituent of air as you suppose, how should it behave in the matter of supporting combustion? Does it so behave?

16. Prepare in jar by Exp. 1 a quantity of the residual air, and let stand till fumes have disappeared. If you now add to this as much of the gas from Exp. 15 as would make up for what has disappeared how should the resulting mixture behave with reference to combustion? Does it so behave? Conclusion?

17. Prepare a number of jars of the active constituent of air by heating the red powder of mercury, or, more easily, by heating a mixture of potassium chlorate and maganese dioxide. *Precautions* :—(1) If an ordinary test-tube is used the flame is apt to fuse it, if allowed to play too long on one spot. (2) Heating should be begun gently and the flame not allowed to play on the empty part of the tube. (3) When the gas has all come off, the delivery-tube must be removed from the water before the flame is taken away, otherwise the water is apt to run back and break the hot tube.

18. Place a small piece of phosphorus in deflagrating spoon, ignite, and plunge into one of the jars of gas. Note what follows. Add water to cylinder, shake up, and test with litmus paper or solution.

19. Ignite piece of sulphur in deflagrating spoon, and plunge into another jar of the gas. Note and test as before.

20. Heat piece of charcoal in deflagrating spoon over flame until red; plunge into jar of gas. Note and test as before.

21. Attach to spoon small spiral of fine iron wire looped at lower end and tipped with sulphur. Ignite this at flame and plunge into jar of gas. Note and test as before. Try other combustible substances for tipping wire. Does the behaviour of the solution vary with the material used for tipping the wire? If so, why?

The jar should have a layer of moist asbestos fibre placed on the bottom, to receive the molten globules which would otherwise crack the jar.

22. Attach small strip of magnesium ribbon to spoon, ignite and plunge into jar of gas. Note and test as before. Try pressing damp litmus paper on white ash.

23. Ignite small piece of sodium in spoon and plunge into jar of gas. Note and test as before.

24. Perform similar experiment with potassium and note and

test as before. State the results obtained from Exps. 18 to 24 tabularly, thus:—Substance burned: Product: Effect of solution on blue litmus: Effect on reddened litmus.

25. Burn phosphorus, charcoal, and sodium as in Exps. 18, 20, and 23. Instead of adding water and litmus to jar add a little lime water, shake up and note result. Try same experiment, burning a splint of wood.

26. Compare solutions obtained from burning of phosphorus, sulphur, and sodium as regards taste and feel.

You have suggested that the fumes from the combustion consist of the substance burned + the active constituent of the air.

You have found that when the fumes are dissolved in water, the water with the fumes in solution behaves differently from the water alone or the fumes alone; and you have suggested that this can be explained by supposing that the fumes are now combined with the water or with something derived from the water.

The group of solutions that have sour taste and harsh feel, and turn blue litmus red, have been called *acids* from their taste; the solutions that have bitter taste and soapy feel, and turn reddened litmus blue, have been called *alkalies*.

The active constituent of air, which is concerned in the production of these acids, has been called oxygen ("acid producer"). What objection do you see to the name?

The first products of the burning substances with the oxygen are called *oxides*.

State results obtained tabularly, thus:—

Substance.	Oxide.	Acid or Hydroxide.
Phosphorus - -		
Sulphur - - -		
Carbon - - -		
Iron - - - -		
Magnesium - -		
Sodium - - -		
Potassium - - -		

27. Does the amount of oxygen require to combine with a burning substance vary with the amount (weight) of the substance?

This may be investigated from two sides:—

(*a*) Does the volume of oxygen given off from such a substance as chlorate of potash vary with the weight of chlorate used, and does the same weight of chlorate always give same volume of oxygen?

(*b*) Does the weight of oxide produced by burning magnesium vary with the weight of magnesium used, and does the same weight of magnesium always give the same weight of oxide?

28. Find, as indicated in (*a*) above, what volume of oxygen is given off from, say, 2 gms. of potassium chlorate. The heating must be continued as long as any gas comes off.

29. Weigh a small piece of magnesium ribbon in a weighed crucible with lid. Oxidise it completely over the flame, lifting the lid a little now and again to admit air, cool in desiccator, and weigh. What percentage of magnesium is contained in the oxide?

Acids and Alkalies.

30. (*a*) A little sulphuric acid is rubbed by means of a glass rod on a piece of paper, and the paper is then warmed. Result? Try same with coloured cloth.

(*b*) Write on paper with a weak solution of sulphuric acid. Let dry; warm. Result?

(*c*) Add a drop or two of sulphuric acid to a tumblerful of water. Taste? Feel?

(*d*) Effect of strong sulphuric acid on strong solution of sugar.

(*e*) Carefully mix with a feather a little powdered potassium chlorate with sugar. Place on a piece of slate. Add by means of glass rod a drop or two of strong sulphuric acid. Result?

(*f*) Effect of dilute sulphuric acid on litmus solution and on litmus paper.

(*g*) Add to a little water a little strong sulphuric acid. Note effect on temperature.

Caution.—Never add water to sulphuric acid. If the two are to be mixed, the acid is to be added a little at a time to the water. Why?

31. Perform experiments similar to (*a*), (*c*), and (*f*) of Exp. 30, using hydrochloric acid instead of sulphuric acid.

32. Similar experiments with nitric acid.

33. Similar experiments with acetic acid.

34. Similar experiments with sodium hydroxide.

(*a*) Add sodium hydroxide solution to infusion of red cabbage.

(*b*) Do the same, using one of the acids.

35. Use potassium hydroxide instead of sodium hydroxide.

36. Use ammonium hydroxide. Tabulate the chief characteristics of acids and of alkalies as found from Exps. 30 to 35.

Water.

37. (*a*) Drop small piece of sodium on water in plate. Result?
Cautions.—Sodium must not be touched with wet fingers. Why?
Keep face well back from plate at end of experiment. Why? Use pieces about size of a half pea.
(*b*) Prevent sodium from moving about by floating piece of blotting-paper in water before adding sodium. Result?

38. Repeat Exp. 37, and immediately after dropping sodium * on water push it under the surface by means of wire-gauze spoon. Note result. How do you think it may be accounted for?
Caution.—No air must be taken down with the spoon.

39. Repeat Exp. 38, and apply taper to the bubbles of gas that come to surface. Result? Is the gas either oxygen or nitrogen?

40. Repeat Exp. 38, and by means of a test-tube filled with water, collect the gas. Take test-tube out of water, mouth down, and immediately apply taper to mouth of tube. Result?

41. Try some other metal than sodium, *e.g.*, magnesium. Place piece of magnesium ribbon in test-tube, add a little water. Any result? You have suggested that chemical action might be aided by adding an acid. Add a little sulphuric acid. Result? What becomes of the magnesium? This question will need investigation at a later stage.

42. Try similar experiment, using zinc instead of magnesium.

43. Collect over water, the gas liberated by the zinc. What will be driven off first? What later? Collect first in small test-tube. Hold test-tube, mouth down, and immediately apply taper. When the gas collected in test-tube ceases to explode and burns quietly, collect a jar of the gas by displacement of water, as was done with oxygen.
Caution.—There must be no air bubbles in jar or bee-hive shelf to begin with.
Prepare several jars in this way.

44. Hold a jar mouth downwards, and take off cover-slip.
(*a*) At once apply taper. Result?
(*b*) Push taper up into jar. Result?
(*c*) Take taper out again. Result?
Inference from each of these?

* As these Notes are being printed, the interesting chemical announcement is made that owing to a recent industrial development in Germany the metal calcium can now be obtained in quantity, and at a small cost. It has been suggested that, as its action with water is less violent than that of sodium, and as the hydroxide produced can be seen as floating particles, it may form a convenient substitute for sodium in school laboratory experiments.

45. Set jar with mouth up, take off cover-slip and let stand open for a minute or two. Apply taper. Result? Inference?

46. (*a*) Using Woulfe's bottle, generate the gas. Use delivery-tube drawn out to small orifice at outer end. When the gas is coming off freely, and, collected in test-tube, has ceased to explode, light it at orifice. Note appearance of flame.

(*b*) Hold over the burning jet for a little time a cold, dry evaporating dish or an inverted cold, dry test-tube. What do you observe? How do you account for it? Remembering that previous cases of burning in air have been the uniting of the substance burning with the oxygen of the air, what substances do you think are contained in this product of the burning gas?

This inflammable gas obtained from water has been called hydrogen ("water producer"). Why?

47. You have now formed a theory as to the composition of water. You have found that hydrogen can be liberated from water by sodium (Exp. 38). What is required to test your theory as to the other constituent of water?

Send strong electric current through water, to which a little sulphuric acid has been added, the poles to be pieces of platinum foil to prevent products combining with the copper. Collect in inverted tubes the gases liberated. When one tube is filled make mark on other in order to determine relative volumes of the two gases.

48. (*a*) Test with taper the gas which is present in greater volume.

(*b*) Test with glowing splint of wood the gas in the other tube. Inference?

49. Find weight of a litre of (*a*) hydrogen; (*b*) oxygen. What is the relative density of oxygen with reference to hydrogen? You have found out from Exp. 47 that the volume of hydrogen in water is to that of oxygen as 2 : 1. Calculate the weight of oxygen that would combine with 1 gm. of hydrogen to form water.

Compare the experiments by which you have produced synthetically air and water from their constituent gases (Exps. 16 and 46), and try to answer the following questions :—

(*a*) Is air a mechanical mixture of oxygen and nitrogen, or does air consist of these two gases chemically combined?

(*b*) Is water a mechanical mixture of oxygen and hydrogen, or does it consist of these two gases chemically combined?

Give reasons for your answer in each case.

At this point a series of experiments might follow on the combustion of a candle and of coal gas. Arrangements would be made for collecting and investigating the products of the combustion—the oxides of carbon and hydrogen, and the unburnt carbon. The gaseous products may be collected by placing immediately over the flame an inverted funnel connected by tubing with a Woulfe's bottle containing the lime-water, or other reagent, through which it is intended to lead the gas, the other neck of the bottle being connected with an aspirator.

50. Refer to Exp. 25 for effect on lime water of the oxide of carbon. You suggested from Exps. 20 and 25 that the oxide of carbon was a colourless gas. Breathe through a tube into lime water. Effect? Inference?

51. Evaporate to dryness the water rendered milky by the breath. Weigh residue on platinum foil. Heat strongly on foil, cool in desiccator and weigh several times until the weight remains constant. What percentage of original weight has been lost? What has come of it?

52. Take about ·5 gm. of chalk on piece of platinum foil after drying in oven. Heat strongly, and weigh as above. Find percentage of loss, as before.

53. Can you suggest any method of determining whether the substance driven off by the heating in the two previous experiments is really oxide of carbon? Try it. Result? Inference?

54. Is the substance left, after heating, chalk? Test it as regards its relative density, action with water, etc.

55. What other method than heating might drive off the gas? You have suggested treatment with water and an acid: try (*a*) sulphuric acid; (*b*) hydrochloric acid. Result?

56. Instead of using chalk use marble with hydrochloric acid. Result?

57. Collect several jars of the gas and examine its properties.

(*a*) Test with taper.

(*b*) Leave jar sitting for some time open, with mouth up; test with taper.

(*c*) With mouth down; test with taper.

Compare result of (*b*) and (*c*) with your observations on hydrogen. Inference?

(*d*) To test correctness of your inference, place burning candle on table, and go through the action of pouring the gas from a jar on the candle, as if it were a liquid. Result?

(*e*) Suspend two large beakers, mouth up, from beam of balance and counterpoise. Pour gas from jar into one of them, taking care not to touch the beam or to make currents of air. Result?

(*f*) Add lime water to a jar of the gas. Result?

(*g*) Determine the weight of a litre of the gas.

58. Seeing you think the gas is oxide of carbon, can you suggest any method of removing the oxygen from it? You suggest burning something in it, but a taper we notice has gone out. Do any of the substances you have been using burn more violently? You have suggested phosphorus and magnesium. Try each of these in turn. Result?

59. Since magnesium burns in it, what does it probably remove? If so, what would you expect to be left behind? Do you find any traces of such a residue?

60. Devise a means of determining the volume of carbon dioxide given off from a weighed quantity of chalk. About 1 gm. is a suitable quantity to use.

61. Is there carbon dioxide normally present in air? Let a saucerful of clear lime water sit for an hour or two in a class-room. Any change? What sources of the carbon dioxide in the atmosphere do you suggest? Why does the carbon dioxide in the air not accumulate?

Defer the answer to this question until the experiments in plant physiology (*infra*) have been worked.

If the percentage of carbon dioxide in the air is required, a measured quantity of air (20 to 30 litres) must be aspirated through a series of U tubes in which the air is dried by means of sulphuric acid and calcium chloride, and the carbon dioxide absorbed by caustic potash, and weighed. A less elaborate method, that of Pettenkofer, is the one in common use.

62. From Exp. 49 it has been found that 1 gm. of hydrogen requires 8 gms. of oxygen to combine with it to form water; from result of Exp. 29 it can be calculated that the weight of magnesium that will combine with 8 gms. of oxygen is 12 gms.

Refer back to Exp. 41. What volume of hydrogen will be liberated from dilute sulphuric acid by a weighed quantity (use about ·2 or ·3 gms.) of clean magnesium ribbon?

The simplest way of doing this is to connect the small flask in which the hydrogen is to be generated, with a large bottle, stoppered air-tight and full of water, from which is a siphon connecting with a graduated measuring jar. The collecting of the gas expels an equal bulk of the water, which, after outside and inside pressures have been equalised, can be measured.

From the result calculate the volume of hydrogen that would be liberated by 12 gms. of magnesium, *i.e.*, the weight which combined with 8 gms. of oxygen. Refer back to Exp. 49, and calculate weight of hydrogen liberated from the acid by 12 gms. of magnesium.

