NEW TRENDS IN HIGH SCHOOL BIOLOGY

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CHAPTER I

INTRODUCTION

Science has added much to the world in terms of change and human benefits. It has also complicated the lives of people so that they need more preparation for daily living. The high school biology course is charged with a share of the responsibility for such preparation.

If a teacher recognizes the potentialities of the secondary biology course and utilizes them fully, his students will emerge from the course better individuals for having entered it.

Thus, this report was written with a four-fold purpose: (1) to show the potentiality of the secondary biology course, that is, to show that it can be taught in a way to develop independent thinking and develop understandings of principles by means of problem-solving and related procedures; (2) to learn new techniques and methods of presenting subject matter material; (3) to evaluate and improve laboratory methods; (4) to apply the knowledge acquired during this year of study.

Teaching experience, classroom observation of professors in the Oklahoma State University botany and zoology departments who have set an example, and a general survey of the literature in this field have served as a basis for this report. The survey of literature in this field included thorough study of present day biology textbooks, laboratory manuals, workbooks, and biology method and technique books. Also included was the reading of numerous professional journals, reports of science study committees and numerous pamphlets published by the National Science Teachers Association.

The original idea for compiling this report was prompted by the discussion of a group of college freshmen. The staggering difference between the level of high school instruction and college instruction had led them to a criticism of high school teachers, in general, for their inability to stimulate independent thinking and initiate problem-solving situations. The group was representative of recent high school graduates from schools of different geographical locations, schools that varied in enrollment from the very small to the very large, and schools that were poorly-equipped and well-equipped. The conclusion drawn by the group was that many high school teachers consider themselves and the adopted textbook a reservoir of information. If the student memorizes the facts, he can pass the course without understanding, independent thinking, or solving any problems that relate to actual reasoning because the answer is unknown.

Thus, the writer hopes to show that the teaching of the facts of biology are important. But, teaching the facts is no more important than to place the students in situations in which they can learn. Learning is really an internal process. Students must be taught to recognize problems, devise methods of solving these problems and formulate their own conclusions. To do this the student will need many experiences. These experiences will include reading, discussion, experimentation, field work and project work. The student must be taught to associate previous knowledge and past experiences with new problems.

CHAPTER II

THE NEW FACE OF BIOLOGY INSTRUCTION

Science and mathematics curricula are receiving much attention in this decade. Today, schools are charged with the responsibility of meeting the needs of all youth insofar as possible. Historically, preparation for college has been the chief influence determining the nature of the elective sciences in the secondary school. The elective sciences in the secondary school are biology, chemistry, and physics. These sciences have been under some degree of pressure and what might be termed "crash influences" in the past few years. However, even before Sputnik and such things much research was being done in the field of biology regarding the effectiveness of the conventional program. Many committees and biology teachers were giving attention to newer practices and methods and predicted needs of future citizens. These future citizens included the college-bound students and those students who would terminate their formal education at the end of the twelfth year.

In a recent publication by the National Science Teachers Association the following items were listed as trends which seem apparent in the basic re-thinking of the functions of science instruction.[1]

1. A trend away from emphasis on verification and formal types of demonstrations and individual laboratory ex-

[1]National Science Teachers Association, Action for Science Under NDEA (Washington, D. C., 1959), pp. 4-5.

ercises and toward an emphasis on the development of understandings or principles by means of problem-solving and related procedures carried on by pupils under the direction of the teacher.

2. A trend away from the use of applied technology as a theme for science courses and toward an emphasis on basic scientific understandings which result in the applications of science principles in a way which leads to improved technology.

3. A trend toward laboratory experiences which run over a much longer time - perhaps several class periods or even weeks to bring to completion - and which may require equipment setpus for the entire time.

4. A trend toward more adequate recognition of science instruction as a necessary component for all liberally educated people whether college bound or not.

5. A trend toward diversified instruction as far as the variety of different experimental approaches is concerned, and in which different students seek solutions to different problems.

6. A trend toward the increased use of science clubs, science fairs, science congresses, and other supplemental devices to encourage and challenge academically able students, and to provide opportunities for all interested pupils to perform experiments and carry on projects in exploratory activities which may not be possible in the regularly scheduled class periods.

7. A trend toward the increased use of audio-visual aids by individuals or small groups of pupils.

8. A trend toward the introduction of new units of study in high school curricula such as wave mechanics, nuclear energy, radioactive isotopes, astrophysics, antibiotics, nutrition, and radiation biology, which will require more over-all space and in addition more small specialized areas, some of which may be remote from the main science room.

