

THE EQUIPMENT AND THE HOUSING OF THE BIOLOGICAL
LABORATORY IN THE SECONDARY SCHOOL

By

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Ida M. Post.

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J. A. M. Bishop, Editor
Catholic World, Vol. 11, No. 6, p. vi

INTRODUCTION

In June, 1871, Thomas Huxley began a six weeks' course in general biology for teachers. A rough laboratory was set up on the ground floor of the South Kensington Museum. He was assisted by Michael Foster, E. R. Lankester, and W. G. Rutherford. Teachers and students were equally excited in taking part in this new experiment. Huxley at once carried the new system into his regular course at the School of Mines (which had been moved to South Kensington) beginning in October, 1872, and thence the laboratory method spread throughout the English - speaking world.¹

Some things have to be taken without questioning too much, but we are becoming more and more of the questioning mind. Mark Twain said, "You just need ignorance and confidence in order to make a success." "If we had no faith in ignorance, think how much fewer the oil-wells approved by the most expert geologists; and how much fewer many other things besides." "Most of the natural sciences that attempt to treat on ultimate causes go awry."² When we speak of a straight line we mean a circle, and vice versa.

¹ Houston Peterson, Huxley, Prophet of Science, (New York: Longmans, Green and Co., 1932), pp. 187-188.

² J. A. M. Richey, "Science With a Sense of Humor," Catholic World, Vol. 131, (September, 1930), pp. 685-8.

In his "Origin of Species", Darwin pointed out that the most important element in the origin of species was the innate tendency to vary.³

Aristotle believed that if two balls equal in size but differing in weight were dropped from the same height at the same time, the heavier would fall more rapidly than the lighter one.⁴ This conception was only a guess, but was held as a truth for years. About 300 years ago the greatest idea of all ages took definite form. It was the idea of science - knowledge produced by experimentation.

Galileo was one of the first standard-bearers of the new idea. He tested this long-standing belief by dropping two balls of the same size but of unequal weights from the same height at the same time and found that Aristotle and all who believed with him for two thousand years were wrong.

A new group -- scientists -- was born into that world. Then began the struggle which is still going on between beliefs and knowledge.

A scientist in his proper role can have a two-compartment mind. In one he is entitled to beliefs pertaining to the spiritual world, if they brighten his outlook upon life; in the other compartment there should be tested and testable facts.

³E. C. Jeffrey, "Some Limitations of the Experimental Method in Biology," Science, (January 10, 1930), p. 32.

⁴D. M. Luckweish, "Science as the Source of Ideas," Scientific Monthly 29: (September, 1929), pp. 236-242.

There is no doorway between these two compartments and, therefore, there can be no intermingling.

Only genius can extend the borders of scientific knowledge, but the humblest man can be taught the spirit. He can learn to distinguish between opinion and knowledge.

Science means a better and more exact knowledge of the world. Mankind is no longer at the mercy of nature. Nature is now a servant, not a master. The age of non-science is past, educationalists are coming to realize that educational method must be placed upon a firmer basis than speculation. Experimental method is the pathway to ideals in educational method.⁵

Shrinkage of time and space occurs as man's knowledge expands. At no previous time has this been so marked as at the present time in the progress of science.⁶

Air transportation brings continents closer together, unmindful of the new problems that it leaves in its air-stream. Deadly microbes and dread diseases may ride on ships of air as well as passengers, mails, and freight.

⁵Wm. D. Tait, "Science and Education," Science, (August, 1929), pp. 132-136.

⁶"Science is Influencing Civilization," Worlds Work, Vol. 58, (December, 1929), pp. 35-36.

Leisure that preserves the incentive to greater discoveries of science's secrets will speed the world's progress. Civilizations rise and fall under the influence of human personality. In conquest of disease, medicine has now entered upon a successful attack upon bodily disorders that owe their origin not to an invading army, but to malfunction of the body itself. Life is shown to be largely what we make it.

During the present century, there have been a number of important developments in biology:⁷ the discipline of heredity, of development, and ecology, to mention only three, have grown from very modest beginnings into true sciences. But the various substances have interlocked, and perhaps the most important single result of the last thirty years' work has been to unify the whole science of biology, which, at the beginning, was sadly disunited.

The biologist is primarily interested in the forces of organic matter. Manifesting these forces are the multitudinous forms of plants and animals. These are the biologist's instruments, for they alone exhibit the phenomena which are the center of his interest. It is the initiation, correlation, and succession of these changes manifested by his instruments which he is endeavoring to understand.

⁷Julian Huxley, "Recent Trends in Biology," New Republic 67: (May 20, 1931), pp. 11-13.

The question of just what the equipment of a laboratory should be to teach such an interesting and important subject often occurred to the writer during the twelve years' experience teaching biology in a portable building with a meagre amount of equipment, but with an abundance of natural material in the vicinity of the school. Animals from the protozoa to the vertebrates inclusive, and plants from the spirogyra to the dicotyledons were studied. During December, January, and February, when the thermometer dropped to the freezing point, and we could not have any aquaria, or outside projects, we studied physiology, or the biology of the human body; and worked the types of experiments, that required preserved materials or those upon which the weather had little effect.

The many angles of the problem concerned in presenting the subject matter in as concrete and as systematic a manner as possible for the advantageous learning of it by students of the early high-school grades seemed of momentous value and of a highly interesting nature.

The phases of the subject seemed to me to have a wide application, especially in their relationship to the fields of human endeavor.

Equipment that will help to attain a satisfactory realization of these principles of living is necessary.

There are so many interesting and available phenomena among living things in any community that it would be doing an injustice to the students not to give them an opportunity to know about them and if possible see them even under the natural conditions of their habitats. This is just one angle of laboratory work.

Chemical and anatomical work present problems in reactions which are very important even though all the details cannot be seen. Because of the slowness of some of these reactions and the complexity of the equipment necessary in some cases, the experiments are often omitted.

The impressions which students receive from laboratory work in biology are of lasting importance if they are produced through the proper kind of work. There are many practical applications of the principles learned and these may be rightly pursued to enhance the students' interest.

Just to what extent the assortment of the equipment for each of the different phases in the biological study is necessary and how it is represented in the different school systems of the state and the housing of the biological laboratory is the problem from which this study is made.

Data for this discussion are based upon twelve years' experience as a biology teacher, visiting science departments in both large and small high schools, a large amount of reading,

and upon the replies received to the following questionnaire which was sent to the biology teachers throughout the state.

A word of explanation seems fitting at this point. This questionnaire was prepared with the idea of putting into brief form a comprehensive survey of the materials required for the everyday practices in the laboratory. Those factors which would facilitate the putting across of the subject matter under reasonably good conditions are the points emphasized. The questionnaire is based upon the minimum equipment in the State Course of Study.⁸

⁸ E. E. Ramsey, Chairman State Course of Study, State Course of Study for Secondary Schools, (Indianapolis: State Department of Public Instruction, 1923), pp. 132-133.

Laboratory Equipment for Biology

Individual Sets for () Students

Fill in quantity needed. If item is not needed, leave blank.

Quantity

- () Alcohol lamps, 4oz.
- () Battery jar, 5x7.
- () Bottles, wide mouth.
- () Beaker 250cc.
- () Dissect. pan, waxed bottom.
- () Dissect. sets,
6 pieces in each case.
- () Evaporating dish.
- () Flask, 250cc.

Quantity

- () Glass plates, 100mm. x 100mm.
- () Magnifier, tripod.
- () Pneumatic trough.
- () Ring stand.
- () Rubber stopper, 2 hole, No. 3.
- () Thistle tube, 30cm. stem.
- () Watch glasses, 3 in.
- () Wire gauze, 5 in. sq.

General

- () Aquarium.
- () Bell jar, 1 gal.
- () Bladders, for Osmosis.
- () Bone forceps, small.
- () Bone forceps, large.
- () Genco Trip scale,
agate bearings.
- () Corks, assorted 0-11.
- () Cork borers.
- () Coordinate paper.
- () Cover glasses.
- () Flasks, 500cc.
- () Flower pots, 4 in.
- () Flower pot saucers, 4 in.
- () Funnels, glass, 65mm.
- () Funnels, glass, 150mm.
- () Filter paper.
- () Glass tubing,
10 to 15mm. assorted.
- () Glass tubing,
4 to 7mm. assorted.
- () Graduate, cylindrical cc.
- () Graduate, cylindrical 250cc.
- () Insect net, collapsible.
- () Insect pins, No. 0.
- () Insect pins, No. 3.
- () Insect spreading boards,
12x4x7/8 in. (Home made).
- () Litmus paper, blue.