It has now been found that 12 gms. of magnesium (which united with 8 gms. of oxygen to form magnesium oxide) in combining with an acid, replaces the same weight of hydrogen as united with 8 gms. of oxygen to form water. The weights actually used have in each case combined in these proportions: 12 gms. of magnesium, 8 gms. of oxygen, and 1 gm. of hydrogen are thus equivalent in the sense that they can unite with one another to form, or replace one another in, chemical compounds.

63. Repeat Exp. 38, using weighed piece of sodium packed tightly into piece of lead tube, and collect and measure the volume of hydrogen given off. Result? From this calculate the weight of sodium required to liberate 1 gm. of hydrogen from water.

64. Add weighed pieces of sodium to water in weighed evaporating basin. From burette add gradually enough normal solution * of hydrochloric acid to neutralise the sodium hydroxide which has been formed. Use litmus paper as the indicator, and stop adding acid when the neutral point is reached. Calculate weight of hydrochloric acid added. Evaporate the neutral solution to dryness, cool in desiccator, and weigh the solid obtained.

Compare the weight of sodium used + the weight of hydrochloric acid used, with the weight of salt obtained. Any sources of error in this and the previous experiment that occur to you should be noted.

65. Take weighed piece of clean magnesium ribbon, as in Exp. 62, place in weighed evaporating basin, and add gradually from a burette enough normal * sulphuric acid to dissolve the magnesium. Calculate the weight of sulphuric acid that has been added. Evaporate solution to dryness, cool in desiccator, and weigh residue.

The weight of magnesium and the weight of sulphuric acid used are now known; compare with the weight of magnesium sulphate produced. Refer back to Exp. 41 and answer the question that was there left unanswered.

The pupil is now in a position to complete the terminology begun in connection with Exp. 26. Sodium (*base*) with oxygen gave sodium oxide (an alkaline or *basic oxide*), which with water gave sodium hydroxide (an alkaline or *basic hydroxide*).

Sulphur with oxygen gave sulphur dioxide (an acid-forming oxide or *anhydride*), which with water gave sulphurous acid (an acid hydroxide or *acid*). Thus the alkalies are hydroxides of the metals; the acids of the non-metals. But one of the acids used, hydrochloric, contains no oxygen. Hence the common feature of the acids is that they contain hydrogen, which, as in Exp. 65, can be replaced by a metal.

When an alkali and an acid are brought together, as in Exp. 64, a *salt* is produced, in the case cited sodium chloride. But salts can also be produced in various other ways, *e.g.*, by the action of an acid upon a metal, as in Exp. 65, in which magnesium and sulphuric acid produced magnesium sulphate, the hydrogen of the acid being given off.

* See Appendix, page 72.

66. Repeat Exp. 27, with potassium chlorate, using a small weighed combustion flask. Measure the oxygen given off, and weigh the residue of potassium chloride. If manganese dioxide has been mixed with the chlorate, it can be separated by washing, as the dioxide is insoluble.

Collect and tabulate the various numerical results as to combining proportions that have been obtained by the previous experiments. Taking, for theoretical reasons that need not yet be gone into, 2 gms. of hydrogen as being combined with 16 gms. of oxygen to form 18 gms. of water, the various results may be tabulated somewhat as follows :—

(1)	H_2	+	O	=	H_2O
	2 gms. of hydrogen	+	16 gms. of oxygen	produced	(2 gms. + 16 gms.) of water

(2)	Na	+	H_2O	=	Na O H	+	H
	23 gms. of sodium (*Natrium*)	+	18 gms. of water	produced	(23 gms. + 16 gms. + 1 gm.) of sodium hydroxide	+	1 gm. of hydrogen

(3)	Na O H	+	H Cl	=	Na Cl	+	H_2O
	40 gms. of sodium hydroxide	+	36·5 gms. of hydrochloric acid	produced	58·5 gms. of salt	+	18 gms. of water

(4)	Mg	+	O	=	Mg O
	24 gms. of magnesium	+	16 gms. of oxygen	produced	(24 gms. + 16 gms.) of magnesium oxide

(5)	$KClO_3$	=	K Cl	+	3 O
	122·5 gms. of potassium (*Kalium*) chlorate	produced	74·5 gms. of potassium chloride	+	48 gms. of oxygen

(6)	Mg	+	H_2SO_4	=	$MgSO_4$	+	H_2
	24 gms. of magnesium	+	98 gms. of sulphuric acid	produced	120 gms. of magnesium sulphate	+	2 gms. of hydrogen

The above, while not the weights actually used, will be found to be the proportions of those weights taking 1 gm. of hydrogen as the unit. The numbers given are the nearest whole numbers. The exact combining weights, as determined by the experiments of skilled investigators, will be found in the Appendix (page 73). The pupils, from a comparative study of their results, will have hit upon the laws of chemical combination :—

(1) When two elements combine they always do so in a definite proportion by weight.

(2) When an element is found present in different compounds in more than one proportion, these are simple multiples of the lowest weight.

It is essential that in a course of practical science the chemical part of the course should reach at least this point of the discovery of the laws of chemical combination.

STUDY OF LIVING THINGS.

The subject of this study may be either an animal or a plant, or preferably both.

Animals.—The difficulty of selection in the case of animals lies in the fact that the creature must be adapted for study indoors, either in the home or the class-room. If the latter, provision must be made for its needs during the interval from Friday evening till Monday morning.

Among suitable objects are the following :—

(1) Butterfly, from egg to imago stage. The common white cabbage butterfly is suitable.

(2) Silkworm, from egg through the cocoon stage.

This has been found very suitable for observation in Infant Schools.

(3) One of the larger moths.

(4) Frog, from egg to adult stage.

(5) The snail (*Helix pomatia*).

There have been cases of a second generation of snails being successfully raised in Infant Schools.

(6) A sea-water aquarium, in which such creatures as periwinkles, anemones, barnacles, serpulae, small shore-crabs and hermit-crabs, may be conveniently studied.

(7) A fresh-water aquarium, in which newts, small fishes, fresh-water shrimps, aquatic beetles, fresh-water molluscs, and young tadpoles may be studied.

(8) Young chicks.

(9) Young kittens.

(10) Young puppies.

The first seven are suitable for class-room study. Their habits and their different stages of growth should be carefully observed and recorded by means of a diary. Entries in this should be made regularly at the time of observation; otherwise it is impossible to keep the dates accurately. This diary should be supplemented by a series of dated drawings showing each new phase of growth. If these can be done carefully in colour so much the better; but even rough pencil drawings, if they illustrate accurately the characteristic features, are of value. As regards

(8), (9), and (10) a series of photographs would be of the utmost interest. In the observation of kittens and puppies special attention should be given to all survivals of characteristics which have been of use to their ancestors in a wild state of life, and the various maternal arrangements for training the young should also be carefully noted. If possible a series of dated weighings of them should be obtained and the graph for these plotted.

Observations of this kind need not be confined to physical development. A study of growth, for example, of especial interest to teachers, is that of the mental development of a very young child, say under two years of age. Little has yet been done with scientific accuracy in this field and every additional diary is of psychological value. But great caution is required not to confuse one's inferences with one's actual observations; for it is extremely easy to read that into the child's actions which is not there.

Plants.—These are more easily kept and the observations more easily recorded than in the case of animals. If possible the study of them should be begun from the seed. Let the children gather the seed from the plants in the autumn, see it dried and stored for the winter and begin observation in the springtime.

The pea, bean, buckwheat, oat, and cress are suitable. Very interesting studies of acorns sprouted in water have been made in some infant schools. The hyacinth and other bulbs are also very suitable for growth in school. As in the case of animals, the most important feature of the study is a series of regular observations entered in an accurately dated diary, and supplemented by a series of dated sketches. The height of the plant should be measured and recorded daily or at other regular intervals, and the graph of growth thus obtained plotted. It might also be possible to obtain a graph showing the plant's increase in weight. The question of how the growth is affected by the conditions as to light, temperature, moisture and the like should receive constant attention.

It is very important to continue the study of the plant into the autumn so as to observe the fruit. The seeds should be collected, allowed to dry, and stored for sowing next spring. It adds greatly to the children's interest to raise new plants from the seeds they have themselves seen produced.

Interesting studies of growth may be made by selecting an individual tree and keeping its diary. The method of opening of leaf and flower buds may be shown by a series of drawings, and for this purpose twigs with buds at different stages may be brought home for study; but in addition to this a particular marked bud on the tree should be kept under regular observation and its growth recorded in a diary. These observations should be continued throughout the whole year, so that the fall of the leaf in autumn and the resting-stage in winter may not be omitted.

A similar series of observations should be made on a growing crop. Country schools are fortunate in having the subjects of study ready to hand.

It is advisable that at least one type of each of the main divisions of the animal kingdom given in the table below should be studied. Compare them as regards complexity of structure and specialisation of function; also as regards the common physiological processes as far as these can be observed without the animal being injured. For school purposes it does not seem either necessary or advisable to do any dissection. More important is it that the living animal should be studied—its relations with other animals, its means of offence or defence, its method of seeking food, its manner of locomotion, its power to deal with unusual conditions. Though observations of this kind involve experiments, these can be of a kind that will not injure the animal which is under observation.

An interesting set of observations can be made by studying throughout a season the plants and animals associated together in some circumscribed area, for example, in a corner of the back-water of a stream, a moorland pool, or a half-tide pool on a rocky beach. Exhaustive lists of the living contents, and of their changes, may be made, supplemented by drawings and notes. Exercises in classification follow; and throughout there is secured what is the most valuable form of nature-study—observation of living creatures in their own home haunts.

A few hours spent over almost any common creature will probably suggest questions that are still unanswered by the scientists. Take, for example, such a much-studied creature as the common sea-urchin. One's attention is readily attracted by the pedicellariae with which it is so abundantly furnished. Observe under the microscope the different kinds and their methods of movement. Various questions arise. How is the stimulus conveyed that so readily directs them towards a foreign body coming into contact with the outer surface? Why are there different kinds of them? What purposes do they serve in the life-economy of the urchin?

The habits of insects, and especially of such social forms as the ants, the bees, and the wasps, furnish a very suitable subject of observation by children. Investigators like Darwin or Fabre or Avebury show us the way in which such a subject may be approached. The commonest creatures become of the utmost interest when under the eyes of an observer animated by the right spirit. A book like Darwin's "Earthworms" will throw a flood of light on the method by which animal life can be best investigated.

Of the Vertebrata, birds offer an attractive field for the schoolboys' investigations. Exercises such as the following may be suggested:—

Observe two or more common species of birds, *e.g.*, sparrow, thrush, blackbird, lark, chaffinch, robin, canary, starling, crow, sea-gull.

Compare their mode of flight.

How do they progress when on the ground? Do they hop or walk?

In what kind of places are they usually found?

What is the nature of their food? When do they seek it?

What kind of nest does each build? Of what nature? Where placed? How hidden? Time of building? How long does the building take? Do both parents work at it?

How many eggs are laid? Compare them as to colour, size, shape.

Length of incubation? Do both parents assist in the hatching?

How many broods in the year?

How are the young cared for? How are they fed? Do both parents feed them? How long is the parental feeding kept up?

If they sing, what kinds of notes do they utter? Note different sounds used. Is there a variety of sounds to express different emotions? When do they sing?

MAIN DIVISIONS OF THE ANIMAL KINGDOM.

		Examples.
Vertebrata.	**Fishes.**	
	Amphibians.	
	Reptiles.	
	Birds.	
	Mammals.	

		Examples.
Mollusca. (With soft unsegmented body, a shell and no limbs.)	**Gasteropods.** (With flat, smooth foot used for crawling; univalve shell.)	Limpet, periwinkle, buckie.
	Lamellibranchs. (With bivalve shell.)	Mussel, cockle, oyster, scallop.
	Cephalopods. (With well-marked head; circle of tentacles with suckers; funnel-shaped foot.)	Squid, cuttle-fish.
Arthropods. (Segmented body—with jointed limbs arranged in pairs.)	**Crustacea.** (Hard coat; two pairs of antennae.)	Crab, lobster, barnacle, wood-louse, water-flea.
	Arachnida. (Head and thorax fused; 4 pairs legs; no antennae.)	Spider, mite, scorpion.
	Myriapoda. (Head distinct; many pairs legs; one pair of antennae.)	Centipede, millepede.
	Insecta. (Body in three distinct parts — head, thorax, and abdomen; one pair of antennae; three pairs of legs, usually two pairs of wings.)	Butterflies, moths, flies, beetles, bees, wasps, grasshoppers, dragon-fly, caddis-fly, ant.
Echinoderms. (Body radially arranged; prickly or spiny skin; a skeleton of limy plates or rods; tube-feet.)		Sea-urchin, star-fish.
Worms. (A very mixed group of animals having body either unsegmented or evenly segmented and with side tufts of bristles; no segmented limbs.)		Earthworm, Serpula, Spirorbis.

	Examples.
Coelenterata. (Body radially arranged; body-cavity serving for circulation and digestion; stinging-cells.)	Anemone, jelly-fishes.
Sponges. (Body of spongy consistence; colonial, but distinctness of individuals lost; internal canals communicate with one another and have one or more outside openings; limy or flinty skeleton).	Bread-crumb sponge.
Protozoa. (Minute animals not composed of definite tissues.)	Amoeba, slipper animalcule.

HOW A PLANT LIVES.

1. Germination and Growth.

1. Germinate on damp flannel, seeds of pea, bean, mustard, grass, etc. Note changes day by day, and make sketches. Summarise what you have learned from these observations.

2. Put a number of dry peas in a bottle. Add enough moisture to start germination. Through cork pass a thermometer until its bulb is in the middle of the peas. Note temperature at beginning of experiment, and at intervals afterwards.

3. After germination has been going on for several days, draw through a tube of lime water, by means of an aspirator, the air accumulated in the bottle. Observation? Inference?