9. A trend toward homogeneous grouping of pupils, especially for basic science courses. This enables, academically talented pupils to be identified at an early age so that they may be stimulated and encouraged to progress at their own rate and to reach the fullest possible academic development. The teachers assigned to the more talented groups are usually those with good backgrounds in science who can challenge and lead pupils to perform

experiments and to do projects not ordinarily attempted in classes with lower interest and ability ranges.

Certainly the stated trends can be used very well as effective methods in the biology classroom. The biology class is an ideal place to develop independent thinking, problem-solving situations, and establish the principles of scientific reasoning. The biology teacher has an advantage over other elective science instructors in that biology is the most popular of the elective sciences in the secondary school. The figures of Brown indicate that a substantial majority of high school students elect biology.[2]

TABLE I

PERCENTAGES OF ELIGIBLE STUDENTS ENROLLED IN SENIOR HIGH SCHOOL SCIENCES 1954

SUBJECT	ACTUAL ENROLLMENT	PER CENT
Biology	1,293,900	72.6% of tenth year enrollment
Chemistry	482,700	31.9% of eleventh year enrollment
Physics	302,800	23.5% of twelfth year enrollment

Also, the biology course is in an advantageous position to develop independent thinking. Much of the material of biology is not controversial; pupils can make decisions calmly and rationally, little effected by prejudices and superstition. Students do not become so emotionally involved as when they are considering problems of race, religion, politics, and social relationships.

To accomplish these new trends in teaching biology the instructor

[2]K.E. Brown, "National Enrollments in High School Science," The Science Teacher, March, 1956, p.122.

must depart from the mere presentation of facts. The instructor who considers himself and the adopted textbook or textbooks a storehouse or reservoir of biological information may inhibit rather than stimulate the activity and learning of his students. The presentation of facts, one right after another, will initiate very little independent thinking and will develop few methods of solving problems. To answer the question or questions of a student in complete detail without challenging him to look for information, to do some research, to establish generalizations, or to use previous knowledge and experiences may end a student's thinking about a subject.

To teach biology as a problem-solving course,

> "A teacher should think of himself as a source book - a source book of problems that challenge pupils, a source book of suggestions for field work and laboratory activities and projects that pupils may use in solving problems, and a source book of references to films, slides, and supplementary science books where pupils can find ways to solve their problems. Only by being such a source of ideas can the teacher begin to attain the goals of science education."[3]

The teacher will be the catalyst which makes the course succeed or fail. To have success with this type of instruction the teacher must be dynamic and creative.

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[3]Walter A. Thurber and Alfred T. Collette, Teaching Science in Today's Secondary Schools (Boston, 1959), p. 11.

CHAPTER III

OBJECTIVES

The generally accepted objectives of a high school biology course are: (1) to gain information; (2) to develop methods of reasoning; (3) to learn the applications of principles; (4) to develop critical thinking.

To the writer the ultimate objective of the biology course should be to help the student become all that he is capable of becoming concerning the field of biology. Thus, the objectives of the secondary biology course could be broadened to include: (1) to gain important subject matter; (2) to enrich the background of experiences so that biological principles may be applied to new problems; (3) to develop new ways of thinking - scientific reasoning; (4) to improve skills; (5) to broaden interests; (6) to improve personality and develop into a worthwhile citizen.

Subject matter learnings are important to any well-planned and well-taught biology course. The college-bound student should emerge with a vocabulary and knowledge of subject matter material suitable for entering the finest university. The terminal student should have gained knowledge and experiences helpful to solving many of the problems of everyday living and a vocabulary that will enable him to be a well-informed citizen.

Enriching the background of experiences of students will help them to take maximum advantages of out-of school experiences as well as classroom situations. The statement has been made:

> "Learning may be likened to rolling a snowball, which as it grows, presents an ever-increasing surface for the accumulation of more snow. Or it may be likened to a nuclear chain reaction in which the fission of one nucleus releases several neutrons that produce fission in several other nuclei. Learning is an ever-expanding process; each new experience gives meaning to additional experiences. The educated person is he whose experiences begin early and continue at a rapid rate."[1]

Thus, the pupil must be provided with a broad background of experiences.

From their work in biology students should learn to look for cause and effect relationships. If they are taught scientific reasoning, they should develop habits of deferring judgment, weighing evidence carefully, and drawing only tentative conclusions. They should become critical of unsupported statements, however, they should develop tolerance for the opinion of others. They should learn to change their opinions when new evidence is revealed. If pupils learn to apply these new ways of thinking to decisions in later life — vocations, families, voting, production, consuming, conservation, and natural resources — their lives will be improved and society will be benefited.