- () Litmus paper, red.
- () Medicine droppers.
- () Microtome, hand.
- () Microscope, 1 for each
() students.
- () Platinum in glass handle.
- () Riker mounts, 4x5 in.
- () Rubber stoppers, 2 hole, No. 9.
- () Rubber stoppers, 2 hole, No. 6.
- () Rubber stoppers, 1 hole, No. 1.
- () Rubber tubing, 3/16 in.
- () Rubber dam.
- () Rubber balloons.
- () Section razor.
- () Snellen's Eye test Chart.
- () Slides for microscope,
blank, 3x1 in.
- () Test tubes, 4x1/2.
- () Test tubes, 6x3/4.
- () Test tube racks.
- () Test tube brushes.
cork tipped.
- () Thermometers - 10 to 100 C.
and 10 to 220 F.
- () Tray, photographic, 5x8.
- () Tripos, 6 in.
- () Water bath, copper, 6 in.
- () Weights with holder,
10 to 500 gr.

Chemicals

- () Acid, Acetic, glacial.
- () Acid, Hydrochloric, com.
- () Acid, Nitric, com.
- () Acid, Sulphuric, com.
- () Ammonium Hydrate, com.
- () Benedict's Solution, qual.
- () Calcium Phos. (acid Phos.).
- () Calcium Phos. (monobasic).
- () Calcium Sulphate.

- () Iodine Sol. in Potassium Iodide.
- () Iron Chloride.
- () Lime water.
- () Lysol.
- () Magnesium Sulphate.
- () Glucose (Dextrose) gran.
- () Manganese Dioxide.
- () Malachite Green.
- () Methyl Blue.

) Canade Balsam, for slides.
) Carbolic Acid, loose cryst.
) Charcoal, wood, lumps.
) Corrosive Sub. tablets.
) Eosin, yellowish,
 water soluble.
) Ether.
) Fehling's Solution A.
) Fehling's Solution B.

() Paraffin, medium.
 () Potassium Bichromate, cryst.
 () Potassium Chlorate, cryst.
 () Potassium Nitrate, gran.
 () Pepsin, powder.
 () Pancreatin.
 () Sodium Carbonate, cryst.
 () Zinc Metal, mossy.
 () Zinc Chloride, pure.

Biological Laboratory

Check and fill as point may indicate.

I. Room

A. Use.

1. For Recitation. ().
a. Size. ().
2. For Lecture. ().
a. Size. ().
3. For Rec. and Lec. ().
a. Size. ().
4. For Laboratory. ().
a. Size. ().
5. For Lab. and Rec. ().
a. Size. ().

B. Location

1. () Basement; () 1st.
floor; () 2nd floor;
() 3rd floor.
2. Facing () North; ()
East; () South; ()
West.

C. Heating.

1. System.
a. Steam. ().
b. Plenum. ().
c. Hot Air ().

D. Ventilation.

1. Direct. ().
2. Indirect. ().

E. Lighting.

1. Windows.
a. Number. ().
b. Size. ().

F. Electric wiring.

1. No. of outlets ().

G. Gas.

1. No. of connections. ().

H. Water.

1. Running. ().
a. From well. ().
b. From city supply. ().

II. Live Room.

- A. Location. ().
- B. Size. ().
- C. Lighting. ().
- D. Plumbing. ().

III. Dark Room.

- A. Location. ().
- B. Size. ().
- C. Plumbing. ().

IV. Projection.

- A. Moving pict. proj. ().
- B. Lantern projection. ().
- C. Opaque projection. ().

V. Tables.

- A. Number. ().
- B. Size. ().
- C. Equipment. ().

VI. Museum.

- A. Location. ().
- B. Size. ().
- C. No. of Specimens. ().

VII. Aquaria.

- A. Kind. ().
- B. Size. ().
- C. Balanced. ().

VIII. Year Biol. is offered. ().

IX. No. of Biol. teachers. ().

X. Text used. ().

XI. Work Book.

- A. Prepared (); Loose Leaf ().

- XII. No. of pupils per teacher (). XVII. Method
XIII. Periods per week. (). 1. Demonstration.
XIV. Enrollment. 2. Individual.
XV. Field work. (). 3. Demonstration and
XVI. Drawing. (). Individual.
4. Project.

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TERRE HAUTE, INDIANA

September 25, 1931

High School

Dear _____:

In carrying on the work for the Master's degree this College, in line with practically all other colleges, requires the preparation of a thesis. In some instances the most useful method of collecting is through the questionnaire plan.

One of our students, Mrs. Ida M. Post, is now engaged in preparing her thesis on the topic "The Equipment of the Biological Laboratory in the Secondary School." In order to secure data, Mrs. Post is sending out a checking questionnaire. It will be considered a personal favor if you will check the various points as time will permit and return the list to the writer of the thesis by November 1.

Very truly yours,

E. E. Ramsey
Head of Department of Education.

EER:EB

CHAPTER I

THE IMPORTANCE OF A BIOLOGICAL LABORATORY AND TRENDS IN SPACE PROVISION

Through wisely chosen laboratory exercises and efficient laboratory administration, science teaching accomplishes its notable part in school instruction. Without its experimental aspects science teaching when attempted is largely shorn of its distinctive features and educational possibilities.¹ Through laboratory exercises there can be developed, and directed, a desire on the part of the pupil to learn. Exercises should beget in pupils a teachableness fundamental to the learning process and therefore provide a way for rapid acquisition of knowledge. Science studies without laboratory exercises are scarcely worth the name. Laboratory exercises are not only a means for first-hand information, concerning facts which are fundamental in the discussion of topics, but in addition they should be thought-provoking. The facts in themselves are not enough. There must be apparent to pupils certain relationships between these facts as they note the results of the experiments being performed. There must be

¹H. Brownell, and F. B. Wade, The Teaching of Science and The Science Teacher, (New York: The Century Co., 1925), pp. 3-6.

such a continuity in these relationships as shall constitute a well-defined thought process, natural and progressive, even when an introductory course in the secondary school.

Facts learned through wisely chosen laboratory exercises have with beginners in science a value in mental processes not possible for information gained from formal statements of text and reference books. The former type of work exceeds in worth the latter in that it is better comprehended and related, and it is more likely to be remembered. When enough of these laboratory exercises have been performed, pupils are mentally equipped for the more rapid interpretation and assimilation of facts as summed up in books wherein the experiences of others are set forth. The attention of pupils having been centered upon a topic, and their interest aroused by laboratory contact with certain of its phases, it may be confidently expected that to some degree at least there has been developed a desire for further knowledge concerning the topic. In the teaching process this becomes the time to turn to text and reference books for further information which has been gained through the experience of others. Practical applications and natural relationships to previously acquired knowledge, together with any historical setting, may now come under consideration. Experiments of whatever grade of difficulty are the best means both in the laboratory and in the classroom of "arresting attention", "stimulating interest", and "arousing a desire to know".

It is unnecessary to emphasize the enormously important part which biological science has in human life. Stock breeding, heredity, environment, human diseases and their biological causes are a few of the applications of biological science.

The maintenance of the health of the community, the care of the water supply, the prevention of disease, much of which is now known to be due to the action of parasitic microbes often transported and spread by other living organisms, and the cure of disease by modern developments of medicine - these belong to the applications of biological science.

When we compare the superstition of the seventeenth century concerning the cause of disease with the present known facts concerning the same problem, we can see biology as one of the greatest factors in the advance of civilization.

When we contemplate such facts that should be known to every one, when we see to what extent the results of biological science are woven through the whole complicated fabric of modern civilization, but when we contemplate further the great amount of money devoted to the training of our future citizens, it must strike us as an extraordinary fact that biological science enters hardly at all into the training of the average citizen.