4. Plant some of the germinating seeds in earth in small flower-pots. Use certain of these for measuring rate of growth in height, and plot growth-curves of several of them on the same sheet. Is the rate of growth uniform? If not, can you find out what conditions it?

5. Is the growth most rapid in the warmth or the cold? Plot the temperatures on the same sheet as the graphs of growth.

6. Does the amount of moisture in the air affect it?

7. Can the plant do without water?

8. Does the barometric pressure affect it?

9. Is the rate greater when much water is added to the soil, or when little?

10. Does the placing of the plants in sunshine or shade affect the rate of growth?

State in summarised form what you have learnt.

2. Circulation of Water.

11. Is the plant's supply of water obtained through the roots or the leaves? Give two of the plants a regular supply of water, taking care to wet only the soil and not the leaves. Take another pair of plants and cease watering the soil, but instead, brush the leaves with water, using camel hair brush, avoiding any dripping on the soil. Keep up this treatment of the two pairs for several days. What conclusion do you come to?

12. Take one of the plants up by the roots. Gently shake off the earth and place the roots in water, to which a little aniline dye or red ink has been added. After the lapse of several hours examine the leaves of the plant and its flowers, if it has any. Observation and inference?

13. Treat similarly a twig cut from a bush. After the lapse of several hours cut the twig across, and say in what part of the stem the water travels.

14. By placing a number of twigs in the same coloured water and cutting one every hour, an approximate estimate of the rate at which the water rises in the stem may be made. Will it be quite safe to assume that the same rate of rise would be found in an uncut plant which possessed its root?

15. Take up one of the young plants as in (12). Fill a flask with water. Take a cork that fits the flask, bore a hole in its centre to receive and support the stem of the plant, and cut the cork across through this hole. Place the root of the plant in the flask and fit the halves of the cork round the stem of the plant. Weigh the whole. Place the flask and plant in the sun, shielding the flask from the sunlight. Mark the height of the water at intervals, and weigh. Is the loss of water greater in sun or shade? Has the water removed from the flask remained in the plant?

16. Treat a second plant in the same way, but strip it of its leaves before beginning the experiment. Note observation. Through which of the plant organs does the transpiration of water take place?

17. Over a leafy plant place a bell jar, and set the plant in the sunlight. Observe the glass after the lapse of an hour or two.

18. (*a*) From one of the plants pick a large fresh leaf. Lay it with its under surface downwards on a polished metal surface. Remove the leaf after a few seconds, and observe the metal surface on which it has been resting.

(*b*) Try a similar experiment with another leaf, placing its upper surface on the metal. Inference from (*a*) and (*b*)?

19. Peel off a little piece of the skin from the under surface of the leaf of a hyacinth or one of the lilies. Examine this under the

microscope for any trace of openings by which the water within the plant could be transpired into the air.

20. Have plants any other means of discharging water? Examine the point of the leaf of a Nile lily in the morning. Examine in the morning, after a damp night without dew, the leaves of the Lady's-mantle, or of *Nasturtium.*

How do you account for the fact that the water of the soil enters the plant root?

3. Respiration.

Which of the gases you have studied chemically is used up by animals in breathing, and which is produced?

21. Fill a small flask with the flowers of the daisy or other plants of the Order *Compositae.* Plug the lower part of the neck with cotton-wool to keep the flowers from falling out, leaving the mouth clear. Invert the flask with its mouth dipping into a vessel containing mercury. Through the mercury introduce into the mouth of the flask 4 or 5 cms. of caustic potash to absorb carbon dioxide, if formed. After the lapse of several hours observe what has occurred. What volume of air has disappeared? Test the residual air and say whether it is any of the gases you have studied. Inference?

22. Can atmospheric air enter the plant?

(*a*) Place blade of a leaf into water, hold the stalk firmly with the lips and blow into the cut end.

(*b*) Bend a piece of glass tubing to a right angle. In a sound cork which fits closely into a flask, bore two holes, one to fit the end of the tube, the other to receive the stalk of a fairly large leaf. That of the common dock is suitable. Cement the leaf-stalk into the hole by means of paraffin wax. Partly fill the bottle with water and fit into place the cork with its tube and leaf, the end of the leaf-stalk dipping into the water, the inner end of the tube clear of the water. See that the apparatus is air-tight. Apply suction to the outer end of the tube. Note what occurs and what you infer.

4. Nourishment.

23. (*a*) Collect the sap oozing from the cut stem of a growing plant. Evaporate gently to dryness on a watch glass.

(*b*) Shake up a portion of garden soil with distilled water. Let settle; decant and filter the clear solution. Evaporate to dryness.

What inference do you draw from the two experiments?

24. Is it only mineral matter soluble in water that is able to enter the plant from the soil? Place fresh rootlets in close contact with damp litmus paper. Note result. Inference?

25. Take a small slice of apple or turnip, cut into small portions, weigh in evaporating basin. Dry for several hours in drying-oven at 100° C. Weigh and heat again until the weight remains constant. What percentage of water has been present?

26. Transfer the dried material of (25) to weighed crucible or piece of platinum foil; heat over the bunsen flame or blow-pipe. Note changes. Continue heating until no black particles remain in ash. Cool in desiccator and weigh. What percentage of original substance has burned away? What percentage is this of the dried substance? What percentage of the original substance is the ash? What percentage is the ash of the dried substance? Do your weights account for the whole of the original substance? If not, what has become of the remainder?

The same experiments may be performed using a few fresh leaves.

27. Weigh out about a gramme of any seed, such as mustard. Dry in oven: find percentage of water.

28. Take about the same weight of the seed undried, and weigh in a small weighed evaporating basin. Calculate from the data given by the previous experiment what weight this represents if all moisture were driven off. Add distilled water and allow the seeds to germinate. When they are well sprouted dry thoroughly in the oven and weigh when all moisture has been driven off. Compare this with the original weight as obtained after deducting weight of moisture. Give percentage of increase. From what source has this increase of substance been derived?

29. Devise experiments to settle whether this increase has been in mineral matter or in the organic matter which disappears on ignition.

30. Make an arrangement by which the gaseous product of the heating in air (Exp. 29) may be collected and examined. Is it any of the gases already known to you? From what do you consider that it or its constituents have been derived?

31. Take two plants of same species. Keep one of them in the dark for a day or two. When the other has been for some time in direct sunlight, pick a leaf from each. Decolorise them both by treatment with hot alcohol, and test for starch by placing them in solution of iodine. Note result and inference. The reaction of iodine with starch produces a blue-black colour.

32. Fasten in the morning a strip of tin-foil across the middle of the growing leaf of a fuchsia or other convenient plant. After an hour or two in sunlight take off leaf, decolorise and test for starch as in previous experiment.

33. Into a glass jar place a cut stem of a water-plant, such as water-thyme (*Elodea*), with the cut end upwards. Over this invert a test-tube filled with water to collect any bubbles of gas given off. Expose to sunlight. Test the gas. Which is it? Whence derived?

34. Fill a jar, inverted over water, with air from the lungs. Into it place a growing plant, its roots submerged in the water. Expose the plant to sunlight during the day. At nightfall test the air now contained in the jar.

35. Devise an experiment to show whether the leaves of a shoot exposed to sunlight in air artificially deprived of its carbon dioxide will form starch.

Summarise the results of these experiments on *carbon assimilation.*

The complete chemical investigation of the food of plants is beyond our pupils at this stage, but they may learn a good deal by repeating Nobbe's classical experiments in water-culture. The nutritive solution recommended by a recent German investigator is as follows:—

Distilled water . . .	1–2 litres.
Potassium nitrate . .	·5 gm.
Ferrous phosphate . .	·5 gm.
Calcium sulphate . . .	·25 gm.
Magnesium carbonate . .	·25 gm.

Two plants may be grown in soil, two in a solution containing all the ingredients, and two in each of the four solutions obtained by leaving out in turn one of the salts. The substances present should in each case be entered on a label on the bottles, which should be numbered for reference. All the cultures should be started on the same date, and kept as nearly as possible under the same conditions as to light, temperature, etc. The results, with sketches of the plants, should be kept in diary form.

5. Movement.

36. Set two pots of seedlings well back from the window, one towards the left of the window and the other towards the right. Observe them at intervals for several days.

37. Lay a germinating bean on its side on the top of the moist soil in one of the pots. Observe at intervals, for a day or two, the direction of growth of the root. Try the same experiment with the tip of the root over a little cup of mercury.

38. Take a pot containing a growing plant with a single stem. Lay the pot on its side so that the plant is horizontal. Keep it in this position for several days and observe direction of growth of growing point.

The shoot in this experiment and the root in the previous one have both been growing under the influence of the force of gravitation. Has the result been the same? In which direction would you expect growth to be?

Consider carefully the significance of this difference between vital phenomena and those which are simply physical.

39. Investigate the night movement of some plant. The clover is a convenient subject of study. Observe and sketch position of leaflets on a marked plant during sunlight. Observe the same plant when evening has come on. What advantage to the plant is afforded by the night position of the leaflets?

Additional exercises in this branch of investigation may be afforded by a study of movements related to moisture and heat, the opening and closing of common flowers such as the daisy and dandelion, the curvatures of climbing plants, and the action of tendrils.

As illustrations of irritability of special organs the two following experiments may be tried :—

40. Take a fairly opened but not old flower of the common barberry. Observe the position of the stamens. With the point of a needle prick the inside of the flower near the base of one of the stamens. What change do you observe?

41. Take a fully opened blossom of the monkey flower (*Mimulus*). Observe the position of the two lobes of the stigma, prick them or touch them with the point of a pencil. What change do you observe? Of what advantage to the plants concerned are the movements observed in (40) and (41)?

6. Reproduction.

42. Propagate a plant by means of cuttings. Propagate the Begonia by planting single leaves. Note the method of vegetative increase possessed by such plants as the strawberry, silver-weed, and couch-grass. What gain is there to the plant in such an arrangement?

43. Reproduction by means of bulbs. Plant the bulbs of such plants as hyacinth, crocus, snowdrop, or onion. Why is it possible for a hyacinth to grow and flower without being planted in soil?

44. Study on any typical flowering-plant the production of the pollen and ovules, and the setting of seed.

The special arrangements connected with cross-fertilisation, and the adaptations of plants and insects to each other, will furnish opportunity for extended observations in this branch of the subject.

The arrangements for securing the dispersal of seeds will furnish another interesting set of observations. The commonest wild plants should be preferred for investigation.

7. Observations on the Sundew.

The special processes of nutrition and irritability exhibited by insectivorous plants may be readily studied in the Sundew. There are two species found on the Lewis moors in almost equal abundance—the round-leaved and the long-leaved (*Drosera rotundifolia* and *Drosera Anglica*). A patch of turf containing several plants may be transferred to a saucer and studied at home, care being taken to keep it moist; or, better, marked plants may be studied in their native habitat. The following questions will suggest lines of observation and experiment :—

Describe the kind of place in which your plant is growing.
Is there only one plant or a colony of them?
Among what other kind of plants is it growing?
Describe your plant, noting among other things number and arrangement of leaves, and nature of root.
Examine a leaf. Describe hairs or "tentacles."
How many (approximately)?
Which part of leaf is longest? Which shortest?
Observe the fluid on the roundish heads of the tentacles.
Its colour? Is it thin? Is it sticky?
Perform the following experiments on a living plant :—
Test a leaf with a piece of damp blue litmus paper.
Place a tiny fragment of meat (beef or mutton), or portion of an insect, on the head of one of the outer tentacles.
Note carefully the following :—
In what time and direction does the tentacle begin to bend? What is the nature of the movement? Do the neighbouring tentacles share in the movement? In what time and where does the movement cease? Has there been any change in the amount of fluid secreted?
Test the fluid now with damp blue litmus paper.
Has the leaf itself, as distinct from the tentacle, moved in any way?
Take observations once a day to see what time elapses before the tentacles unbend again.
Has any change taken place in the piece of meat?
Try similar experiments placing small fragments of wood or of stone instead of meat on tentacle.
Is the effect the same?
What conclusion do you draw?
Try touching the head of a tentacle on another leaf with the point of a needle. Is there any movement from once touching it? Is any result produced if it is repeatedly touched? Has the falling on the leaf of drops of water any effect?

What conclusion do you draw?

Record anything you have noted not indicated above.

Try any further experiments of your own that you think would yield interesting results.

Considering the size of root, and the kind of soil in which your plant grows, can you draw any conclusions as to the value to the plant of the habit which you have been investigating?

SOME FIELD OBSERVATIONS ON TREES AND OTHER PLANTS.

1. Select three or four common species of trees and during winter make diagrams to illustrate the branching. Compare these.

2. Make a comparative study of the bark of these trees. Can you distinguish them by touch?

3. Compare the leaves and the way in which these are massed when in full leafage, so that the tree can be recognised at a distance by its habit.

4. Compare the sounds made by the leaves in the wind. Can you distinguish your selected trees from one another at night time by the characteristic rustle of their leaves?

5. Observe the time of flowering, sketch the flower, compare the fruits, and note the arrangements that secure the dispersal of the seeds.

In studying plants generally always give attention to those peculiarities of structure that seem to have special reference to the mode of life or place of growth. Every peculiarity of structure involves some explanation which is worth seeking for. Comparison of one plant with another is the most fertile means of extending one's knowledge. You will probably be struck at an early stage of your investigations by what one might call the flexibility of resource shown by plants, as shown by the fact that very different organs may serve to perform the same function on different plants. Take as an illustration such an exercise as this:—

6. Select a dozen different species of plants and note the method in which in each case the young flower-buds are protected.

Note should always be made of the plants associated with one another in the same habitat. Animals associated with certain plants should also be carefully observed. Consider also what benefit, if any (supply of food or shelter, etc.), the animals obtain from the plants; and what benefit (*e.g.*, aid in cross-fertilisation) or injury the plants sustain from the animals.