The purely biological skills such as determining the kind of bacteria in a throat infection, determining the red blood count of a human being, or identifying the type of pathogen that causes wheat stem rust disease are of value only to those students who enter special biological fields. Just as important are the skills developed by those students who will not become specialists.

The biology course can be very beneficial to the development of

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[1]Walter A. Thurber and Alfred T. Collette, <u>Teaching Science in Today's Secondary Schools</u> (Boston, 1959), p. 33.

the skills of reading, writing, speaking, computing, and manipulation of the hands, tools, and materials. Many situations can be created which will stimulate students to report on discoveries or discuss project plans with others. Many observations and problems, can be explained only by turning to authorities in textbooks, original papers, and current periodicals. Many biological activities require mathematics to form satisfactory conclusions.

If the biology course is based on extensive laboratory work, field work and supplemented with project work it will encourage manipulative activities. The students learn the use of the microscope and many other scientific instruments. They can learn to observe and use the hands. They can learn self-expression and devise methods of problem solving.

CHAPTER IV

COURSE CONTENT AND SEQUENCE

Organizing the biology course is of great importance. The individual teacher should decide upon a general plan which will allow teaching the basic principles and fundamental concepts involved in the course in the most logical sequence. After deciding on the general plan, then the course can be organized into units so as to correlate classroom and laboratory work.

It would be desirable to include in the first unit an explanation of the major areas which are studied in the biology course. This explanation would include explanations and illustrations of research and technical methods. The students would be given opportunity to find out the many professions and occupations which require a knowledge of biology. The class would be given the opportunity of seeing how the knowledge which can be acquired in biology can be developed into worthwhile experiences for everyday living and how the knowledge can be applied to leisure time activities and hobbies. Of course, the areas studied may vary with different teachers and biologists, but the following seem to cover the field in an acceptable manner: morphology, physiology, taxonomy, ecology, evolution, paleontology, genetics, and pathology. These fields apply to both plants and animals. One should not be overemphasized nor should one be neglected. Each field has a contribution to make to a well-rounded course. It is natural for a teacher to "lean to" the field in which he has the greatest interest, but other areas should not be neglected.

Following the introductory unit, a unit on the structural and functional bases of life and relationships of living things gives the student a background for the entire study of biology. In the unit on the structural and functional bases of life a comparison of living and non-living things should be made. Also, in this unit the instructor should include a study of the relationships between various organisms, their struggle for existence, and their improvement. The essential functions of all living things are studied and the respect in which all life functions are universal is emphasized in this unit. In the way of motivation this unit can be used to take advantage of the student's natural curiosity about their own bodies to stimulate interest and to impress upon the student that the basic life needs are the same for all living things, regardless of size, classification or complexity. A comparison of plant and animal cells is made here and the basic chemical relations of the two can be included in this unit. As a final section in this unit, or as an introduction to the next unit, the classification of plants and animals should be introduced and emphasized.

There are various methods of presenting a section on classification which will make it interesting and easier for the students to learn basic principles involved. In the study of classification the instructor will have to employ many types of learning activities. Taxonomic keys can be used by the student. However, the writer does not propose to subject high school students to materials or complex keys which would be impossible for the students to competently use, but does believe that the student should be subjected to the materials he can use and understand. "Home made" keys work to very good advantage.[1] "The Golden Nature Series Guides" are a good series which present things which are most common and most easily seen. The guides include birds, flowers, insects, mammals, reptiles and amphibians, and trees. In addition to this series, books should also be provided which are on a more advanced level for the superior students. The instructor can use many sources in compiling "home made" keys. Classification can be emphasized also as one progresses through the study of plants and animals as individual groups.

With this information the student is ready to study specific groups of plants and animals.

There are many different methods of studying the plants and animals. One method is the study of plants and animals concurrently. In this case there would be a study of one-celled animals and plants and then proceed progressively to the higher organisms, bringing out the structural changes and developments as they become more complex. However, the greatest problem in this method is in using living biology, that is, obtaining the fresh plant and animal specimens. Timely field trips are also very difficult to arrange.

Another method which can be used to continue the study of plants and animals is to study them separately. Using this approach, the instructor would start in the fall with animals and work up to the human body during the winter months; follow this with the study of plants in the spring. However, to use this method it is necessary for the teacher and the students to gather some plant materials, such as seed pods, in

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[1]B. L. Berks, "Keys for Your Classroom," The American Biology Teacher, XVII (1955), pp. 75-76.

the fall of the year. This can be done on early field trips. The teacher must be very careful that the relationships existing between plants and animals and their environment are emphasized and brought continously to the attention of the members of the class.