With the steadily increasing high school enrollment of the past twenty years has come an increasing demand for more and better buildings. Changes in organization and curricula

have necessitated many changes in building plans. The trend indicates a growing preference of the science work of a more generalized nature rather than an intensive study of separate though highly specialized subjects.

According to the study made by Prof. A. L. Spohn, "Trends in Space Provision",² biology showed an increase in number of rooms while chemistry and physics showed decreases from 1917 to 1927.

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²Prof. A. L. Spohn, "Trends in Space Provisions in Plans for High School Buildings", School Review, Vol. 38, (1930), pp. 33-49.

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CHAPTER II

INDIVIDUAL EQUIPMENT

"What we most need is a crop of science teachers with a large fund of constructive imagination, who have been trained by college and university professors who bow somewhat less reverently before the shrine of research and realize rather that the kingdom of heaven can be found in the lives of growing boys and girls."¹

"The good teacher, too, will not be above employing many little tricks and devices to arouse interest, keep attention, and encourage application."²

"Education in science today does not depend solely upon a few book facts, it is breaking away from academic ideals and developing in the direction of practicability in the knowing how to live and enjoy life."³

The increased population and the keen competition of making a living places increased emphasis upon individual thinking.

¹J. E. Peabody, "Biology in Secondary Schools," Proceedings of the National Education Association, (1914), p. 748.

²W. F. Ganong, The Teaching Botanist, (New York: Macmillan Co., 1899), p. 62.

³R. P. Halleck, In Proceedings of the National Education Association, (1907), p. 523.

Good work in biology has been done with few facilities, but under great difficulties. The ideal laboratory provides an opportunity for the development of individual thinking. The student should be independent as far as possible of the teacher's aid in securing materials and in doing work. He should be able to work his own problems without being hindered or helped by his teacher or classmates.

He must be free from the limitations of any specific science, free to use materials as he needs to good advantage.

The average laboratory is very poorly provided with sufficient individual equipment and most of the work has to be done at the teacher's desk or demonstration table.

"Laboratory work presupposes student participation in that work. In practically no case should more than two students work together. In by far the greater part of the laboratory exercises, individual work should be required. Student participation in laboratory work presupposes several things. Among these are the following: (a) In the biological sciences in particular where materials are necessary, assignments of duties need be made definitely. This means "keeping one star ahead" on the part of the teacher; (b) It means that every science pupil must own a definite group of supplies. Pencil, drawing pencil, pen and ink, ruler, notebook, carefully prepared laboratory outline, permanent note book back with fillers. These are just as much a part of the pupil's equipment

as the text book. In some of the sciences, the text may be dispensed with more readily than the pupils equipment can.

(d) It means that the laboratory is so organized that every one is engaged at once on entering the laboratory. The first five letters of the word laboratory are the cue. (e) This

means that the teacher has anticipated the lesson and has laboratory directions as well as laboratory supplies ready.

(f) This means that the school must furnish an adequate supply of essential laboratory materials, if the science program is to succeed. (g) The teacher must see that all can read laboratory directions. (h) It means that the teacher should be watch-

ful after a proper understanding is so obtained by the class, but that, above all things else, he should keep out of the way of the class. (i) The teacher should watch "how" results are

obtained as well as to watch "what" results are obtained. When the "how" is considered fairly large errors may be preferable to very accurate results obtained by poor or vicious methods. Honesty is above par in science. (k) The teacher should see

that results are carefully interpreted and just as carefully stated. Here the science teacher can do his bit in English.

(l) The teacher should see that the experiment - its materials, manipulations, results, and interpretations - is faithfully put in permanent form. (m) The teacher in a quiz should see

that the experiment and its results are related (1) to the text matter or (2) to the outside world. The latter makes

that the experiment and its results are related (1) to the text matter or (2) to the outside world. The latter makes

science practical; the former should train inductively in the understanding of the principles underlying science."⁴

The following houses furnish laboratory supplies:⁵

Central Scientific Co.,	Chicago, Illinois.
W. M. Welch Mfg. Co.,	Chicago, Illinois.
Chicago Apparatus Co.,	Chicago, Illinois.
Sharr and Co.,	Chicago, Illinois.
L. E. Knott,	Boston, Mass.
E. W. Kiger and Co.,	Indianapolis, Indiana.
E. L. McCabe and Son,	Terre Haute, Indiana.

Individual sets for the biological laboratory of the secondary schools of Indiana include alcohol lamps (if gas is used, Bunsen burners) battery jar, wide mouthed bottles, beakers 250ccm, dissecting sets of six pieces, dissecting pan, evaporating dish, 250ccm flask, glass tubing, magnifiers, ring stand, two-hole rubber stopper, thistle tube, 50cm watch glass, wire gauze, five inches square.

The tables in this study have all been formulated from data given in the replies to a questionnaire sent to the biology teachers of Indiana.

⁴ E. E. Ramsey, Chairman of Course of Study, State Course of Study for Secondary Schools, (Indianapolis, Indiana: State Department of Public Instruction, 1923), pp. 128-180.

⁵ Ibid., p. 172.

Table I shows the distribution of individual equipment in the high schools ranging from 58 to 150 enrollment.

Eleven of the schools had no equipment, classes ranging from ten to thirty-nine.

Six of the schools had from five to nine sets for classes ranging from fifteen to twenty-nine.

Ten of the schools had from ten to fourteen sets for classes ranging from fifteen to thirty-nine.

Seven of the schools had from fifteen to nineteen sets for classes ranging from ten to thirty-nine.

Five of the schools had from twenty to twenty-four sets for classes ranging from fifteen to nineteen.

One school had twenty-five to twenty-nine sets for classes ranging from fifteen to nineteen.

Two schools had thirty to thirty-four sets for classes ranging from twenty-five to twenty-nine.

Three schools had thirty-five to thirty-nine sets for classes ranging from twenty to thirty-four.

TABLE I

SETS OF INDIVIDUAL EQUIPMENT FOR A BIOLOGICAL LABORATORY
IN SCHOOLS ENROLLING FROM 58 TO 150 STUDENTS

Number of sets supplied by schools	To supply the following number of students							Totals
	10-14	15-19	20-24	25-29	30-34	35-39	40-44	
0	2	2	3	2	1	1		11
1-4								
5-9		1	2	3				6
10-14		2	4	2	1	1		10
15-19	1	1	2	2		1		7
20-24		5						5
25-29		1						1
30-34				2				2
35-39			2		1			3
Totals	3	12	13	11	3	3		45

For the schools ranging in enrollment from 151 to 300, as given in Table II, the tabulation shows that six schools had no equipment for classes ranging from twenty-five to forty-four.

One school had from one to four sets of equipment for classes ranging from twenty-five to twenty-nine.

Four schools had from five to nine sets for classes ranging from fifteen to nineteen.

Seven schools had from ten to fourteen sets for classes ranging from fifteen to thirty-nine.

Two schools had fifteen to nineteen sets for classes ranging from twenty-five to twenty-nine.

One school had twenty to twenty-four sets for classes ranging from twenty to twenty-four.

TABLE II

SETS OF INDIVIDUAL EQUIPMENT FOR A BIOLOGICAL LABORATORY
IN SCHOOLS ENROLLING FROM 151 TO 300 STUDENTS

Number of sets supplied by school	To supply the following number of students							Totals
	10-14	15-19	20-24	25-29	30-34	35-39	40-44	
0				1	4		1	6
1-4				1				1
5-9		4						4
10-14		1	2	2	1	1		7
15-19				2				2
20-24			1					1
25-29								
30-34								
35-39								
40-44								
Totals	0	5	3	6	5	1	1	21

For the schools ranging in enrollment from 301 to 500 students as given in Table III, the tabulation shows that three schools had ten to fourteen sets of individual equipment for classes ranging from twenty to thirty-nine.

Two of the schools had from fifteen to nineteen sets for classes ranging from fifteen to thirty-nine.

Two of the schools had from twenty to twenty-four sets for classes ranging from twenty to twenty-nine.

Three of the schools had from twenty-five to twenty-nine sets for classes ranging from twenty-five to twenty-nine.