Some further hints as to field observations are indicated in the excursion-notes in the Appendix.

The great variety of plants, their resemblances and differences, render necessary some scheme of classification. The following table exhibits the great divisions of the plant kingdom :—

MAIN DIVISIONS OF THE PLANT KINGDOM.

Group.		Class.
Phanerogamia (Plants reproduced by seeds).	Angiosperms - - (Seeds enclosed in an ovary).	Dicotyledons. Monocotyledons.
	Gymnosperms - - (Seeds naked).	
Cryptogamia (Plants reproduced by spores).	Pteridophyta - - (Vascular cryptogams).	Lycopodiaceae (Club-mosses). Equisetaceae (Horse-tails). Filices (Ferns).
	Bryophyta - - - (Have stems and leaves, but no true root).	Musci (Mosses). Hepaticae (Liverworts).
	Thallophyta - - - (With vegetative body not differentiated into root, stem, and leaf).	Fungi. Algae.

A typical plant of each of the above groups should be examined. As a good part of botanical work in schools is devoted to flowering plants, a number of typical flowering plants should be examined and described. The plant as a whole should always be considered first—its general appearance, mode of growth, and habitat. Then each of its organs—root, stem, leaves, and flowers—should be examined. The structure of the flower has been made the basis of classification.

Description of a Flower.

Calyx.—Superior or inferior, regular or irregular, polysepalous or gamosepalous, number of sepals.

Corolla.—Regular or irregular, polypetalous or gamopetalous, number of petals.

Stamens.—Number; hypogynous, perigynous, epigynous, or epipetalous; (if united) monadelphous, diadelphous, or polyadelphous, syngenesious (united by anthers). Filament—long or short, filiform or petaloid. Anthers—1 or 2 lobed.

Pistil.—Stigma—terminal or lateral; (if lobed) 2 or 3 lobed. Style—long or short.
Ovary—superior or inferior, apocarpous or syncarpous, 1, 2, 3 or many-chambered, 1 or many-ovuled; placentation (attachment of ovules)—axile, free-central, septal or parietal.

Ability to run down a plant readily into its Natural Order is a necessary preparation for using a Flora intelligently. With a view to giving practice in this, some of the more important British Orders have been selected. Only a few have been given (*e.g.*, the Thalamiflorae embraces 22 British Orders, of which 3 have been selected) but the others can be readily fitted, when required, into their place in the following table:—

CLASSIFICATION OF THE ANGIOSPERMS.

- **Dicotyledons** (2 seed-leaves, leaves net-veined, parts of flowers in 4's and 5's, etc.)
  - Polypetalae (petals separate)
    - Thalamiflorae (stamens hypogynous)
      - Ranunculaceae (*e.g.*, buttercup).
      - Cruciferae (cuckoo-flower).
      - Caryophyllaceae (campion).
    - Calyciflorae (stamens perigynous or epigynous) .
      - Leguminosae (whin).
      - Rosaceae (hawthorn).
      - Umbelliferae (pignut).
  - Gamopetalae (petals united) . . . .
    - Primulaceae (primrose).
    - Compositae (daisy).
    - Scrophulariaceae (foxglove).
    - Labiatae (dead-nettle).
    - Boraginaceae (forget-me-not).
  - Apetalae.

Classification of the Angiosperms—*continued.*

Monocotyledons (1 seed-leaf, leaves parallel - veined, parts of flowers in 3's, etc.)	Petaloideae (coloured perianth)	Liliaceae (hyacinth). Amaryllidaceae (daffodil). Iridaceae (iris). Orchidaceae (orchis).
	Glumaceae	Cyperaceae (sedges). Gramineae (grasses).

Examine and write a description of a typical plant of each of the Orders given above.

By comparison of these, the following list of characteristics may be gradually compiled, and may then be used as the basis of exercises in running down unknown plants.

Distinguishing marks of these Orders:—

Ranunculaceae.—Stamens many, ovary apocarpous.

Cruciferae.—Corolla of 4 petals arranged cross-wise, stamens 4 long and 2 short.

Caryophyllaceae.—Leaves opposite, joints of the stem swollen, placentation falsely free-central.

Leguminosae.—Flowers papilionaceous, stamens 10, perigynous, monadelphous or diadelphous.

Rosaceae.—Flowers regular, stamens many, perigynous, ovary spuriously syncarpous when ovary is adherent to calyx.

Umbelliferae.—Flowers in umbels, petals 5, stamens 5, epigynous, fruit splitting into 2 seed-like portions.

Primulaceae.—Corolla hypogynous, stamens 5, epipetalous, opposite corolla lobes, placentation free-central.

Compositae.—Flowers capitate, surrounded by an involucre, calyx membranous or pappose, stamens syngenesious.

Scrophulariaceae.—Corolla irregular, stamens 2 long and 2 short, ovary 2-celled, many-seeded.

Labiatae.—Stem square, leaves opposite, corolla irregular, stamens 2 long and 2 short, ovary deeply 4-lobed.

Boraginaceae.—Leaves alternate, flowers regular, stamens 5, ovary 4-lobed.

Liliaceae.—Stamens 6, ovary superior.

Amaryllidaceae.—Stamens 6, ovary inferior.

Iridaceae.—Stamens 3, ovary inferior.

Orchidaceae.—Perianth irregular, stamen 1, ovary inferior.

Cyperaceae.—Sheaths of leaves not split, stems solid, 3-cornered, flower in a single glume.

Gramineae.—Sheaths of leaves split, stems hollow, flowers sheathed by 2-rowed bracts (glumes).

A REGIONAL SURVEY.

A detailed study of the district in which the school is situated will afford an excellent training in observation and in reasoning. Such a study will also bring the pupils into contact in a practical way with some of the larger problems of geography and sociology. The course would include as many of the following sections as time could be found for, and class excursions would form an essential feature. To get the full good out of such excursions the teacher would consider carefully beforehand the features that were to be studied, and would try to go over the ground himself a day or two before that on which the excursion was to take place. Sometimes he may wish the class to see the ground before studying it on the map; at other times he may wish the class to make a detailed study of the map beforehand. Whatever the arrangement, the teacher should know the district and should have clearly in his mind what he wants to achieve by the day's outing. The human side of geographical study should on no account be lost sight of.

The sections of work suggested are as follows:—

I. Weather phenomena and the meteorological records.

II. The build of the district, studied in the field and on the survey map. This will be made the occasion of a training in map-reading.

III. Nature of the rocks and their weathering, with the scenery of the district.

IV. Nature of the soil, crops grown, native plants (terrestrial and marine), and their local distribution.

V. Native animals and their distribution. The shore fauna.

VI. Distribution of population. Industries. Anthropology. Folklore and antiquities.

WEATHER OBSERVATIONS.

Note barometric and thermometric readings in sun and shade for a period, and plot curve.

Measure amount of rainfall.

Note direction of wind and its force according to the following scale:—calm, very light air, light air, light breeze, fresh breeze, very fresh breeze, blowing hard, blowing a gale, violent gale.

Note the kind and amount of clouds, and the number of hours each day of bright sunshine.

The most interesting way of making and preserving these observations for school purposes is to keep a Weather Calendar. A large sheet of paper is fastened on the wall of the class-room, and in columns ruled for the purpose entries are made of the following:—

Day of the month.

Height of barometer in inches.
Temperature at noon (a) in the sun; (b) in the shade.
Rain: number of hours in which it fell, amount in inches.
Wind: direction, force.
Clouds: velocity and direction, kind.
Thunder, lightning, storms, hail or snow.
Birds, trees, etc.
Agricultural operations.

For younger children a selection of the more simple observations should be made. Older pupils can make a more elaborate record, and should plot on a piece of squared paper their thermometric and barometric readings, taken two or three times a day. The Meteorological Society's published records and weather forecasts will help to widen their horizon and show how local observations may throw light on the general conditions prevailing over the British Isles. Even young children can report as to the hoisting of the storm-cone, and observe whether the predicted storm comes or not.

It might add to the interest of the weather observations of the older pupils if, by a series of observations, extending over a year or more, they gradually evolved as many as possible of the following indications of change of weather, and were then encouraged to attempt weather forecasts for themselves. The following extract from *Whitaker's Almanack* gives in brief form the principal rules at present in use for forecasting the weather:—

A rising barometer usually foretells less wind or rain, and a falling barometer more wind or rain, or both; a high barometer fine weather, and a low one the contrary.

If the barometer has been about its ordinary height at the sea level, and is steady or rising, while the thermometer falls and the air becomes drier, north-westerly, northerly, or north-easterly wind, or less wind may be expected; and, on the contrary, if a fall takes place with rising thermometer and increasing dampness, wind and rain may be looked for from the south-east, south, or south-west; a fall of the barometer, with low thermometer, foretells snow.

With the barometer below its ordinary height a rise foretells less wind, or change in the direction towards the north, or less wet; but when the barometer has been low, the first rising usually precedes strong wind or heavy squalls from the north-west, north, or north-east, and continued rising foretells improving weather. If the barometer falls and warmth continues, the wind will probably back, and more southerly or south-westerly winds will follow.

In northern latitudes the heaviest northerly gales occur after the barometer first rises from a very low point. A rapid rise generally indicates unsettled weather; slow rise or steadiness, with little moisture in the atmosphere, fair weather. A considerable and rapid fall signifies stormy weather and rain. The barometer generally falls with a southerly and rises with a northerly wind ; though sometimes the contrary happens, and then the southerly wind is dry and the weather fine, or the northerly wind wet or violent.

When the barometer sinks considerably, high wind and rain or snow will follow ; wind from the northward, if the thermometer is low for the season ; from the southward, if high.

When a gale sets in from the east or south east, and wind veers by the south, the barometer will continue falling till the wind becomes south-west, when, after a lull, the gale will be renewed.

The north-east wind tends to raise the barometer most, and the south-west to lower it most.

Instances of fine weather often happen with a low barometer, and are generally followed by a duration of wind or rain, or both.

Predictions founded solely on the indications of the barometer and thermometer may be made with more certainty if combined with careful observation of the appearance of the sky, and the atmospheric effects peculiar to that particular locality.

A rosy sky at sunset, whether clouded or clear, a grey sky in the morning, a low dawn (that is when the first signs of the dawn appear on the horizon), all indicate fair weather. A red sky in the morning indicates bad weather, or much wind ; and a high dawn (or when the first signs of the dawn are seen above a bank of clouds) presages wind.

From the clouds we may draw the following conclusions :—Soft-looking and delicate clouds foretell fine weather, with moderate breezes ; hard-edged clouds, wind ; rolled or ragged clouds, strong wind. A bright yellow sky at sunset also presages wind, and a pale yellow sky wet.

Dew and fog both indicate fine weather, while remarkable clearness of the atmosphere near the horizon (causing distant objects to appear very distinct and nearer than usual) is one of the most characteristic signs of coming wet.

Lewis is rich in local Gaelic proverbs relating to the weather, and a collection of these should be made, and the children encouraged to see how far their own observations bear out the truth of these old weather-sayings.

Such observations as the following in connection with the return of the seasons may be suggested :—

Trees (as ash, plane, beech)—at what date leaf-buds first appear, when in flower, in full leaf, leaves fallen.

Shrubs (as elder, hawthorn, laburnum, rowan, flowering-currant)—at what date first in blossom, when in full flower.

Fruits (as apple, black currant, etc.)—at what date first in blossom, when the fruit is ripe.

Crops (as barley, oats, potatoes, turnips, rye-grass)—date of sowing or planting, appearance above ground, when in ear or flower, when first cut or raised, when the gathering-in is completed for the neighbourhood.

Migratory birds (as cuckoo, starling, corncrake)—date of first arrival, date of departure.

MAP-READING.

Determine the N. and S. line. This can be done by marking a shadow in the playground or in the class-room. A line drawn from the point on the floor marking the shortest limit of the shadow of the corner of the window-sill to the point on the floor vertically below that corner will run from N. to S.

In the field, orientation is most easily done by using a watch. Hold the watch horizontally with the small hand pointing directly to the sun, that is, the small hand and its shadow in a straight line. If the watch dial were marked in 24 hour-divisions the point of the dial at present marked XII. would give the S. direction, seeing the sun makes a complete circle in 24 hours. But as the watch is in 12 hour-divisions the angle between the small hand and the XII. must be halved to give the line running S.

The pupils should also be able to find the compass-directions at night by reference to the Pole Star. It is also advisable to let them learn the appearance and relative positions of the most striking constellations.

Study of a Survey Map :—

Determination of the scale of a map.

Various methods of indicating the orographical features of a district—contour lines, use of different tints, hill-shading.

The study from a contoured map of the mountain and river system of the district in which the school is situated.

By climbing a neighbouring hill, settling the direction by means of compass or watch, and placing the 1-inch map in its proper position, the map and the district may be compared, and the general build of the district most easily understood.

Plotting the valley-curve of a river. Its significance.

Accounting for the route followed by railways and roads, and for the position of towns or villages.

Section-making along a given line.

Exercises on the Map of Lewis—½-inch, 1-inch, and 6-inch map :—

1. Construct a model in cardboard or clay of part of the district from the 6-inch map.

2. Account for the position of Stornoway.

3. Can you make any generalisation as to the position of the Lewis villages?

4. Which of them, from its position, might be expected to develop?

5. Sketch the valley-curve of (*a*) the Barvas River; (*b*) the River Creed.

6. Can you make any generalisation as to direction of greatest length of Lewis lakes? Any explanation of this?

7. Mark on the 1-inch map approximate limits of the conglomerate.

8. Compare this with the hill-shaded map, and note what you discover.

9. Is it possible to tell from a distant view of the scenery where the conglomerate ends and the gneiss begins?

10. Draw a profile sketch of a gneiss headland, and of a conglomerate one. How do you account for the difference?

11. On the 1-inch map draw a straight line through Ben Barvas N.E. to Aird Mor Barvas, and S.W. to Stornoway Harbour. Make a section along this line, using the same vertical scale as horizontal.