Very few high school texts are arranged for concurrent study of plants and animals. Neither are they arranged to study animals, human biology and plants in that order. Therefore, the sequence of the course can be left to the individual teacher. He can re-arrange textbook material and use supplementary material in any order to achieve the best results that he believes to be possible.

An outline that the writer likes to follow for a high school biology course is the following:

TABLE II

COURSE OUTLINE FOR HIGH SCHOOL BIOLOGY

UNIT I: The Scientific Study and Relationship of Living Things

- A. Introduction
- B. Structural and Functional Bases of Life
- C. Relationships of Living Things
- D. Classification of Plants and Animals

UNIT II: Animal Life

- A. Invertebrates
- B. Vertebrates

UNIT III: Human Biology

UNIT IV: Plant Life

- A. Plants without Vascular Tissues
- B. The Vascular Plants

UNIT V: Genetics and Evolution

UNIT VI: Ecology

The above outline is simply suggested because of the effectiveness that can be created in using local biota. Laboratory work is essential to effective teaching. The above outline can be used and with careful planning and supervision learning situations can be created which actually use local biota for field trips, fresh specimens, and the student's own environment.

The work can be based on observations of living things, laboratory experiments, collections, problem-solving projects and similar activities. The student can be encouraged to do individual experimentation on his own. In this way the student can discover for himself about that which he is inquistive.

Every unit is organized around basic concepts or focusing ideas. These concepts are presented in the form of learning activities which are the jobs for the students. The concepts should begin with some activity within the realm of the student and then the learning is extended by a variety of activities such as reading, outlining, reports, experiments, demonstrations, projects, visual aids, and field trips and field work. By the time a basic concept is completed the pupil can generalize or summarize the material as a final activity or project.

CHAPTER V

METHODS IN THE CLASSROOM

The development of biological interests is one of the major goals of the high school biology course. Biological interests do not arise spontaneously; they must be stimulated and motivated. These interests develop best when there is a dynamic and creative biology instructor who allows opportunities to explore and experiment. These interests are rarely, if ever, developed in the classroom where mass instruction techniques and an autocratic instructor prevail. Biological interests help determine future occupations. Many biologists, doctors, dentists, botanists, zoologists, pathologists, and laboratory technicians have entered their careers because of the influence of a high school biology teacher or because he encountered biology as a subject of special appeal in the way it was presented.

To accomplish the best results, the teacher must be a diagnostician. He must realize a biology class is not a uniform structure, even if there should be homogeneous grouping. The students are not sterotyped personalities. Each student is an individual with his own interests, abilities and experiences. The outside world has a place for each special ability. The teacher must develop each student's ability to the degree possible. He must take the student from the niche he finds him and never try to mold all students to the same pattern.

The students must be motivated. It may be as simple as a pat on the back and a simple sentence to the student or it may be the solving of a complex problem. Motivation must be built from things that are of interest to the student. The value of the work is little motivation for high school students. Motivation is probably best achieved by connecting the things with which the student is familiar with the new facts to be learned.

The nature of the biology course can be motivation in itself. The well conducted, informal laboratory period can be a refreshing departure from the academic classroom lectures. Surveys indicate that the informal laboratory period is more conducive to learning than the formal method still used by some teachers.[1]

There are many ways to arouse the curiosity of students as an instructor begins a unit or even parts of units. As an example, take methods of introducing photosynthesis to biology students. The instructor would first want to get across the idea to the students that plants are food makers.

A very good way to arouse interest is to seal a snail in a soft glass test tube of pond water and then put a simple question to the class, "How long will the snail live? Why?" By using suitable questions the class can be directed or motivated into a discussion toward the notion that green plants make food. With the idea in mind that green plants make food, the students will become curious as to how plants make food and what materials the plants need for food making.

Another method used commonly is to introduce the subject with a film. There are several good films on the subject of photosynthesis. Among these are Gift of Green (New York Botanic Gardens), Leaves (Encyclo-

[1]Doris H. Hawse, "Ooh! Worms!", Science Education, III (1959), p. 436.

pedia Britannica) and Photosynthesis (United World). The teacher must be careful that the films are not too difficult to comprehend.