Two of the schools had from thirty to thirty-four sets for classes ranging from twenty to thirty-nine.

TABLE III

SETS OF INDIVIDUAL EQUIPMENT FOR A BIOLOGICAL LABORATORY
IN SCHOOLS ENROLLING FROM 301 TO 500 STUDENTS

Number of sets supplied by school	To supply the following number of students							Totals
	10-14	15-19	20-24	25-29	30-34	35-39	40-44	
0								
1-4								
5-9								
10-14			1		1	1		3
15-19		1				1		2
20-24			1	1				2
25-29				3				3
30-34			1			1		2
35-39								
40-44								
Totals		1	3	4	1	3		12

For schools ranging in enrollment from 501 to 1719, as given in Table IV, the tabulation shows that five schools had no individual equipment for classes ranging from twenty to thirty-four.

Seven of the schools had ten to fourteen sets of individual equipment for classes ranging from fifteen to forty-four.

Two of the schools had fifteen to nineteen sets for classes ranging from twenty-five to thirty-four.

Two of the schools had twenty to twenty-four sets for classes ranging from twenty to twenty-four.

One school had twenty-five to twenty-nine sets for classes ranging from twenty-five to twenty-nine.

Five of the schools had thirty to thirty-four sets for classes ranging from fifteen to twenty-nine.

Three of the schools had thirty-five to thirty-nine sets for classes ranging from twenty-five to twenty-nine.

Summary:

The individual equipment varied from none to a set for each student. This does not comply with the State Course of Study which suggests as a minimum list a set for each four students if at four-student tables or a set for each two students if at two-student tables. Eleven of the 105 replies reported that their biological laboratories had no individual equipment.

TABLE IV

SETS OF INDIVIDUAL EQUIPMENT FOR A BIOLOGICAL LABORATORY
IN SCHOOLS ENROLLING FROM 501 TO 1736 STUDENTS

Number of sets supplied by school	To supply the following number of students							Totals
	10-14	15-19	20-24	25-29	30-34	35-39	40-44	
0			1	2	2			5
1-4								
5-9								
10-14		1	2	2	1		1	7
15-19				1	1			2
20-24			2					2
25-29				1				1
30-34		1	1	3				5
35-39				3				3
40-44							2	2
Totals .		2	6	12	4		3	27

CHAPTER III

GENERAL EQUIPMENT FOR A BIOLOGICAL LABORATORY

"Costly thy habit as thy purse can buy" may at times express the thought of a taxpayer as he inspects modern laboratories and their equipment in some of the larger secondary schools, and again when he audits bills for laboratory supplies and upkeep. In marked contrast to this, however, the equipment and supplies of the smaller high schools oftentimes will be found wretchedly inadequate for the teaching undertaken. In the smaller high schools where one teacher has, it may be, all the science subjects, the teaching problems are entirely different from those of special teachers in large high schools. Nevertheless, economy rather than waste applies equally well to all science teachers, and is as applicable to their time and energy as it is to expenditure for apparatus and supplies."¹

The prepared equipment of a general nature for biological use is the most important kind because of the fact that biology

¹H. Brownell, and F. B. Wade, The Teaching of Science and The Science Teacher, (New York: The Century Co., 1925), pp. 35-36.

is such a broad subject and requires the use of the equipment in diverse experiments.

The nature of the experiments is not limited to any one phase of the subject and for that reason calls for a larger equipment than some specialized subject.

In the writer's experience, the general equipment does not need to be of a very elaborate nature, but of a very practical nature. Some of the equipment can be used only for a few specific purposes, while other items can be used for a number of experiments.

If finances are much limited, it is necessary in many cases to make a portion of one's own equipment.

Ready-made equipment usually works better and requires less of the instructor's and student's time in assembling for the experiment. Since the equipment is not the thing we are interested in, but the results of the experiment, our interest is more or less confined to the equipment that is thoroughly usable.

From the writer's experience, better results are obtained if home-made equipment supplements rather than is used as a substitute for ready-made equipment.

If the teacher desires to have experiments, when an insufficient amount of equipment is furnished, he has to furnish the material himself or get the students to furnish it.

Nature supplies abundant material for project work in biology if the instructor is a good director.

The State Department of Public Instruction has a list of supplies or general equipment for the biological laboratories of the secondary schools of Indiana.²

The tabulation in Table V gives a list of the general laboratory equipment and the number of schools supplied. Seventeen of the 105 replies reported their schools having no aquaria, fifteen schools had no microscopes. Thirty-one did not have any glass tubing and twenty-three did not have any litmus paper.

TABLE V

GENERAL LABORATORY EQUIPMENT FOR A BIOLOGICAL LABORATORY
IN SCHOOLS ENROLLING FROM 88 TO 1736 STUDENTS

Kind of Equipment	No. of Schools Supplied With
Aquaria.....	88
Bell jar, 1 gallon.....	71
Bladders, for osmosis.....	61
Bone forceps, small.....	46
Bone forceps, large.....	42
Trip scales, agate bearings.....	66
Corks, assorted 0-11.....	71
Cork borers.....	52
Coordinate paper.....	42
Cover glasses.....	67
Flasks, 500cc.....	58
Flower pots, 4 inches.....	71
Flower pot saucers, 4 inches.....	71
Funnels, glass, 150mm.....	60
Funnels, glass, 65mm.....	62

²E. E. Ramsey, Chairman of Course of Study, State Course of Study for Secondary Schools, (Indianapolis: State Department of Public Instruction, 1923), pp. 132-133.

TABLE V (CONTINUED)

Filter paper.....	83
Glass tubing, 10 to 15mm. assorted.....	74
Glass tubing, 4 to 7 mm. assorted.....	74
Graduate, cylindrical, 500cc.....	57
Graduate, cylindrical, 250cc.....	62
Insect net, collapsible.....	70
Insect pins, No. 0 and No. 3.....	57
Insect spreading boards, 12x4x7/8 inches (home-made).....	70
Litmus paper, blue.....	82
Litmus paper, red.....	82
Medicine droppers.....	70
Microtome, hand.....	45
Microscope.....	90
Platinum wire in glass handle.....	51
Riker mounts, 4x5 inches.....	20
Rubber stoppers, 2 hole, No. 9.....	65
Rubber stoppers, 2 hole, No. 6.....	65
Rubber tubing, 3/16 inches.....	65
Rubber dam.....	44
Rubber stoppers, 1 hole, No. 1.....	65
Rubber balloons.....	48
Section razor.....	50
Snellen's Eye Test Chart.....	58
Slides for microscope, blank, 5x1 inches.....	90
Test tubes, 4x1/2.....	80
Test tubes, 6x3/4.....	80
Test tube racks.....	80
Test tube brushes, cork tipped.....	80
Thermometers - 10 to 100 C. and 10 to 220 F....	62
Tray, photographic, 5x8.....	20
Tripod, 6 inches.....	29
Water bath, copper, 6 inches.....	20
Weights with holder, 10 to 500 gr.....	66

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CHAPTER IV

CHEMICALS FOR A BIOLOGICAL LABORATORY

The type of work which is necessary for the various phases and different angles of the subject requires the use of a number of reagents and stains. Most of the chemicals needed for this type of work are those that belong to the field of bio-chemistry.

However, some of them fall into the strict inorganic class, such as those which act upon foods, bones, and textiles. The action of the enzymes on foods, the actions of organic substances, and some of their less complicated processes, and the make-up of a number of simpler organic materials should be studied.

Dyes and stains are important because of the fact that they are necessary to make some of microscopic structures visible. Some of the substances necessary in the elements of slide preparations for the microscope use should be at hand if the morphology of the specimens is to be studied to any considerable extent. However this is not an absolute necessity; but if the work is given in detail and facilities permit, this adds an interesting touch.

Preservative substances, of which formaldehyde and alcohol are typical examples, permit the instructor to not only lay up

a supply of specimens when they are plentiful but to keep on hand preserved examples of the rarer and exotic forms of life.

Again, all living things can be considered from the standpoint that they are the composite totals of groups of chemical elements, and the occasional recalling of this fact solves some of the most perplexing of the animal and plant reactions.

Chemicals for each of the different phases of the work are given in the following table.