12. On the 6-inch map draw a line through the hills on the W. side of Stornoway Harbour. Draw the section along this line. From the wharf at Stornoway sketch the outline form of the hills as they show against the sky. Compare this drawing with the section. Have the forms of the various hills in your sketch anything in common? How do you account for this?

The notes of the excursions in Appendix will suggest further exercises.

ROCKS.

A rock and a rock-forming mineral compared.

Granite and its constituents.

Granite and gneiss compared.

The appearance and characteristic properties of the following rock-forming minerals, occurring locally:—quartz, felspar, mica, hornblende, augite.

Illustrations of the three great groups of rock—sedimentary, igneous, and metamorphic—may be found in the neighbourhood of Stornoway. The chocolate-coloured conglomerate on which the town is built is an example of the first class, the dolerite which occurs in several volcanic dykes exposed on the neighbouring beach is of the second class, and the various kinds of gneiss to be found so abundantly in the district furnish typical examples of the third class.

Another local deposit of interest is the glacial clay, of which there is a very fine exposure, containing striated blocks and resting on a glacially polished platform of rock, on the beach near Holm. What example of glacial action is seen in the forms of any of the neighbouring hills?

The district furnishes also good illustrations of the formation of peat-deposits of the shallower kind, and the relation of the peat to the underlying clay and overlying soil. From which plant-remains is the Lewis peat mainly derived? Identify as many plants as possible from their remains in the peat.

Weathered and fresh specimens of rock should be compared. The weathering action of air and sea, as exhibited by the rocks on our sea-beaches, may furnish material for lessons involving wide-reaching physiographic principles.

Classification of Rocks.

Adapted from Sir Archibald Geikie's "Text-Book of Geology" (1893 edition, Macmillan).

- Sedimentary
  - Fragmental
    - Sand rocks
      - Soil, debris, sand, gravel.
      - Breccia, conglomerate
      - Sandstone.
      - Greywacke.
      - Quartzite.
    - Clay rocks
      - Clay, mud.
      - Fire-clay.
      - Loam.
      - Boulder-clay.
      - Shale.
      - Clay-slate.
    - Volcanic fragmental rocks
      - Volcanic ash.
      - Volcanic breccia.
      - Volcanic agglomerate.
      - Volcanic tuff.
    - Fragmental rocks of organic origin
      - Some limestones.
      - Chalk.
      - Diatom-earth.
      - Flint.
      - Peat.
      - Coal.
      - Bog iron-ore.
      - Clay-ironstone.
  - Crystalline
    - Some limestones.
    - Gypsum.
    - Ironstone.

Classification of Rocks—*continued.*

Massive—Eruptive—Igneous	Acid Series	Granite. Quartz-porphyry. Felsite. Obsidian. Pitchstone. Pumice.
	Intermediate Series	Orthoclase-porphyry. Diorite. Trachyte. Porphyrite.
	Basic Series	Gabbro. Dolerite. Basalt. Serpentine.
Schistose—Metamorphic		Argillaceous schist. Quartz-schist. Quartzite. Augite-schist. Hornblende-schist. Chlorite-schist. Talc-schist. Mica-schist. Gneiss.

Common rock-forming minerals studied in class:—quartz, felspar, mica, hornblende, augite, calcite.

Stratification, dip, unconformity, metamorphism, and the significance of these.

The succession of sedimentary rocks.

Superposition as a test of relative time of deposition.

When one layer of rock rests on another, which is presumably the older deposit?

Fossils in rocks and how they have come to be imbedded.

The evidence of fossils as to the relative age of the containing rocks.

Limits to the application of the fossil test as determining the time of deposition.

Order of Succession of the Stratified Rocks in Britain.

Quarternary or Post-Tertiary	Recent. Pelistocene.

Tertiary or Cainozoic - - - -	Pliocene Miocene. Oligocene. Eocene.
Secondary or Mesozoic - - - -	Cretaceous. Jurassic. Triassic.
Primary or Palaeozoic - - - -	Permian. Carboniferous. Devonian and Old Red Sandstone. Silurian. Cambrian. Precambrian.

Our Lewis conglomerates are probably Precambrian, that is, they belong to the most ancient of all the groups of stratified rocks. But notice the difficulty of settling such a point with certainty in the case of a patch of rocks like these isolated from the mainland.

Since these conglomerates, as we have found during our excursions, consist of fragments of gneiss, what inference may be drawn as to the relative age of the Lewisian gneiss?

LOCAL INDUSTRIES.

Pupils can acquire for themselves much information regarding the three Lewis industries—agriculture, fishing, and tweed-weaving. The facts collected by various members of the class can be pooled, systematised in summary form, and may then form interesting material for some of the composition exercises of the class.

The relation of these industries to the geographical features of the district, and their effect on the life of the people pursuing them, should be investigated. Features of the industries peculiar to the locality should be carefully noted; for example, in connection with the weaving the still current use of certain of the primitive native dyes would receive attention.

ANTIQUITIES.

The Island is also rich in antiquities which would furnish the pupils with interesting subjects for investigation during their holidays. Specially striking are the "standing-stones" of Callanish and the various stone circles and monoliths scattered over the district, the duns in various stages of preservation, many of them built on islets in the lochs, and the ruins of the old churches.

Some of the ancient history of the Island still survives in oral tradition, and the collection of these floating fragments and their recapitulation in writing would make pleasant vacation exercises for older pupils. A considerable number of folk-lore tales still survive and might be similarly utilised.

[Concluding Note.

CONCLUDING NOTE.

As regards method generally, perhaps the most important point is to avoid giving to the pupils knowledge which they can discover for themselves. It is so easy to tell, and so tedious and difficult to stand by and be an interested spectator of one who is an inapt discoverer, that there is a great temptation for teachers to help more than is necessary. The function of the teacher of science is that of a fellow-student, one who can help by showing how results can be tabulated and how questions are to be asked, one who will aid in making negative instances obtrusive and will not allow the too eager investigator or the too weak logician to leave gaps in the chain of reasoning.

Absolute honesty on the part of the young investigator is essential. He must record only what he has seen—"the truth, the whole truth, and nothing but the truth." Experiments that give results different from those expected must be faithfully entered in the note-book, and if further investigation makes plain the cause of the failure, this can be added as a subsequent note.

To allow pupils to work regularly in pairs does not seem advisable. Such an arrangement generally means that the better pupil does the work, and the other one looks on, or in his work is dependent on his stronger neighbour.

It is not to be considered sufficient that the pupils seek answers to the questions which the teacher propounds; they must become investigators on their own account. The experimental work in the laboratory should give scope for originality and should constantly encourage self-reliance. So in their field-work: to observe things that they have been told to look for is only the poorer part of their training. If the nature-study is having the effect aimed at the children must become discoverers. A training in science that in this way develops the inquiring mind that not only solves problems but propounds them, will fully justify the time and care spent on it.

A teacher need not be afraid to suggest from time to time to his pupils the investigation of problems in nature-study of which he himself does not know the solution. Neither he nor they will lose by feeling that they are fellow explorers of the unknown.

There is at present a good deal of discussion as to how far the heuristic method is applicable in the study of elementary chemistry. Our work together has led us to the conclusion that almost all the problems of an elementary course can be so treated, but that there are points here and there in which its rigid application would be accompanied by great difficulties. We have found these difficulties to be chiefly of three kinds:—(*a*) that pupils do not come to the study free of all scientific information, and therefore work with a bias and to that extent are not *bona fide* discoverers; (*b*) to answer experimentally some of the questions casually raised would involve lengthy investigations constituting digressions of doubtful value; and (*c*) some of the explanations of experimental results that will occur to even a moderately intelligent boy would involve in their verification or refutation experiments of a kind far beyond the manipulative skill of a schoolboy and the resources of an ordinary school laboratory.

But having said this we come back again to the fundamental position that the pupil is not to be told what he can reasonably be expected to find out for himself. Every teacher should lay to heart Fröbel's words in his *Education of Man*:—"It is, no doubt, easier to listen to the statement of another than to formulate one for oneself. But the quarter of a self-found answer is of infinitely greater value to your child than one, half-understood, from you. Only secure to your child the conditions under which the answer is to be found."

APPENDIX.

FIGURES USEFUL FOR REFERENCE AFTER THE COURSE HAS BEEN WORKED THROUGH.

1 inch = 2·540 cm.
1 foot = 30·480 cm.
1 metre = 39·37 inches = 3·2809 ft. = 1·0936 yds.
1 kilometre = 1093·6 yds. = ·6214 mile.
1 sq. inch = 6·45 sq. cms.
1 sq. ft. = ·0929 sq. metre.
1 sq. cm. = ·155 sq. inch.
1 sq. metre = 10·764 sq. ft. = 1·196 sq. yds.
1 lb. = 7000 grains = 453·59 gms.
1 gm. = ·0022 lb. = ·0353 oz. = 15·43 grains.
1 kilogm. = 2·2046 lbs.
1 cub. in. = 16·387 c.c.
1 cub. ft = 28·349 litres = 6·25 gallons = 1000 ozs.
1 gallon = ·16 cub. ft. = 277·463 cub. ins. = 160 fl. ozs. = 4·5434 litres = 70,000 grains of water.
1 pint = ·568 litre.
1 litre = ·0353 cub. ft. = 61·027 cub. ins. = ·2205 gall. = 1·76 pints = 1000 c.c.
1 cub. cm. = ·0610 cub. in.
Weight of 1 cub. ft. of air at 0° C. and 760 mm. pressure = ·0807 lb.
Weight of 1 litre of air ,, ,, ,, = 1·2937 gm.
Weight of 1 litre of dry hydrogen at 0° C .and 760 mm. pressure = ·0896 gm.
Volume of 1 gm. of hydrogen at 0° C. and 760 mm. pressure = 11·16 litres.
Relative density of air, hydrogen being unit = 14·43.
Weight of 1 c.c. of mercury at 0° C. = 13.596 gm.
Length of seconds pendulum at London = 39·139 inches.

To make Standard Solutions:—

Normal sodium carbonate.—Dissolve 53 gms. pure dry salt in water and make up to 1 litre.

1 c.c. of this solution = ·053 gm. of Na_2CO_3.

Normal sodium (or potassium) hydroxide.—Dissolve 42 gms. of pure caustic in 800 c.c. of water.

1 c.c. of this solution = ·040 gm. of NaOH (·056 gm. KOH).

Normal sulphuric acid.—Dilute 30 c.c. of acid of 1·84 sp. gr. to 1 litre.

1 c.c. of this dilute acid = ·049 gm. of H_2SO_4.

FIG. 1 DIAGRAM showing relation of SANDWICK LOCH to SANDWICK BAY J.R.F.

A. Sandwick Loch B. Sandwick Bay C. Bar of shingle D. Marshy ground.

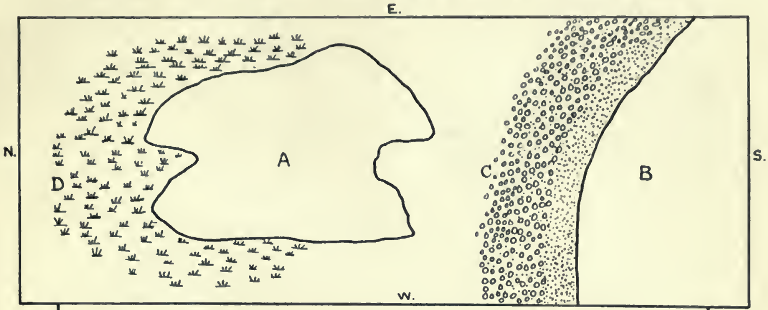
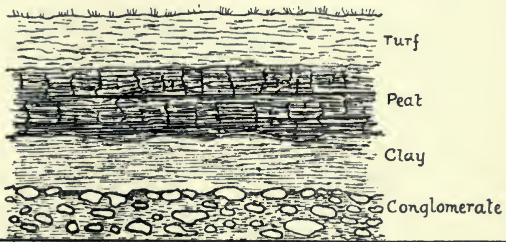


FIG. 2

SECTION NEAR BATTERY POINT.

J.R.F.



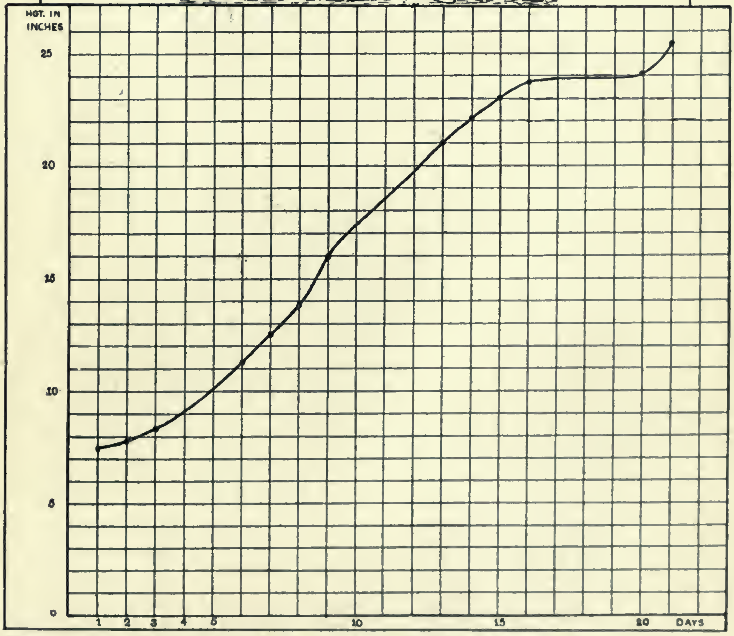


FIG. 3. CURVE SHOWING 3 WEEKS' GROWTH OF BEAN PLANT, 8.6.04 - 28.6.04. H.M.