Testing a silver-edged geranium leaf for starch is another good method of introducing the subject of photosynthesis. The instructor can guide the students into giving elicit reasons why the white portion of the geranium leaf does not contain starch and why the green portion of the leaf does. In using this method the teacher should be cautious because the absence of starch does not always mean that photosynthesis has not taken place. The presence of starch is a good indication that photosynthesis has taken place. After discussing various reasons for the presence of the starch and drawing tentative conclusions, the students will probably want to design their own experiments to test the importance of light, of carbon dioxide, and other factors that are important in food making.

A case study can be developed around the topic of photosynthesis using the reprint of Rabinowitch's paper on the subject.[2] The reprint is now available to high schools from the Atomic Energy Commission. One can also use van Helmont's experiment with a willow twig to initiate thinking and problem-solving situations concerning photosynthesis.[3]

Many times class discussion can be initiated by laboratory work. As a good example of this, have the class to examine epidermal cells in the onion bulb and cells of the Elodea plant and make a comparison of

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[2]Eugene Rabinowitch, "Photosynthesis," Scientific American, (March, 1949), (November, 1953).

[3]L. Nash, Plants and the Atmosphere, Harvard Case History Series, (Cambridge, 1952), p. 15.

the cells observed. When the cells are compared under the microscope they will find that they are different. This can lead into a discussion of chloroplasts and their function.

Naturally, a teacher will select those activities and techniques which are applicable to the classroom situation. Teaching and methods of motivation are personal inventions. No writer could hope to include in one report all of the individual procedures and their variations. The intention is not to plan an entire course or to complete an entire and detailed group of techniques and procedures, for any experienced biology teacher realizes the futility involved in such work, but to emphasize what can be done. Teachers must change from the old "assign-read-study-recite-test" method and use many and varied learning activities. All the methods or techniques employed by a teacher should hinge on the idea of making students "want to know". This wanting to know can be brought into the classroom only if the teacher introduces concrete experiences, allows participation in learning activities and problem-solving, and is himself constantly seeking new answers.

To succeed in using biological subject matter as a means to an end of independent thinking, changed attitudes, broadened interests, subject matter comprehension, improved skills, scientific development and better adjustment the teacher will no doubt encourage scientific reasoning.

Dressel and Mayhew list five abilities that the Natural Science Committee of the Cooperative Study of Evaluation in General Education believe to be necessary for scientific reasoning. The list includes the following:[4]

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[4]Paul L. Dressel and Lewis B. Mayhew, Science Reasoning and Understanding, (Dubuque, 1954), pp. 4-5.

1. Ability to recognize and state problems.

2. Ability to select, evaluate, and apply information in relation to problems.

3. Ability to recognize and state hypotheses.

4. Ability to recognize and evaluate conclusions, assumptions, and generalizations.

5. Ability to recognize and formulate attitudes and take action after critical consideration.

Scientific reasoning can very well be developed and applied in the laboratory, which will be shown in a later chapter. However, the five abilities of scientific reasoning can also be developed by the use of lecture, textbook materials, current periodicals, newspaper articles, student beliefs, and teacher motivation.

Printed material, of course, lends itself better to teaching: (1) the ability to recognize and state problems; (2) ability to select, evaluate and apply information and (4) the ability to form or evaluate conclusions.

To enhance the ability to recognize and state problems from printed matter must involve questions for which the answer is not known to the person seeking it. Usually, problems are stated in the form of questions but it must be kept in mind that not all questions are problems. As a good example of this, Dressel and Mayhew make the following statement involving a question which is a problem:

"The answer to the question should not be immediately available to the asker in factual form. The question 'What time is it?' is hardly a problem for a person located in a large railroad station, but if he were in uninhabited country without a radio or timepiece it would constitute a genuine problem, for which he might attempt a partial solution by scientific means. It should be noted that there are occasions in teaching when a question arises in a student's mind which can be answered

> directly and factually. Although not ordinarily considered a problem, treating a question like this in problem form has certain advantages. This is not an uncommon technique in teaching, when, instead of stating the answer categorically, the teacher guides the student's thinking so that he has engaged in some of the mental steps of problem solving in a simple situation."[5]

Thus to answer the question or questions of a pupil in complete detail without challenging him to look for information or do some research on his own and form his own conclusions may end a student's thinking and curiosity about the subject.

To accomplish the above, the teacher can present an outline or brief overview of a subject to point out key ideas. This discussion will lead to questions in the minds of the students. Some of these questions can be answered by the reading of the textbook, others will be of the problem type and will require further reading, research, and even student projects. It may even lead to the reading and interpreting of scientific articles. This allows the student to practice the skill of the ability to read and interpret the writings of scientists. Many of the experiments and demonstrations in laboratory and much of the actual subject matter and content of biology are recorded in history by original papers. The better students may even want to read sections of or entire original papers. These can be applied to applications and understandings of biological principles.