TABLE VI
CHEMICALS FOR A BIOLOGICAL LABORATORY

Chemicals	Number of Schools Supplied
Acid, Acetic, glacial.....	63
Acid, Hydrochloric, com.....	75
Acid, Nitric, com.....	72
Acid, Sulphuric, com.....	71
Ammonium Hydrate, com.....	46
Benedict's Solution, qualitative.....	38
Calcium Phosphate (acid phosphate).....	33
Calcium Phosphate (monobasic).....	30
Calcium Sulphate.....	39
Canada Balsam, for slides.....	63
Carbolic Acid, loose crystals.....	35
Charcoal, wood, lumps.....	52
Corrosive Sublimate.....	30
Eosin, yellowish, water soluble.....	42
Ether.....	70
Fehling's Solution, A.....	50
Fehling's Solution, B.....	50
Anilin, Red.....	1
Phenolphthalein.....	5
Alcohol, wood.....	20

TABLE VI (CONTINUED)

Alcohol, grain.....	20
Agar Agar.....	75
Cyanide jars.....	75
Iodine Solution in Potassium Iodide.....	67
Iron Chloride.....	49
 Lime Water.....	 71
Lysol.....	43
Magnesium Sulphate.....	50
Glucose (Dextrose) granulated.....	60
Manganese Dioxide.....	53
 Malachite Green.....	 60
Methyl Blue.....	66
Paraffin, medium melting point.....	60
Potassium Bichromate, crystals.....	30
Potassium Chlorate, crystals.....	40
 Potassium Nitrate, granulated.....	 20
Pepsin, powder.....	35
Pancreatin.....	30
Sodium Carbonate, crystals.....	25
Zinc Metal, mossy.	25
 Zinc Chloride, pure.....	 20

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CHAPTER V

EQUIPPING THE BIOLOGICAL LABORATORY

"For the teaching of biology by proper methods a good laboratory is a necessity. The character of the desks and the arrangements for seating and lighting of an ordinary class room are entirely inadequate and may be permitted only when no other place for work is to be had. A good laboratory is one with good lighting, ample space for comfortable work, places for storing equipment, and room for aquaria and vivaria."¹

"Good biological equipment is expensive; poor equipment is extravagance. The problem, then is not 'how cheap?' but 'how good?'" Economy should be practiced in the field of utilization. The new trend in science work is to use the combination laboratory which serves for more than one science and for lecture room as well.

New buildings are doing away with the lecture room, and provision for recitations and class demonstration are included in each by removing from the lecture room its special furniture and equipment, and the room is used for a laboratory and a recitation room.

¹F. E. Lloyd, and M. A. Bigelow, The Teaching of Biology in the Secondary School, (New York: Longmans, Green and Co., 1919), p. 209.

The replies to the questionnaire verify the above statement. The 105 replies reported that one room was used for, lecture, recitation and demonstration. These data are tabulated in Table VII.

TABLE VII
BIOLOGY ROOM SIZES AND USES TO WHICH THESE ARE PUT

Room Size	No. of Combination Rooms (L. R. D.)	Biology Rooms - Use			Total No. Rooms
		Lecture (Only)	Recitation (Only)	Demonstration (Only)	
From 15'x10' To 15'x15'	2	0	0	0	2
From 16'x24' To 16'x70'	3	0	0	0	3
From 18'x20' To 18'x40'	5	0	0	0	5
From 20'x24' To 20'x60'	28	0	0	0	28
From 21'x30' To 21'x36'	5	0	0	0	5
From 22'x30' To 23'x36'	2	0	0	0	2
From 24'x30' To 24'x36'	24	0	0	0	24
From 25'x25' To 25'x35'	14	0	0	0	14
From 30'x30' To 30'x50'	17	0	0	0	17
From 31'x32' To 33'x42'	2	0	0	0	2
From 40'x35' To 40'x60'	3	0	0	0	3

The present usage in school buildings is to have everything practical.² The principal reasons for eliminating the lecture room are economy in space, in building cost, and a claimed pedagogical advantage. The cost of providing a separate lecture room is the cost of an average recitation room, from \$2500 to \$5,000, depending upon the type of construction of the building and local building costs. If this room were in continuous use the waste would be less, but surveys made in high schools of all sizes throughout the country show that these lecture rooms are very seldom used for the entire school day or even for a large part of it. When the lecture room is in use, the laboratories, as a rule, are idle.

The combined laboratory-demonstration and recitation room saves most, if not all, of this wasted space and in addition has educational advantages of much merit. The instructor may stop the individual experimental work when he finds it advisable and can assemble his class for instructions or for demonstrations. He may assemble his class for a short recitation at the beginning of the laboratory period, and he can make use of the last part of the period. He has space available when the more rapid pupils who have finished their experiments may sit and write them up or study, out of the way of the others who are still working on their experiments.³

² J. J. Donovan, B. S. School Architecture, (New York: The Macmillan Company, 1921), pp. 385-390.

³ Laboratory Construction, Equipment and Exercises, (Indianapolis: State Superintendent of Public Instruction, 1925), Plate I.

The rooms used for the biological laboratory in the secondary schools of Indiana varied from 10 feet by 15 feet to 40 feet by 60 feet (Table VII).

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CHAPTER VI

HEATING AND VENTILATION

The replies to the questionnaire reported eighty-eight laboratories heated by steam and seventeen by hot air. Sixty-five of the replies reported they had direct ventilation and forty had indirect ventilation.

Whatever system is used, the laboratory should be comfortably warmed in cold weather, it is not only impossible to carry on the work of the school, but it is positively dangerous to the health of student and teacher to work in a cold laboratory. The heating and ventilation systems should provide eight complete changes of air per hour. The temperature should be from 68° to 70° F.

A positive supply of outdoor air, whether brought to the laboratory by direct ventilation or by indirect (mechanical means), should be provided to the laboratory equal to or in excess of the minimum requirements per occupant per hour.¹

A laboratory should have fume chambers and vent ducts to carry off the fumes and gases generated during experimental work. And these ventilators must extend to the outer air above the building.

¹Frank W. Hart, A Standard State Schoolhousing Code, (Albany, New York: C. F. Williams and Son, Inc., 1924), p. 126.

Laboratories are often provided with special ventilators which are independent of the system serving the rest of the building. The odors which occur in these rooms must be quickly removed to prevent diffusion to other parts of the building.

The laboratory should be supplied with an independent exhaust flue with either a heating coil or a disk fan to accelerate the removal of the air from the room. Frequently an electric fan is placed in the base of a vent flue. In most installations no fresh air duct is provided from the main ventilating system. This makes it possible for the exhaust fan to produce a partial vacuum in the room. When the door of the laboratory is opened, air rushes into the room and odors do not penetrate to other parts of the building.²

Recent tendencies in general ventilation are towards making increased use of natural ventilation. The chief difficulties in the utilization of window ventilation in a laboratory are interference with hood ventilation, which is necessarily forced, the necessity of warming incoming air during a major portion of the year in most climates, and the effect of direct drafts upon gas heating appliances. Air employed in ventilation is generally moved by means of electrically driven fans. If possible a ventilating fan should be removed some distance from the room it is desired to ventilate,

²C. E. Reeves, and H. S. Ganders, School Building Management, (New York: Teachers College, Columbia University, 1928), pp. 298-299.

for fan noises are transmitted through short air ducts. The materials to be used for ducts and fans for general ventilation should receive more attention in a laboratory. Vitrified tile wall ducts are recommended, but if sheet metal ducts are used they should be protected from corrosion. The fan housing and wheel should also be protected.

Laboratories are usually heated by steam; the pressures should be constant and sufficient to effect uniform distribution. The shape of radiators, the materials used in them and in connecting piping, and the type of return system are largely determined by the position in the room, the nature of the system and standard heating practice.

In general, the capacity of the exhaust fans for hoods and general ventilation should exceed the capacity of intake fans or gravity heating stacks. The proper balance between these two factors must be worked out if each part of the laboratory is to be properly ventilated. Impurities in the air admitted to a laboratory may be lessened if the air is washed by a device which makes a fine spray that removes not only dust but also a large proportion of smoke and odors which at times may be carried in from the outside. The air-washer can be procured with the regulating device which maintains the humidity or moisture in the air at any desired degree, doing away with the excessively dry and parching steam heat effects ordinarily experienced.