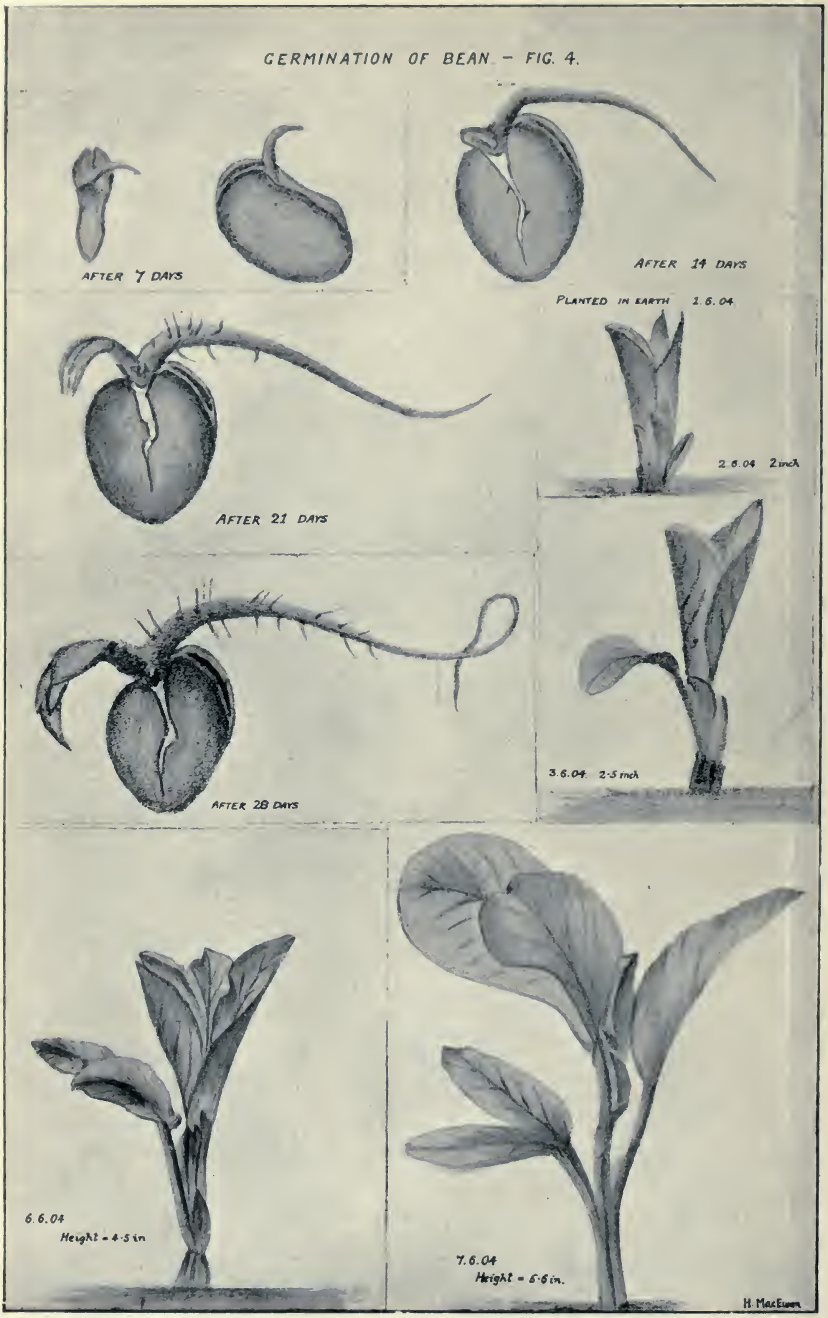
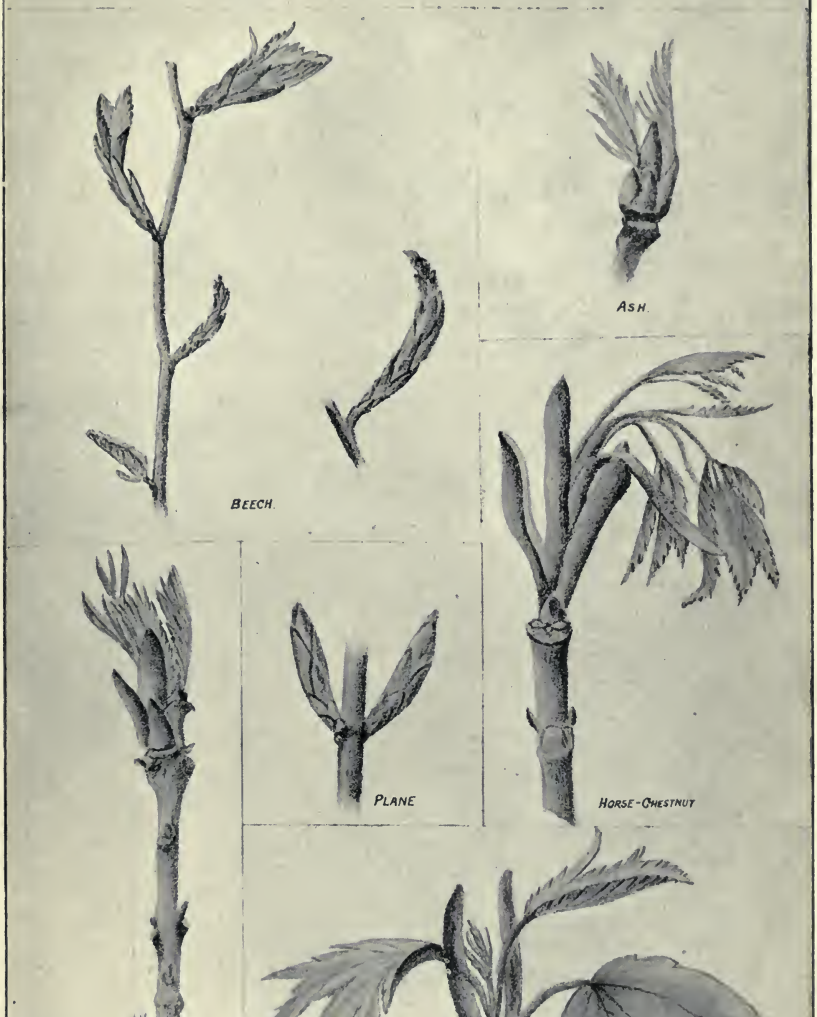

GERMINATION OF BEAN - FIG. 4.
AFTER 7 DAYS
AFTER 14 DAYS
PLANTED IN EARTH 1.6.04
2.6.04 2inch
AFTER 21 DAYS
AFTER 28 DAYS
3.6.04 2·5 inch
6.6.04
Height = 4·5 in
7.6.04
Height = 6·6 in.
H. MacEwen

FIG. 5.
THE OPENING OF LEAF-BUDS.



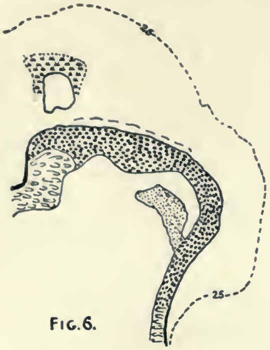


FIG. 6.

FIG. 7.

SKETCHES from ORDNANCE MAP showing loch formed at head of bay.

FIG. 6. Sandwick Bay and Loch. FIG. 7. Mol Sandwick Beg.

FIG. 10.

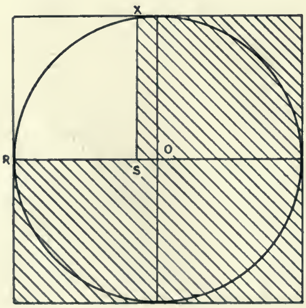


FIG. 8

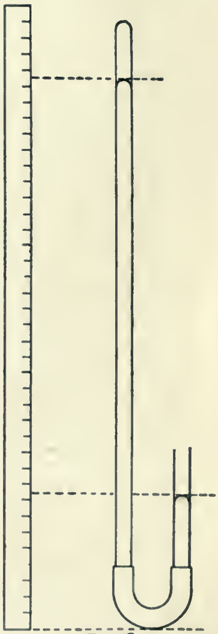


FIG. 9.

Normal hydrochloric acid.—Dilute pure strong acid to 1·10 sp. gr. at 15°·5 C. Dilute 180 gms. of this to 1 litre.

1 c.c. of this dilute acid = ·0365 gm. HCl.

To ensure the strength of the dilute acids being exact they should be titrated against normal sodium carbonate and diluted to the right point.

Combining weights of certain of the Elements.

Element.	Symbol.	Combining Weight.
Calcium - - -	Ca	40·00
Carbon - - -	C	12·00
Chlorine - -	Cl	35·45
Copper - - -	Cu	63·30
Hydrogen - -	H	1·00
Iron - - -	Fe	56·00
Magnesium - -	Mg	24·33
Manganese - -	Mn	55·05
Mercury - - -	Hg	200·40
Nitrogen - -	N	14·04
Oxygen - - -	**O**	**16**
Phosphorus - -	P	31·03
Potassium - -	K	39·14
Sodium - - -	Na	23·06
Sulphur - - -	S	32·06

Latitude and Longitude of Sun-dial in the grounds of Lews Castle, Stornoway :—

Latitude, 58° 12′ 38″·5 N.
Longitude, 6° 23′ 35″·6 N.

EXTRACTS FROM THE STUDENTS' NOTE-BOOKS.

1. Weather Calendar for June and September 1904, kept by one of the Infant Classes of the Nicolson Institute.

June 1. Wet, sky cloudy. Trees in leaf. Daisy, buttercup, marsh-marigold, violet, cuckoo-flower, forget-me-not are seen in the fields. Primroses still blossoming but not so plentiful.

,, 2. A fine fresh morning – a gentle wind blowing from the west. Sky has white clouds with patches of blue.

June 3. Bright—a few light clouds. Breeze from south.
,, 6. Sunny—streaks of white cloud. North-east wind. Lambs in field growing big—also calves. The green blade of the corn is considerably above ground.
,, 7. Warm, sunny. Blue sky, no clouds. Gentle south wind.
,, 8. Bright—sky blue and cloudless. Strong north-east wind, dust flying.
,, 9. Dull, cloudy sky. East wind—cold.
,, 10. Bright, cold. East wind blowing.
,, 13. Dull grey sky—very wet.
,, 14. A little dull. Wind from south—clouds.
,, 15. Dull—some showers of rain.
,, 16. Dark sky—lighter at horizon. Rainy and very windy.
,, 17. Dull—wet
,, 20. Dull in the morning. Afternoon, clouds broke up, the sun came out and it became milder.
,, 21. Showers—some sunshine. Windy.
,, 22. Bright—a little wind.
,, 23. Very wet morning, cleared in afternoon.
,, 24. Raining in morning.
,, 27. Warm. White clouds, with patches of blue.
,, 28. Very warm and sunny.
,, 29. Warm, sunny, and windy.
,, 30. Bright, wind from south. Dusty.

Aug. 30. Sunny, very warm. Sky at times dull. Corn still green, with yellow patches. Peats being carted.
,, 31. Dull morning, bright later on.

Sept. 1. Cloudy, cool, west wind. Light showers.
,, 2. Dark clouds with blue between. Warm.
,, 5. Boisterous, wind from south. Dull.
,, 6. Strong south wind blowing. Bright, some showers.
,, 7. Sunny. South-west wind. Blue sky with white clouds.
,, 8. Cold, south-east wind. Dull sky. Slight showers.
,, 12. East wind. White clouds, bright. Dust blown along by wind. Corn growing yellow.
,, 13. Dull and wet. Dry in afternoon.
,, 14 Frost on ground melted by sun, very sunny.
,, 15. Warm and sunny. Little white clouds.
,, 16. Dull and rainy, ground damp.
,, 19. Fine, warm, dry, sunny. Sky blue.
,, 20. Warm. Slight breeze.
,, 21. Warm, sunshine. Blue sky. Slight breeze from south-east.

Sept. 22. Bright and sunny. Blue sky, very few white clouds. Corn cut, made into sheaves, sheaves set up in stooks in the field.
,, 23. Sunny.
,, 26. Rainy, sky dark. Grass wet, road muddy.
,, 27. Rain during morning. Afternoon fair.
,, 28. Showers.
,, 29. Mild, sunny. Big white clouds low down.

H. M. M.

2. Notes on a School Aquarium kept by the Second Senior Class.

Aquarium was started in school about middle of September. Boys brought two small shore-crabs, a hermit-crab, a limpet, a whelk, and stones with barnacles, serpulae, and seaweed attached. We also had a star-fish, but it lived only for two days. Small fish, such as the gunnel and flounder, added to the aquarium, were after a day or so eaten by the shore-crabs. The crabs have been seen also attacking each other, but not often; they rather seemed to keep out of one another's way. The hermit-crab seemed specially sensitive, and would draw into his shell if you came suddenly close to the trough. The serpulae did not draw in their heads unless they were touched.

The serpulae were able to do without fresh water longer than the other occupants of the aquarium, the barnacles dying first. One barnacle was found dead with its feathery plume extended in the water. When the water was not changed daily, the action of the barnacles became sluggish, and the fishing-tuft changed from clear to a grayish tint before they stopped feeding altogether.

The limpets did not thrive long in the aquarium, but we were able to see the action of the "foot" as they climbed up the side of the glass, and to experience the difficulty of prising them off the piece of rock to which they sometimes adhered.

The whelks were nearly always found outside the trough in the morning, and climbed up the side of the glass when they were put back. The head was drawn in whenever the shell was touched. One large whelk was seen seemingly eating a small piece of seaweed which was floating in the aquarium.