Students enjoy discovering things for themselves. When a student first becomes interested in a problem area there is no focus. He just explores for an answer and then there develops a certain amount of clarification. Once the answers seem to become clear then the student can actually begin a period of preparation. He wants to read more, explore

[5]Dressel and Mayhew, pp. 15-16.

techniques, discuss the problem and draw on previous experiences. They work to solve the problem. When they reason out a conclusion or a solution there is a certain satisfaction in discovering for themselves a relationship or a basic understanding.

Developing the ability to select, analyze, and evaluate information in relation to problems and the ability to formulate, recognize and evaluate conclusions from printed material follows much the same pattern as stimulating the ability to recognize and state problems. Of course, encouraging the ability to select, analyze, and evaluate information can be derived from the textbook but other sources of information must be utilized. These other sources of information can include the subject knowledge possessed by the teacher, general knowledge possessed by the students, available references and audio-visual materials. The student should learn to differentiate between simple facts and generalizations. Dressel and Mayhew say that it is often difficult to differentiate between simple facts and generalizations. They show that there are two kinds of facts, one is a fact by definition and the other is a fact by experience. A fact by definition is related in its nature to language or some type of accepted symbol as, "Zero on the centigrade scale corresponds to the freezing point of water." This kind is a fact simply because the makers of the centigrade scale defined it so. On the other hand there are facts by experience such as determining the components of the compound called glucose, these components were established by experimentation. The latter type of fact bears much relationship to generalizations. Facts by experience may constitute a generalization. The generalization is usually based on several facts and is synonymous in most sciences with the word "idea".[6]

In using textbook and printed material the students should learn to consider certain points in interpreting what they read. They should learn to consider the authority, his background, his experience, his job or position professionally, his reputation among fellow workers, and the amount of research he has done in the field about which he is writing. They should also learn to evaluate the source of the data. Not all that is in print is reliable, therefore, the student should learn which sources are apt to contain more accurate information.

Since the subject of biology has many terms which are new to the student, it is recommended that the teacher make use of the scientific terms as they occur in the content of the course. However, this vocabulary of biological terms that the student is expected to develop during his first year of biology is immense and the teacher will have to emphasize the importance of learning the meaning or definition. In no case should the words be defined in a memorizing-drill fashion. Probably the best method for facilitating better comprehension of the biological vocabulary is found in the use of Greek and Latin derivatives. The use of derivatives in teaching vocabulary simply means to take Latin and Greek prefixes, suffixes, and root clusters and have the student learn them thoroughly. With these derivatives in mind the student can associate and realize the meaning of many terms. Our present day scientific vocabulary is derived almost entirely from Greek and Latin, therefore, with a good knowledge of derivatives the student will have the foundation for a good vocabulary. The following is a list of sources which contain

[6]Dressel and Mayhew, pp. 17-18.

excellent lists of biological terms and their origins, prefixes and suffixes:

Robert J. Boles, <u>Principles of Biological Terminology</u> (1957).

Dale E. Braungard and Sr. Reta Buddeke, <u>Biology the Study of Living Things</u> (1957).

Edmund C. Jaeger, <u>A Source-Book of Biological Names and Terms</u> (1950).

To evaluate the biology program is to determine the success of the teaching and learning processes. The objectives of a course largely control the type of evaluation techniques used. If the objectives are narrow in scope and deal largely in the memorization of facts, then the factual objective testing may serve as a valid means of evaluation. Whereas, if the course objectives are broad in scope and provide for not only factual knowledge but also functional learning, critical thinking, development of attitudes and the forming of concepts by the pupils, as previously stated, then it is almost impossible to test objectively and reliably. Therefore, the biology instructor must recognize that evaluation is more than testing and the assigning of grades.

Course objectives and evaluation are closely related. The first step in evaluation is to determine whether or not the objectives are achievable by a particular group of pupils. If not, they should be modified to fit the needs of the group. This does not mean lowering of standards: it could as well mean raising them -- the modification being based largely on the ability of the group. Sound evaluation is a continuous process from the beginning to the end of a unit of work and is based on an analysis and diagnosis of pupil abilities in respect to the objectives to be achieved.