As a substitute for large plenum spaces or extensive duct systems, some use has been made of inlet air heater and fan outfits placed below windows. These devices consist of enclosed radiators and small fans, driven by quiet motors, the outfit being of such dimensions that it can be placed in a window recess. Fresh outdoor air can be forced into the room or the air in the room recirculated over the radiator at will.³ The first object in ventilating a laboratory is to properly introduce the fresh air into the room and also to withdraw the foul air in all portions of the room while a secondary object is to circulate the air in such a manner as not to make air currents disagreeable or even perceptible.

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³ National Research Council Committee Report, Laboratory Construction and Equipment, (New York: The Chemical Foundation, Inc., 1930), pp. 61-69.

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CHAPTER VII

NATURAL LIGHTING

Since the light of the laboratory is modified both in amount and quality by the color of the walls, the color should be such as not to absorb the rays of light. The wall space between the floor and the window sills and the chalk troughs should be light brown. Side walls and ceilings should be a light buff tint, or a light gray. Light colored wood should be selected.

The amount of glass used depends upon the locality and surroundings. In the south and southwest, where sunshine is abundant and where the sun is higher above the horizon at noon-time, the states require one-sixth as much glass surface as floor space.

In general, where there are no hills, high buildings, or trees to obstruct the light, one-fifth as much glass surface as floor space will suffice. The ratio of one to six is used by the Central States, with the exception of Ohio, which has one to five. Five states require glass to be provided in the exterior wall to sixteen and two-thirds per cent of the floor space, or one to six, thirteen states require twenty per cent,

or one to five, and two states require twenty-five per cent, or one to four.¹

Indiana's standard is one to six, or sixteen and two-thirds per cent as much glass surface as floor space.

Thirty-three of the 105 replies reported less than sixteen and two-thirds per cent glass surface to the floor space.

Table VIII gives the variations from 13.6- per cent to 33.4+ per cent.

TABLE VIII
LIGHTING OF THE BIOLOGICAL LABORATORY

No. of rooms	Floor space in square feet	Glass areas of these rooms vary from:	Light ratio of these rooms vary from: Percentage	Variation + or - from state standards Percentage + or -
4	149' to 350'	45' to 160'	20 to 40	4.6+ to 33.4+
10	351' to 550'	72' to 160'	16.6 to 33.3	0 to 16.7+
52	551' to 750'	64' to 272'	8.8 to 31.2	7.8- to 14.6+
31	751' to 1150'	24 $\frac{1}{4}$ ' to 300'	3 to 33.3	13.6- to 16.6+
2	1151' to 1350'	108' to 162'	5.3 to 13.5	11.3- to 3.1-
4	1351' to 1750'	84' to 200'	6.2 to 14.4	10.4- to 2.2-
2	1751' to 2400'	200' to 231'	9.5 to 12.7	5.1- to 3.9-

¹May Ayres Burgess, J. F. Williams, and T. D. Wood, Healthful Schools How To Build Equip and Maintain Them, (New York: Houghton Mifflin Co., 1918), pp. 66-67.

Laboratories do not show as radical developments in the amount of glass used as industrial buildings, but it is not uncommon to observe laboratories in the newer buildings where between one-third and one-fourth of the exterior walls are occupied by windows.² Every possible square inch of window space should be fitted with glass. Lintels, mullions, and piers should be made of steel and all beveled, so that every obstruction is removed.

Prism glass is a useful agent for increasing lighting effects. Rays which otherwise would be lost are caught and bent, so that the amount entering the room is greatly increased. Ribbed and corrugated glass should not be used because they reflect light in bright tints and cause eye strain and fatigue of the optic nerve.

In laboratory as well as industrial construction, an increasing use of skylight illumination is being made. Vertical illumination has certain inherent points of superiority, and few disadvantages to horizontal illumination. On account of the proximity of other buildings to the laboratory, it sometimes becomes a necessity of using the vertical illumination. The upper floors of school buildings are often used for laboratories. Such laboratories are often lighted by means of skylights.

² Natural Research Council Committee Report, Laboratory Construction and Equipment, (New York: The Chemical Foundation, Inc., 1930), pp. 91-94.

Light diffusion in a laboratory can be aided by panels of so-called prismatic glass, and by the use of partitions, of similar or ordinary glass. Large buildings require more careful consideration to natural light diffusion than smaller buildings where the ideal arrangement of having windows on more than one side of the laboratory is possible.

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Pp. 298-299.

CHAPTER VIII

ELECTRIC WIRING, GAS FIXTURES, AND WATER

Several important, general tendencies are noted in modern lighting practice. Buildings which were considered adequately lighted five years ago now appear gloomy by comparison with recent installations.¹ Gas, natural or artificial, may in certain special localities be used for illumination. The modern mantle has made possible a light of satisfactory quality. The use of mantles with gasoline and other volatile liquid fuels has made it possible to use portable lights for certain special purposes, but the perfection of small automatic electric generating units makes it possible for even the smallest and most remote laboratory to have a supply of electricity. For an ordinary sized laboratory 25 feet by 30 feet, four electric outlets will give fair light, six outlets will give good light, and nine outlets will give excellent results with direct illumination. With four outlets 150-watt lamps are generally used giving 600 watts per room.

¹ Natural Research Council Committee Report, Laboratory Construction and Equipment, (New York: The Chemical Foundation Inc., 1930), pp. 94-99.

With nine outlets, lamps of sixty watts each or 540 watts are sufficient. The nine lamps of sixty watts each are much easier upon the eyes of the students and instructor than four 150-watt lamps.²

Every laboratory should be supplied with electricity, gas, and water. There should be water and gas at the instructor's demonstration table and also at one or two sinks at the side of the room. For proper locations of electric outlets, the laboratory should be divided into as many rectangles as outlets and an outlet should be placed in the center of each rectangle. One economy is that of putting the series of lights along the window side of the room on a separate switch. There are gloomy days when there is plenty of light near the windows but not on the opposite side of the laboratory.

Table IX shows that fourteen of the 105 laboratories reported do not have electricity. The outlets in the others varied from two to eight.

Table X shows that fifty-three laboratories did not have any gas connections. The others varied from nine to ten or more.

Table XI shows that seventeen laboratories did not have any running water. Eighty-eight laboratories had running water, thirty-six from wells, and fifty-two from city supply. Three laboratories had hot and cold water.

²H. J. Alt, Mechanical Equipment School Buildings, (Milwaukee: The Bruce Publishing Co., 1916), pp. 37-38; 99-100.

TABLE IX
ELECTRIC WIRING OF BIOLOGICAL LABORATORY

Number of Schools	Number of Outlets
14	0
6	2
8	3
13	4
42	5
5	6
4	7
13	8

TABLE X
GAS FIXTURES OF BIOLOGICAL LABORATORY

Number of Schools	Number of Connections
53	0
22	1
10	2
0	3
7	4
1	5
3	6
1	7
2	8
6	10 or more

TABLE XI
WATER SUPPLY OF BIOLOGICAL LABORATORY

Number of Schools Using				
No Running Water	Running Water	From Wells	From City Supply	Hot and Cold Water
17	88	36	52	3

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CHAPTER IX

LIVE ROOM, DARK ROOM, PROJECTION ROOM, MUSEUM, AND AQUARIUM

The live room seems not to be thought of by many architects or Boards of Education when building a school house; but any real wide-awake biology class enjoys working with live material, and with little encouragement will have enjoyment and interest. Such materials should be available for class study first, then placed on the school grounds for further enjoyment and study where possible. A "menagerie" or live room may be within the class room, or an outdoor laboratory. Only nine of the replies to the questionnaire reported a "live room".

Twenty-nine had a moving picture and lantern projection apparatus, sixty-nine had a lantern projection apparatus, and seven had opaque projection apparatus. Ten schools were supplied with a small storage closet, but none had a regular dark room.

The moving picture, the lantern projection, and opaque projection may be used to furnish both instructive and entertaining information. Many pupils can be taught more satisfactorily by visual means than by auditory means.