We also had a sea-urchin, which climbed up the side of the glass with a kind of circular motion, and we could see the action of the small tube-feet quite plainly. It seemed to thrive well in the aquarium, and has been there now for over a month.

The aquarium is usually kept on the sill of a window with a northern outlook, but on one occasion in September it had been placed during a sunny day in a window with a southern aspect, and the next morning all the crabs and fishes were dead.

At first, when the weather was warm, the water needed to be changed daily, or something was dead next day.

When any of the creatures died, a slight milkiness of the water proclaimed that things were amiss, and we then made haste to remove whatever was dead and to change the water. There was some difficulty at first in getting them successfully over the week-ends. The plan we found to answer best was that by which the boys changed the water on Saturday and again on Monday morning.

Since the days have become so much colder, less frequent changes of water seem to be required. On one occasion, when it was too stormy to send the boys down to the sea, the water was not changed for so long a period as three days, and the occupants of the aquarium did not seem any the worse.

M. J. M.

3. Diary of a germinating bean, water only being supplied.

9.5.04. The bean which has been swelling, splits its covering, and from the end of the triangular area nearer the scar issues the point of the radicle.

12.5.04. The radicle, which is quite white, has grown somewhat in length.

20.5.04. The radicle is now 1 cm. in length.

27.5.04. The plumule has made considerable growth, and is now 2·5 cms. in length, while the radicle is 1·5 cms.

30.5.04. From the main axis of the root lateral roots are beginning to arise. Length of plumule 4 cms., of radicle 1·5 cms.

1.6.04. The leaf-like outgrowths on the plumule are darker in colour and more withered looking. Length of plumule 5 cms. Main root is same length as at previous entry, but the lateral roots have developed, and the longest of these is now 1 cm. in length.

3.6.04. Length of shoot is now 5·5 cms., and that of the longest lateral root 1·5 cms. There has been a corresponding growth of the other lateral roots. The main root is withering at the point, and the dark colour which originated there is gradually ascending.

5.6.04. Length of shoot = 6 cms.; 7.6.04., 6·8 cms.; 9.6.04, 7·7 cms.; 11.6.04, 8·1 cms.; 13.6.04, 8·1 cms. The plant seems to have reached the limit of growth that its own supply of plant-food renders possible, and is now planted.

D. M.

For drawings showing development of another bean-plant see Figs. 3 and 4, and for studies of bud-opening, Fig. 5.

4. Class Excursion, 21st May 1904.

Started from Goathill Farm, to which land rises gradually from Stornoway Harbour and gradually sinks northward to the shore washed by the waters of Broad Bay. Roadside covered with daisies; grass, owing to late spring, brown and bare at roots. At Farm, dandelions; and on bank with north-west exposure thyme-leaved speedwell and dog-violet. Along bank thyme-leaved speedwell, chickweed and mouse-ear chickweed plentiful. On either side of the road pasture-land and corn-fields—corn just sending up tiny green blade through the somewhat peaty soil—sweet vernal prominent along bank at side of field—scentless feverfew in blossom. In hollow of dyke bedstraw in bloom—leaves of sheep's sorrel abundant, but no flowers—whin in full dress. Marsh marigold in blossom, but only one buttercup seen. Rye-grass, ribwort plantain, cocksfoot and common sorrel all grew on the higher slope. and in the hollow were found spear-wort, and the leaves of ragwort, and the creeping and upright buttercup. In the ditch were starwort, stitchwort, and hairy bitter-cress. We now climb the slope—in a sheltered nook milk-wort found—rushes abundant in the ditch. Road continues to ascend and on each side is moorland. Sandwick village reached, a long row of houses straggling southward down the hill to sea-level. Houses low and thatched—many showing a tendency to improvement. Road running west into Stornoway cuts across the village in the middle dividing it into an upper and a lower village. Ground in the lower reaches flat—oats and potatoes cultivated. Sea beach reached—at margin thrift growing on its wiry stem. On the conglomerate cliff that forms side of small bay, the sea-plantain and stagshorn plantain grow abundantly. Considerable time now spent in studying the seaweeds of the rocky beach and the animal and plant contents of the rock-pools. Route was continued along the beach westwards to Stornoway.

M. M.

5. Class Excursion, 3rd June 1904.

Route by Newton and on to beach near Battery Point—concrete wall to keep off encroachments of sea, but sea has eaten away the ground behind the wall. Good section here showing the relation of the soil, the peat, and the underclay (see Fig. 2). Underneath the grassy sward was a layer of dry brown turf, below which another layer showed, darker, moister, and more compressed. Then came a layer of hard black peat below which was a layer of blue clay. Rocks of coast consisted of coarse conglomerate containing large boulders. The sea was of a deep blue, specked with the brown sails of the fishing-boats. At the harbour-mouth a tongue of Arnish Moor runs seaward, supporting Arnish Lighthouse on its outer point. Opposite it, on the other side of the harbour mouth, is Holm Point. In a pool on the beach at Battery Point was an interesting collection of hermit-crabs in shells of all shapes and sizes. Fresh specimens of weeds and several of the smaller animals were collected for the purpose of forming an aquarium. Realising, just in time to save ourselves from being surrounded, that the tide was coming in, we turned off from the beach into a marshy field at the head of Sandwick Bay. An interesting geographical feature was the small fresh-water loch produced, evidently, from a sea-water lagoon by the bay having cut off its own head by means of a shingle bar (see Figs. 1 and 6). The field afforded numerous specimens of marsh-plants, giving place to the common pasture-plants as we climbed to the drier ground and reached the Stornoway road. J. R. F.

6. Class Excursion, 4th June 1904.

Route:—Goathill Farm—Broadbay beach to near Steinish—road to Melbost Farm—sandy beach at Melbost Links—back to Stornoway by the road.

At farm, orange cat birding—suggestion of tiger-habit in its movements—at roadside and at turf top of wall thyme-leaved speedwell, wall speedwell, field woodrush, bedstraw not yet in flower, dog violet, field violet, several species of grasses and chick-weeds — in ditch water-blinks, ivy-leaved ranunculus — copious spring at bottom of slope which supplies Coulregrein with drinking water—its clearness a contrast to the peaty colour of most Lewis water—in deep ditch water-cress, ivy-leaved ranunculus, floating meadow-grass. Crossed meadows reclaimed from Broad Bay—tidal ditches—occasional patches of mud showed sun-cracks and footprints of birds—geological interest of such markings—large clump of scurvy-grass growing on the side of one of the ditches—the two common buttercups, spearwort, thrift, butterwort not in flower, cathartic flax, sedges—embankment to keep out sea—bird's-foot trefoil, trivial chickweed—Broad Bay stretching to the north with great stretches of sand exposed at low tide—corner of moor crossed showing a different flora—red-rattle, tormentil, milkwort, whin—mouth of stream passed—river gravel more angular than beach gravel—brood of ducklings swimming in ditch at roadside—hen foster-mother quite unconcerned—on dry-stone walls along the road were various species of well-grown lichens—corncrake running along the road with its leg hurt was caught—legs of a crane-fly protruding from its bill gave indication of its last meal—plumage various shades of brown—body balanced far forward on legs. On turning towards Melbost Farm the stones of the wall with northern aspect were abundantly covered with moss, those in the wall with southern aspect had none—affords a possible means of orientation—crotl, the yellow lichen still used in Lewis for dyeing, abundant on some of the stones—field on one side of the road with recently-sown turnips—sweet cicely luxuriant in corner of garden at farmhouse—in neighbouring pool patches of starwort. Party now emerged on links of Broad Bay—marigolds in the ditches at side of path, butterwort—moonwort on the sandy links—at this point the corncrake, after quite half-an-hour's carrying by one of the ladies, opened its bill and the crane-fly flew off—says a good deal for the vitality of *Tipula*—sand-dunes held together by a grass with long stolons—effect of wind on the sand—wind ripple-marks—abundance of shells on the beach—*Donex* drifted into masses by waves, forming layers often over a foot thick—many species of shells, mostly single shells of bivalves—numbers of crab-carapaces and heart-urchins—sea purslane growing in sand, not yet in flower—at eastern end of sandy beach cliff of chocolate-coloured conglomerate, not so coarse as that at Battery Point or Arnish—probably farther from the ancient beach—Melbost village—Norse ending—bost—beach at the isthmus probably offered convenient landing-place for Norse rovers—crofters' houses—corn well up, hardly any showing a fortnight ago, now about four inches high—young chickens—puppy-dog readily attached itself to party—had to be reclaimed by his mistress—ready friendliness of puppies towards strangers presumably an acquired habit—how is it in the case of kittens? Crossed field to Point Road—road elevated above level of ground on both sides, owing to peat having been cut away—its springiness when carts passed—on south side peat has been cut down to underlying rock—is this the conglomerate or overlying boulder-clay? Dragon-fly captured—*Pyrrhosoma*—first dart so rapid that eye unable to follow—Sandwick village—Norse ending again—the bay opening to south with its pebbly beach an ideal viking ground—natives pronounce name "Sandi-vik," which is even more characteristically Scandinavian—village on a long ridge, succeeded on the Stornoway side by a long hollow, then another ridge and another hollow—on second ridge quarry for road-metal in the conglomerate, which seems somewhat "altered"—very rough indication of bedding—dip seems about 10 degrees—conglomerate rough but not so much so as that at Battery Point—at head of Sandwick Bay gravel bar and a small fresh-water loch occupying lagoon on landward side of bar—hollow crossed before entering Stornoway, only slightly above sea-level of Broad Bay and Stornoway Harbour.

7. List of Animals found on Excursions of 3rd and 4th June, either living or represented by their shells.

Bread-crumb sponge.

Anemone (three species).

Serpula, spirorbis.

Sea-urchin, heart-urchin, common star-fish, brittle star-fish.

Shore-crab, edible crab, long-armed crab, hermit-crab, acorn barnacle.

Dragon-fly (Pyrrhosoma).

Limpet, blue-rayed limpet, whelk (two species), dog whelk, buckie, purple top, common top, Natica, Helix (land snail).

Common mussel, cockle, Donax, oyster, saddleback oyster, Mactra, Lucina, Cyprina, Tellina, scallop (two species).

Gull (two species), corncrake, lark, hen and chickens.

D. M.

8. Class Excursion, 25th June 1904.

Started from the Glen House and proceeded at first along road in north-westerly direction. A quarry at the roadside showed a section of the rotten rock that runs along the junction of the conglomerate with the gneiss. In the roadside ditches or on the banks were found water-blinks, thyme-leaved speedwell, pearl-weed, Dutch clover, willow-herb, crested dogstail, yellow-and-blue scorpion-grass—in a wetter part of the ditch tufted scorpion-grass—on the dryer banks bedstraw in abundance, bird's-foot trefoil, milkwort of two colours, eyebright, the hard fern, and the polypody. Water milfoil was growing submerged in the running water. *Cotoneaster* growing at roadside, evidently an escape from the Lews Castle grounds. Turned westward along Lochs Road. On a patch of hard, gravelly earth were found growing soft-leaved geranium and wall speedwell. In the bog near the road were found growing several species of bog-moss (*Sphagnum*), sundew, and bladderwort submerged in the pools. On the drier banks were heather, cross-leaved heath, fine-leaved heath, hair moss, dwarf red-rattle, and tormentil. The cup-lichen was found in the bog, and liverworts were common on the damp rocks of the hillside. In a pool the water-boatman was swimming; and several beetles were found among the heather. The butterwort was growing on damp places on the hill, and its insectivorous habit was shown by a number of dead ants and half-digested gnats which were found on the leaves of some of the specimens. Brackens were growing on the edge of the wood, and a number of plume thistles on a patch of flat land at the foot of the hill. From the hillside a pheasant rose. We now topped the hill and began to descend to the River Creed, picking up on the way crowberry, self-heal, the early orchis, and a few club-mosses. On a strip of flat ground near the river were growing bog-myrtle, yellow rattle, marsh pennywort, oxeye, bitter-vetch, and cathartic flax; and on the rocks bearberry, St John's wort, stonecrop, and honeysuckle. Numbers of moths were started, and a large brown caterpillar was carried off by one of the party with a view to its metamorphosis being watched in the class-room. Protective colouring was illustrated by a black and white speckled spider, which had its home on a bare surface of hornblendic gneiss. As the party went downwards the gorge in the gneiss which the Creed has worn began to be contracted. An iron-well was visited and its water tasted. The iron-spring was rising from the side of a wide dolerite dyke which here cuts across the gneiss. The rocky sides of the gorge were overgrown with trees, and many of the rock-faces covered with the glossy leaves of the bearberry. Several specimens of the pyramidal bugle (*Ajuga pyramidalis*), a rare plant in the British flora, were seen, but were past flowering. On the route home through the woods of the Castle grounds various other wild flowers were found, among them being foxglove, angelica, bugle, vetch, greater stitchwort, bistort, and bishopweed; and the flat-lying meadow near the head of the bay, to which the sea has access at high tide, yielded orach, scurvy-grass, and sea milkwort.

D. M.

LIST OF PLANTS OBTAINED IN FLOWER DURING THE CLASS EXCURSIONS, MAY AND JUNE 1904.

(Generic names in Italics: where none is given the genus is the same as for the preceding plant.)

Seaside rue (*Thalictrum*).
Upright buttercup (*Ranunculus*).
Creeping buttercup.
Spearwort.
Ivy-leaved ranunculus.
Marsh marigold (*Caltha*).
Cuckoo-flower (*Cardimine*).
Hairy bitter-cress.
Shepherd's purse (*Bursa*).
Scurvy grass (*Cochlearia*).
Dog violet (*Viola*).
Field violet.
Milkwort (*Polygala*).
Sea campion (*Silene*).
Ragged Robin (*Lychnis*).
Mouse-ear chickweed (*Cerastium*).
Trivial mouse-ear chickweed.
Chickweed (*Stellaria*).
Greater stitchwort.
Marsh stitchwort.
Sea purslane (*Arenaria*).
Pearlweed (*Sagnia*).
Corn spurrey (*Spergula*).
Seaside spurrey (*Buda*).
Water clinks (*Montia*).
St John's wort (*Hypericum*).
Cathartic flax (*Linum*).