Clearly, the technique, the procedure, the device, the motivation, the evaluation - whatever it is - fits within the curriculum pattern of the biological course. The teacher plans a unit of work. At the end of the unit the students are to have mastery of a large concept or "idea". In planning to help students achieve true learning of this large concept, the teacher must use all methods and techniques at his disposal to develop scientific reasoning and worthwhile experiences.

All that has been said is based on the premise that teachers will instruct and guide pupils instead of reciting to them, "parrot-like". Good teachers consider all of the mentioned things as a definite part of the teaching and learning process.

CHAPTER VI

THE LABORATORY

Laboratory work is essential to effective teaching. The aims of a biology course cannot be achieved if each pupil's work consists only of reading and listening. For the aims of the course to be achieved the pupils must engage in much overt activity both individually and in groups. The functional laboratory is the best way to develop critical thinking.

Laboratory Work

The high school biology laboratory must provide for high school students of different levels of ability. Therefore, the teacher must include techniques and procedures not only for the "average" class, if there is such a thing, but for all individuals who are enrolled in the biology course, regardless of how they have been grouped. The laboratory must provide stimulation for the student no matter what his interest or ability may be. Therefore, the laboratory must include demonstrations, involving visual aids, experimentation involving and requiring manipulation of various instruments and materials, those requiring reading, observing, thinking: all the processes which serve to make up biology. It must include short and long-range processes.

In order for the high school laboratory to be effective and in order to make the most fruitful use of time, it must be carefully guided by the teacher. Guidance, permissive in nature, not autocratic, seems to be necessary.

Laboratory work is never used in isolation but is a part of the teaching development of the course.

The present commercial workbooks and so-called laboratory manuals seem entirely unsatisfactory for teaching biology as a doing and learning and applying situation. Most of the workbooks and manuals now on the market merely involve "busy work". Most of these merely require the student to look up answers in a textbook and fill in a few blank lines or complete and label a drawing which has already been drawn or at least partially drawn. This type of exercise only serves to give the teacher the problem of who to evaluate. True, the commercial workbooks are time savers for the teacher. Also, the prepared workbook does have its advantages as more materials are crowded into the biology course. But the major objective of the course is not to cover a specified number of pages of textbook material. The disadvantages of the commercial laboratory manual far outweigh the advantages if the best learning situations are to be created.

Much of the efective teaching of biology is done by laboratory exercises that are of the type that the student uses materials and observes results. These exercises are not something that he can copy from a book. They are experiences like using a microscope, preparing slides, using prepared slides, using fresh and preserved materials, making media, collecting specimens, and many other worthwhile experiences. The laboratory should not be a talking process but a doing process. The laboratory is an ideal place for improving the terminology and vocabulary of the student.

There seems to be two conceivable functions of laboratory work:

> "Seeing is believing — one appeals not to the authority of a living person or a book; but one looks squarely at the facts,

> the infinitely varied phenomena of nature. Thus the first function of biology lab is to present evidence from nature to illustrate the bases of our biological concepts.
>
> To convey something of the nature of science and its methods is the second function."[1]

There is really no need for the "cookbook" biology laboratory with our present day visual aids. There is no need to give the student an exercise for which the answer is known or clearly inevitable. Laboratory experiments should actually be experimentation, not just something so that the student will be busy or something for which the answer is obviously already known. The laboratory should provide real participation in scientific investigation which will characterize concepts and give the student an understanding of the nature of scientific methods and a stimulus for further investigation as well as enable him to learn certain facts and techniques.

Dr. Bentley Glass suggested to the AIBS Biological Science Curriculum Committee the "block" idea in biology instruction in the laboratory. The "block" would cover investigations on a specific biological problem and would cover a duration of several weeks. The block would begin with simple questions and experiments and proceed to more complex experimental approaches. These would start with things simple enough to challenge the average student and proceed to the more complex with no limit to the complexity and individual experimentation on the part of the gifted student.[2]

The AIBS Biological Science Curriculum Committee on Laboratory In-

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[1]Addison E. Lee, "The Block of Time Idea in Biology Instruction," The American Biology Teacher, XXII (March, 1960), p. 135.

[2]Lee, p. 138.

struction suggested the following specific "blocks" of laboratory work:[3]

1. Regulation and homeostasis
2. Interdependence of structure
3. Regulation in plants
4. Growth and nutrition
5. Coordination and behavior
6. Animal growth and development
7. Plant growth and development
8. Energy relations
9. Dynamic ecology
10. Genetic continuity
11. Evolution

These blocks could be rearranged to the sequence that has been selected by the individual instructor.