Twenty-four of the 105 schools had museums varying from twenty to 1000 specimens. With a little effort any school

could easily begin to create a museum. Seventeen of the 105 did not have any aquaria, the remaining eighty-eight had from three- to twelve-gallon ones. All were balanced.

Surely those seventeen schools that were not supplied with any aquaria could manage in some way to earn money to get a few necessary facilities with which to work, and it would be a wise thing for the eighty-one schools which did not have any museum materials to begin to collect material.

TABLE XII
BIOLOGICAL LABORATORY FACILITIES

No. of Schools Supplied With Balanced Aquaria		No. of Schools Supplied With Museums	
No. of Schools	Size of Aquarium	No. of Schools	No. of Specimens
60	3 Gal.	3	20
20	5 Gal.	4	50
5	10 Gal.	3	100
3	12 Gal.	3	150
17	None	7	200
		2	300
		1	600
		1	1000

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CHAPTER X

TABLES

"The science of biology has traveled far in the intervening decades, and educational aims and methods have advanced even more rapidly. On the one hand biology in the strict sense of the term is concerned chiefly with the physical chemistry of living stuff, and therefore, requires the facilities of a chemical laboratory. On the other hand, biology as a school subject is becoming more and more the study of relations among living creatures, especially between man and his living environment. Biology of the modern academic type then demands as complete a laboratory equipment as do physics and chemistry, in addition to the strictly biological apparatus; while civic biology concerns itself with the great outdoors and community conditions. The fact that we are working with living stuff, demanding exact conditions and unusual facilities for care, makes the selection and provision of this equipment more difficult."¹

¹ J. J. Donovan, School Architecture, (New York City: The Macmillan Co., 1921), pp. 390-391.

Standard tables for four students are 42 inches by 72 inches by 30 inches high. Two-student tables are 24 inches by 72 inches by 30 inches. They should be equipped with drawers. An instructor's desk 3 feet by 8 feet by 54 inches is needed.²

If the tables are home-made then they should be treated to prevent stains. F. B. Dresslar in his American School-houses gives the following formula:³

"For tops of laboratory desks or tables, northern pine, whitewood, cedar and California redwood may be used.

Home-made tables should be acid proof by using the following solutions:

Solution 1.

100 grams aniline hydrochloride
40 grams ammonium chloride
650 grams water

Apply solution 1, let dry then apply

Solution 2.

100 grams copper sulphate
50 grams potassium chlorate
615 grams of water

When dry wash with hot soap suds, when dry again rub down with vaseline."

²Laboratory Construction, Equipment and Exercises, (Indianapolis: State Department of Public Instruction, 1925), pp. 11-12.

³Fletcher B. Dresslar, American Schoolhouses, (Washington, D. C: Government Printing Office, 1911), pp. 33-35.

Table XIII gives eight of the schools using the standard size table, 42 inches by 72 inches by 30 inches; the tables in eighty-three schools vary from 21 inches by 84 inches by 30 inches to 60 inches by 144 inches by 30 inches. Fourteen of the 105 schools use regular school desks for biological work.

TABLE XIII

TABLE SIZES

Table Sizes Varying		Number of Tables
From:	To:	
60"x84"x30"	60"x144"x30"	16
48"x48"x30"	48"x240"x30"	23
46"x60"x30"	46"x65"x30"	2
42"x60"x30"	46"x216"x30"	3
40"x96"x30"	40"x216"x31"	3
36"x54"x30"	36"x288"x32"	32
30"x48"x30"	30"x108"x31"	3
24"x48"x30"	24"x50"x30"	3
22"x72"x30"	22"x82"x31"	2
21"x72"x30"	21"x84"x31"	2
Regular School Desks.....		14

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CHAPTER XI

THE COURSE OF STUDY IN BIOLOGY

Before one can effectively plan the knowledge content of that portion of the course of study in our school system which seeks to impart knowledge, three things need to be known: first, what are the important principles needed to solve the problematic situations involving biology that arise in life? second, how much time is required to teach each of these principles so that it will function in life? third, at what grade level can each principle best be taught with the least expenditure of time and energy on the part of pupil and teacher?

What biology needs to know to meet life's practical and potential needs, that is the stuff that should constitute the course of study.¹ There are many problematic situations involving biology that arise in the life of the average person. Theoretically one might list all the questions pertaining to biology that arise in a given community and teach the answers to every pupil in the biology work of the schools in that particular place, but that seems an impossible task, for the specific questions are so multitudinous. But the principles

¹National Society for the Study of Education, Thirty-First Year Book, Part I, (Bloomington, Illinois: Public School Publishing Co., 1932), pp. 224-226.

involved' in them are relatively few. It is wiser, therefore, to give the pupils an understanding of the more important principles - important because they do help in solving these oft-recurring questions - and enough drill in applying them to typical life problems to insure skill in their use when the need may arise in their lives.

To give pupils a mastery of some of the more important principles of biology gives some assurance that they will still be able to meet situations that arise when they go, as many will, into quite different communities from the particular ones in which they attended school.

It assures the ability to meet the problems that will arise in their maturity when the particular problems to be settled will probably have changed greatly from those we have to face at the present time. Specific problems are local in place and in time. Moreover, the teaching of principles in the essential step in developing in the pupil a clear understanding of major realizations.

A List of the Principles:²

- I. Energy cannot be created nor destroyed,
but merely transformed from one to another.
- II. The ultimate source of the energy of all
living things is sunlight.
- III. Micro-organisms are the immediate cause of
diseases.

²National Society for the Study of Education, op. cit., pp. 224-226.

- IV. All organisms must be adjusted to the environmental factors in order to survive in the struggle of existence.
- V. All life comes from previous existing life and reproduces its own kind.
- VI. Animals and plants are not distributed uniformly or at random over the surface of the earth, but are found in definite zones and in local societies.
- VII. Food, oxygen, certain optimal conditions of temperature, moisture, and light are essential to the life of most living things.
- VIII. The cell is the structural and physiological unit in all cell organisms.
- IX. The more complex organisms have been derived by natural processes from simpler ones, these in turn from still simpler, and so on back to the first living forms.

The course in biology in the schools will consist of the following: (1) such an understanding of most of, possibly all of, the principles listed that the pupil will, in all probability, apply them to the solution of such problems of a biological character as will arise in his life; (2) an appreciation of some of the scientific attitudes exemplified in the work of

such great biologists as Vesalius, Malpighi, Pasteur, Koch, Jenner, Darwin, Huxley, and others; and (3) a reasonable degree of skill in the use of the scientific method of thinking on matters biological.

The course in biology consists usually of one year or two semesters and the replies to the questionnaire showed that seventy-nine of the 105 schools offered biology in the ninth grade, ten schools offered the course in the ninth or tenth grade, ten offered the course in the tenth year only, and six offered the course in the ninth, tenth, eleventh, or twelfth year. All of the 105 schools reported 300 minutes or more per week for biology. Sixty-six schools had one biology teacher, thirty-five had two biology teachers, and four had three biology teachers.

TABLE XIV

BIOLOGY - YEAR OFFERED AND
NO. OF BIOLOGY TEACHERS

No. of schools offering biology in years:				No. of schools with:		
9's	9's or 10's	10's	9's, 10's, 11's or 12's	1 Teacher	2 Teacher	3 Teacher
79	10	10	6	66	35	4

Ten teachers used the text book and lecture method, fifty-nine used the demonstration method and text, thirty-one used the demonstration method, project method, and text. Twenty-two teachers used prepared work books, eighty used loose leaf work books, and three used no work book. Table XV.

Five of the 105 schools used Gruenberg's Elementary Biology, eleven used Hunter's Civic Biology, seventeen used Kinsey's An Introduction to Biology, twenty-five used Moon's Biology for Beginners (Revised Edition), and forty-seven used Smallwood, Revely, and Bailey's New General Biology.