List of Plants—*continued.*

Soft-leaved geranium (*Geranium*).
Stork's-bill (*Erodium*).
Wood sorrel (*Oxalis*).
Whin (*Ulex*).
Broom (*Cytisus*).
Clover (*Trifolium*).
Hop trefoil.
Dutch clover.
Lady's-fingers (*Anthyllis*).
Bird's-foot trefoil (*Lotus*).
Bush vetch (*Vicia*).
Tufted vetch.
Bitter vetch (*Orobus*).
Meadow vetchling (*Lathyrus*).
Silver weed (*Potentilla*).
Tormentil.
Marsh cinquefoil (*Comarum*).
Lady's-mantle (*Alchemilla*).
Field lady's-mantle.
Hawthorn (*Crataegus*).
Dog rose (*Rosa*).
Stonecrop (*Sedum*).
Round-leaved sundew (*Drosera*).
Long leaved sundew.
Mare's-tail (*Hippuris*).
Water milfoil (*Myriophyllum*).
Water starwort (*Callitriche*).
Willow herb (*Epilobium*).
Marsh pennywort (*Hydrocotyle*).
Wild angelica (*Angelica*).
Gout-weed (*Ægopodium*).
Hogweed (*Heracleum*).
Honeysuckle (*Lonicera*).
Smooth heath bedstraw (*Galium*).
Water bedstraw.
Goose-grass.
Yellow bedstraw.
Field madder (*Sherardia*).
Devil's-bit scabious (*Scabiosa*).
Daisy (*Bellis*).
Michaelmas daisy (*Aster*).
Mountain everlasting (*Antennaria*).
Cudweed (*Gnaphalium*).
Yarrow (*Achillea*).
Sneezewort.
Ox-eye (*Chrysanthemum*).
Scentless feverfew (*Matricaria*).
Butterbur (*Petasites*).
Groundsel (*Senecio*).
Ragwort.
Marsh ragwort.
Burdock (*Arctium*).
Thistle (*Carduus*).
Plume-thistle (*Cnicus*).
Knapweed (*Centaurea*).
Hawkweed (*Hieracium*).
Dandelion (*Taraxacum*).
Sow thistle (*Sonchus*).
Bearberry (*Arctostaphylos*).
Heather (*Calluna*).
Cross-leaved heath (*Erica*).
Fine-leaved heath.
Thrift (*Armeria*).
Primrose (*Primula*).
Sea milkwort (*Glaux*).
Buckbean (*Menyanthes*).
Comfrey (*Symphytum*).
Small bugloss (*Lycopsis*).
Field scorpion grass (*Myosotis*).
Tufted scorpion grass.
Yellow-and-blue scorpion grass.
Common speedwell (*Veronica*).
Germander speedwell.
Wall speedwell.
Field speedwell.
Thyme-leaved speedwell.
Eyebright (*Euphrasia*).
Bartsia (*Bartsia*).
Red rattle (*Pedicularis*).
Yellow rattle (*Rhinanthus*).
Bladderwort (*Utricularia*).
Butterwort (*Pinguicula*).
Corn mint (*Mentha*).
Self-heal (*Prunella*).
Woundwort (*Stachys*).
Hemp-nettle (*Galeopsis*).
Purple dead-nettle (*Lamium*).

List of Plants—*continued.*

Bugle (*Ajuga*).
Pyramidal bugle—in fruit.
Greater plantain (*Plantago*).
Ribwort plantain.
Seaside plantain.
Stag's-horn plantain.
Orach (*Atriplex*).
Glasswort (*Salicornia*).
Knot-grass (*Polygonum*).
Amphibious persicaria.
Spotted persicaria.
Bistort.
Dock (*Rumex*).
Common sorrel
Sheep's sorrel.
Nettle (*Urtica*).
Burning nettle.
Bog-myrtle (*Myrica*).
Willow (*Salix*).
Dwarf willow.
Crowberry (*Empetrum*).
Early purple orchis (*Orchis*).
Spotted orchis.
Common rush (*Juncus*).
Heath rush.
Great woodrush (*Luzula*).
Field woodrush.
Seaside arrow-grass (*Triglochin*).
Marsh arrow-grass.
Pondweed (*Potamogeton*).
Cotton-grass (*Eriophorum*).
Tufted cotton-grass.
Sedge (*Carex*).
Oval-spiked sedge.
Yellow sedge.

Crested dog's-tail (*Cynosurus*).
Yorkshire fog (*Holcus*).
Cock's-foot (*Dactylis*).
Foxtail (*Alopecurus*).
Sweet vernal (*Anthoxanthum*).
Sea-reed (*Ammophila*).
Annual meadow-grass (*Poa*).
Couch-grass (*Triticum*).
Rye-grass (*Lolium*).
Floating meadow-grass (*Glyceria*).
Creeping fescue (*Festuca*).
Purple molinia (*Molinia*).

Ferns (Felices).

Common polypody (*Polypodium*).
Black spleenwort (*Asplenium*).
Hard fern (*Blechnum*).
Bracken (*Pteris*).
Moonwort (*Botrychium*).

Horsetails (Equisetaceae).

Common horsetail (*Equisetum*).

Club-mosses (Lycopodiaceae).

Fir club-moss (*Lycopodium*).

List of Seaweeds found.

Halidrys siliquosa (Podded sea-oak).
Fucus serratus (Serrated wrack).
Fucus nodosus (Knotted wrack).
Fucus vesiculosus (Twin bladder wrack).
Fucus canaliculatus (Channelled wrack).
Himanthalia lorea (Sea thongs).
Alaria Esculenta.
Laminaria digitata (Tangle).
Laminaria saccharina (Sugar tangle).
Laminaria fascia (Tufted Laminaria)
Chorda filum (Sea laces).

List of Seaweeds found—*continued.*

Ectocarpus littoralis.
Odonthalia dentata.
Rhodomela.
Polysiphonia fastigiata.
Laurencia pinnatifida (Pepper dulse).
Lomentaria ovalis.
Chylocladia.
Furcellaria fastigiata.
Corallina officinalis (Common coralline).
Melobesia.
Delesseria sanguinea.
Delesseria sinuosa.
Delesseria alata.
Nitophyllum punctatum.
Gelidium.
Rhodymenia palmata (Dulse).
Plocamium coccineum
Chondrus crispus (Carrageen).
Schizymenia edulis.
Ceramium.
Ptilota sericea.
Ptilota plumosa.
Callithamnion.
Porphyra (Laver).
Enteromorpha intestinalis.
Enteromorpha compressa.
Ulva linza.
Ulva latissima.
Cladophora rupestris.
Conferva.

LIST OF BOOKS RELATING TO LEWIS.

"A Description of the Western Islands of Scotland," by Martin Martin, Gent. The writer visited Lewis about 1695, and his work contains an interesting account of the Island and its people as he saw them.

Sir John Sinclair's "Statistical Account of Scotland," 1797. County of Ross is Vol. 19.

For the History of Lewis two books may be consulted :—

Gregory's "History of the Western Isles" (Morison, 12s. 6d.), and

Wm. C. Mackenzie's "History of the Outer Hebrides" (Gardner, 12s. 6d.).

There are various descriptive accounts of the Island, among which the following may be mentioned :—

Hogg's "A Tour through the Highlands in 1803" (Gardner). These are letters written to Sir Walter Scott by "The Ettrick Shepherd," who visited the Highlands and Islands, including Lewis, in the year indicated.

"Twenty Years of Wild Sport in Lewis," by "Sixty-One." This book, now out of print, is concerned chiefly with the sport of Lewis, but reproduces, with marked success, some of the essential characteristics of the Island, especially those connected with the weather and the moor.

Miss Goodrich-Freer's "Outer Isles" (Constable, 5s.). Part of this work deals with Lewis.

Of novels having their scene laid in Lewis, the best known is Black's "A Princess of Thule." Though one of

Mr Black's most popular novels, the atmosphere is not characteristically Lewisian, nor can it be regarded as in any marked degree a successful presentation of Lewis life and character.

Smith's "Lewsiana" (Daldy, Isbister, & Co., 1875).

"Days in Thule," by "John Bickerdyke" (Constable). The descriptions given are chiefly connected with the Gress shootings, and are illustrated by some characteristic snap-shots.

LIST OF HELPFUL BOOKS ON GEOGRAPHY AND NATURAL HISTORY.

Geography.

Daily and weekly weather reports are issued by the Meteorological Office, 63 Victoria Street, London, S.W. The Annual Subscription for the Weekly Report is £1, 10s.

Geikie: "The Teaching of Geography" (Macmillan, 2s.). A very useful presentation of the new methods in geography, which should be read by every teacher.

Arnold-Forster: "This World of Ours" (Cassell, 2s. 6d.). This is intended as a school text-book, but contains much matter that teachers will find valuable.

Articles by Dr Herbertson in *The School World* of August, September, October, and November 1900 on "Practical Work in Physical Geography" (Macmillan, 6d. each).

For the larger aspect of Geographical study:—Herbertson: "Illustrated School Geography" (E. Arnold, 5s.). "The International Geography" (Newnes, 15s.). Huxley: "Physiography," revised edition (Macmillan, 4s. 6d.). Herbertson: Outlines of Physiography (E. Arnold, 4s. 6d.).

Maps:—"London School Atlas" (E. Arnold, 1s. 6d.). This is a convenient atlas for general school use. The maps are well printed and coloured, and the introduction on map-making is written by Dr Herbertson.

Ordnance Survey Maps of the district, on 6-inch and 1-inch scale, and 1-inch map with hill-shading, can be obtained through the post-office. The greater part of Lewis is on Sheet 105 of the 1-inch map.

In Bartholomew's half-inch district maps of Scotland, coloured to show heights (1s. each, paper; 2s., cloth-mounted) Lewis forms Sheet 23.

The Ordnance Survey Office is now prepared to supply to school authorities district maps on the 1-inch scale at nominal rates (1½d. upwards per copy, according to size and number of sheets from which printing has to be done). The least number of copies that will be supplied is 200. Application has to be made in a special form to be obtained from the Director-General of the Ordnance Surveys, Southampton.

Plants.

Wilson: "The Study of Flowers" (Chambers, 8d.). A book for beginners consisting of an examination of a few common flowers.

Grant Allen: "Story of the Plants" (Newnes, 1s.).

Johns: "Flowers of the Field" (S.P.C.K., new edition, 7s. 6d.). This is a convenient book for a beginner to use in identifying wild flowers. It contains all the British species, is well illustrated, and the descriptions are not too technical.

Animals.

1. "Syllabus of Course in Natural History for Students in the Training Colleges and for King's Students—Natural History Department, Marischal College, University of Aberdeen." This little booklet has been printed for the use of the students indicated above, who attend the class conducted under the supervision of Prof. J. Arthur Thomson. Every teacher who can secure a copy should do so. It will be found most helpful and suggestive.
2. Prof. Miall: "The Natural History of Aquatic Insects" (Macmillan, 6s.).
3. Furneaux: "Butterflies and Moths."
4. Furneaux: "Life in Ponds and Streams."
5. Hudson: "British Birds." This and the two preceding volumes are popularly written and have coloured illustrations. (Longmans, 6s. each, net).

   The following seven deal with the Natural History of the Sea-shore:—
6. Wood: "Common objects of the Sea-shore" (Routledge, 1s.)
7. Furneaux: "The Sea-shore" (Longmans, 6s net). This and the preceding volume are written from the popular standpoint and are illustrated.
8. Newbigin: "Life by the Sea-shore" (Sonnenschein, 3s. 6d.).
9. Step: "Shell Life" (Warne, 6s.). A well-illustrated popular account of the Mollusca.

10. Murray: "An Introduction to the Study of Seaweeds" (Macmillan, 7s. 6d.). Coloured illustrations.
11. Mrs Clarke: "Common Seaweeds" (Warne, 1s.).
12. Johnstone and Croall: "Nature-Printed British Seaweeds" (Bradbury, Evans, & Co., 1859). This is an expensive work in four volumes which may be consulted in some of the larger libraries. A special feature is its very fine set of coloured plates.

General.

13. Kingsley: "Madam How and Lady Why" (Macmillan, 2s. 6d.).
14. Prof. Miall: "Round the Year" (Macmillan, 5s.).
15. Those interested in infant school teaching will find some very suggestive remarks on the Nature-Study in infant classes, and its correlation with their other subjects, in the first three chapters of Miss Lyschinska's "The Kindergarten Principle" (Isbister, 4s. 6d.).
16. Article on "Nature Teaching" in April 1902 issue of *The Journal of Education* (6d.).
17. Prof. Thomson: "Seasonal Natural History in Schools," in the April, July, and November 1901 issues, and other articles on Nature-Study in the May and September 1901, and June 1903 issues of *The School World* (Macmillan, 6d. each).
18. Hodge, C. F.: "Nature Study and Life" (Ginn, 7s.). A book full of helpful suggestions.

The teacher will find it convenient to have for purposes of reference a general text-book of Zoology, such as Prof. Thomson's "Manual of Zoology" (Pentland, 15s.), or Shipley and MacBride's "Zoology" (Cambridge University Press).

The study also of one or two of the works of the great masters in Natural History will not be omitted. Such works as Fabre's "Insect Life" (English translation, Macmillan), and Darwin's "Earthworms" or "Insectivorous Plants," will be found well suited to reveal the earnest spirit of truth-seeking and of reverent waiting on nature that has characterised all the great naturalists, and to which even the smallest worker in the field of Nature-Study can, if he will, serve himself heir.

H. & J. Pillans & Wilson, Printers, Edinburgh.