TABLE XV
METHODS OF TEACHING BIOLOGY

No. of Schools	Methods of Teaching
10	Lecture and Text Book
59	Demonstration and Text
31	Demonstration, Project, and Text
22	Prepared Work Book
80	Loose Leaf Work Book
3	No Work Book

CHAPTER XII

COLLATERAL READING MATERIAL FOR BIOLOGY

Unless there is a branch library connected with the school, the biological laboratory should have a case for collateral reading materials. No study in the high school is better supplied with more interesting or more practical reading than biology.

Various kinds of collateral reading can be and should be used in every course. Some of these are:- (1) textbooks by different authors, (2) encyclopedias, (3) more specific accounts of special topics, (4) opposite and parallel points of view, (5) magazines and newspapers that contain articles of interest on the subject, (6) reading to vitalize the subject, (7) practical application.

If a pupil has only one textbook and no collateral material he will get a narrow view of the subject. Collateral material has several purposes: it enriches the textbook requirements; it causes the pupil to think along broader lines; it trains the pupil to think and judge for himself; it teaches him to avoid extremes; it teaches him not to be led by everything he sees pointed out; it broadens the knowledge of values in literature.

The teacher should be careful about the method and length of the assignments of collateral material. Some of the methods for using collateral material are: oral reports, handing in outline or written reports, notebooks, tests, and socialized recitation.

Collateral reading performs a great mission for the superior child, it helps to broaden the teacher's knowledge and helps the child directly and indirectly. The habit formed in the child of using collateral material does not end with his school days, for once the habit is formed it will remain throughout life. The school should be held responsible for the habit of extensive, rapid, useful reading, for the skill in finding readily all accessible material in books and magazines on any desired topic.

Some of the books on biology to be used as collateral material are:-

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Magazines for Collateral Reading:

Bird Lore.

Guide to Nature.

Hygeia.

Literary Digest.

The National Geographic.

Natural History.

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CHAPTER XIII

SUMMARY

To the observing student of secondary education, it is very apparent that the sciences, pure and applied, are in a state of transition. We shall never again have a formal academic division into specialized fields, any more than we shall go back to the organization of our school courses on the basis of textbook work. There will be constantly increasing efforts to afford opportunity for creative work by students, and thereby a chance for individual and community betterment. It is not an easy matter to plan a laboratory to fit exactly the needs of a class in biology for the future. But since school buildings are not built for a short time, but for a generation, it would seem to be the better part of wisdom to build a generalized biological laboratory in which all the essential tools of the special sciences are available, where classes will enjoy the greatest freedom in selecting problems and solving them.

The replies to the questionnaire which was sent to the biology teachers of the state showed that the biological laboratories were not uniform as to size or equipment.

The teaching of biology is in a state of transition going from the study of preserved specimens to living questions,

and to the betterment of the community. According to the replies received, many of the schools are using the project method along with the laboratory method. This is a great help, since the average laboratory is very poorly provided with sufficient individual equipment and most of the work has to be done at the teacher's desk or demonstration table. Sets of individual equipment varied from none to a set for each student.

There were also great variations in the amount of general equipment for a biological laboratory. Seventeen laboratories had no aquaria, fifteen had no microscopes. Some of the schools with large enrollments did not have any laboratory equipment and were using the textbook method of teaching biology.

A few of the biological laboratories had access to the chemicals belonging to a chemical laboratory in the same building, a few biological laboratories had a good supply of chemicals for their own use, but a great many biological laboratories of the state had very few chemicals and some none. Many of the 105 replies to the questionnaire reported a meagre supply of chemicals.

The combined laboratory, demonstration, and recitation room was used by all of the 105 biology teachers that replied to the questionnaire. The size of the biological laboratory varied from 10 feet by 15 feet to 40 feet by 60 feet.

Eighty-eight biological laboratories were heated by steam and seventeen by hot air. Sixty-five biological laboratories had direct ventilation and forty had indirect ventilation. A laboratory should have fume chambers and vent ducts to carry off the fumes and gases generated during experimental work, but few had these appliances.

Indiana's standard for natural lighting is one to six, or sixteen and two-thirds per cent as much glass surface as floor space. Thirty-three of the 105 replies reported less than sixteen and two-thirds per cent surface to the floor space. The variations were from 13.6- per cent to 33.4+ per cent. The newer school buildings are using one-third (thirty-three and one-third per cent) to one-fourth (twenty-five per cent) as much glass surface as floor space for their laboratories. Vertical lighting is preferable to horizontal lighting, many laboratories have to use the vertical lighting on account of the proximity of tall buildings to the school building.

Laboratory work calls for artificial lighting, gas, and water. There was a large variation of the number of laboratories supplied with these facilities. Fourteen laboratories did not have electricity, fifty-three laboratories did not have gas, seventy did not have running water.

when laboratories were built, a live room, dark room, or projection room were seldom thought of and this fact was shown by the fact that only nine of the 105 replies to the questionnaire reported a "live room". The "dark room" faired

less favorably than the "live room", for none of the 105 were supplied. Picture machines and projection apparatus may be secured at any time after a building is completed, so more of those facilities were reported. Twenty-nine laboratories had moving picture and lantern projection apparatus, and seven had opaque projection apparatus. Seventeen of the 105 replies reported their laboratories had no aquaria and seventy-one reported their laboratories had no museums.

Fourteen of the 105 biology teachers reported that they used school desks in their laboratories, the remainder reported that they used tables varying in size from 21 inches by 72 inches by 30 inches to 60 inches by 144 inches by 30 inches. Only eight of the schools used the standard size 42 inches by 72 inches by 30 inches.

The course of study for biology usually consists of one year, or two semesters, and the replies to the questionnaire showed that seventy-nine of the 105 schools offered biology in the ninth grade, ten schools offered the course in the ninth or tenth grade, ten offered the course in the tenth year only, and six offered the course in the ninth, tenth, eleventh, or twelfth year. All of the 105 biology teachers reported 300 minutes or more per week for the subject. Sixty-six schools had one biology teacher, thirty-five had two biology teachers and four had three biology teachers.

Collateral reading matter should be placed in cabinets along the wall of the laboratory if there is no school library in the building.

The equipment and the housing of the biological laboratories of Indiana are not uniform and do not comply with the standards given by the State Department of Public Instruction, which shows that biology teaching is in an undeveloped stage.

CHAPTER XIV

FINDINGS MADE FROM THE REPLIES TO THE QUESTIONNAIRE

1. That there is a growing tendency to gain as much knowledge first hand as possible in order that better relations in knowledge and appreciations may be had.

2. That students trained in the Herbartian or laboratory way of thinking will think before he acts.

3. That the six steps process of solving a problem is not only a biological study but also a psychological way of reasoning.

- a. The problem or question.
- b. Collecting materials or data.
- c. Getting the right method of solving the problem.
- d. Observing the results and choosing.
- e. Finding whether the conclusion really answers the problem.

f. Seeing how that conclusion is applicable.

4. Drs. Lazear, Carroll, and Reed solved the problem "What Causes Yellow Fever?" by the laboratory method.

5. The "Pure Food Law" was a result of the laboratory method.

6. Biological laboratory method will make living better and overcome superstition.

7. All the high schools used the three-hundred-minute-per-week basis.

8. A few are using the text book method in the large schools.

9. Many of the schools are using the inductive - deductive method.

10. Many of the smaller schools are doing field and project work.

11. The majority of the schools used the loose leaf work book.

12. The equipment varied from a meagre supply to a large quantity.

13. The second floor was used more than any of the others for biology.

14. There were a few poorly lighted basement rooms used for biology.

15. Steam was used in the majority of heating plants.

16. Some biology rooms were not supplied with electricity or gas.

17. But few had a live room and dark room.

18. The table sizes varied from small 21 inches by 84 inches to 60 inches by 144 inches.

19. The standard table size for four pupils is 42 inches by 72 inches by 30 inches. (State Course of Study, pp. 132-180).

20. Only eight of the 105 replies to the questionnaire stated that their schools used the above size tables.

21. Community problems were used as projects in some of the schools.

22. More time is spent in observing living characteristics of plants, and animals than formerly.

23. But few laboratories conformed to the standards given in the State Course of Study for Secondary Schools.

Conclusion:

This lack of compliance with the standards given in the State Course of Study for Secondary Schools indicates that biology teaching is still in an undeveloped state.

CHAPTER XV

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