The laboratory should be used as a supplement to the daily classroom instruction. The laboratory schedule should be flexible. Some days it would be used for actual experimentation, other days for lecture-demonstration, at other times for audio-visual instruction, other days for independent study from available references, other days for writing by observations and results.

The high school student should learn to make neat, accurate drawings which are correctly labeled and he should be able to write up observations and results in a creditable form.

The writer has found that requiring students to make drawings on graph paper in the early part of the course allows beginning students to get better proportions. However, the graph paper is discarded early in the course and replaced by ordinary drawing paper.

To teach biology in this manner requires facilities and equipment. Modern biology teaching requires that laboratory or experimental activities be used whenever they are needed in the course of instruction. However, on September 2, 1958 the National Defense Education Act was signed into

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[3]Lee, pp. 136-138.

law and science teachers have since had an opportunity to purchase more equipment. Many tools are now made available to the biology teacher. However, facilities are means to ends. The best facilities and equipment are to no avail in the absence of a good teacher. Therefore, it shall be considered in this report that the flow of educational experiences should be unhampered by restrictions imposed by the educationally extraneous limitations of inadequate space and equipment.[4]

Examples of Techniques and Procedures Within a Block

Just as the use of techniques and methods and procedures is expressed in teaching patterns known as "syllabus", "course of study", or "curriculum", so the use of various laboratory and field techniques and procedures may be used in the laboratory. These procedures depend on the special situation in which the teacher finds himself and his own personal preferences of how to obtain the best results. There is no one best way, and the teacher should not get in a rut and use the same way all of the time but use a variety of techniques in the biology course.

The teacher may use a self-demonstration. The self-demonstration is often used to initiate the beginning of a unit or to guide students in a learning activity. Sometimes a teacher may modify a self-demonstration to turn it into an exercise for the students to plan an experiment. A simple example of this kind or procedure is the following:[5]

> "Place the following materials on the demonstration table: carbon paper or aluminum foil, pins, a growing geranium,

[4]National Science Teachers Association, Action for Science Under NDEA, (Washington, D. C., 1959), pp. 3-10.

[5]Evelyn Morholt, Paul Brandwein, and Alexander Joseph, A Sourcebook for the Biological Sciences, (New York, 1958), pp. 6-7.

alcohol, dilute iodine, a beaker or a hot plate or a test tube in a water bath over a burner.

Ask the students to plan an experiment to answer the following question: IS LIGHT NEEDED BY GREEN LEAVES TO MAKE STARCH?

Have the students to write an explanation of their own plan of action to solve the problem with the materials provided. After they have devised the plan, ask the entire group the following questions:

1. Have you provided for a control?
2. How could you find out whether leaves made starch?
3. If the leaves were covered would they make starch?

After the students have finished the experiment, have them compare their results and draw conclusions. In this way, they will be able to draw conclusions from many investigations, not just one."

Another example of the type of technique or procedure that the instructor may use is that of using a specific exercise in planning controls. Students learn to use the method of scientists or they learn by "doing". A very simple exercise of this type is the following:[6]

"IS CARBON DIOXIDE USED BY GREEN PLANTS? Do water plants use carbon dioxide? Since carbon dioxide is a colorless gas, an indicator, such as brom thymol blue, is used to keep track of the amount of carbon dioxide in the water. Fill a large beaker with brom thymol blue solution and blow into it through a straw. What happens? The carbon dioxide in the breath caused a change in color from blue to yellow. What color would result if the carbon dioxide is removed from the solution?

Fill four test tubes with this brom thymol yellow (rich in carbon dioxide). Add sprigs of Elodea plants to two of these test tubes. Wrap one tube containing Elodea in carbon paper; also, wrap another tube without the plant in carbon paper. Set all the tubes in bright sunlight (or electric light). Examine the tubes periodically for change in color. Explain the findings and results. Compare results with other students. Summarize an answer to the stated problem. Explain what tactics of scientists have been used in the experiment."

The biology teacher may have the students do simple investigations. The students should start with simple investigations and work toward the more complex. Some students will be more interested in carrying the in-

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[6]Morholt, Brandwein, and Joseph, p. 7.

vestigations further than others. The students could do experiments involving the role of light and chlorophyll in photosynthesis, such as (1) starch-making by green leaves; (2) sugar-making by green leaves; (3) test for cane sugar in plants; (4) role of light in starch-making by green plants; (5) role of chlorophyll in starch-making and (6) analysis of chlorophyll by paper chromatography.[7]

Here, the writer would like to say that to do the best job of teaching biology it would certainly be to the student's advantage to have had a course in general chemistry previously. It is true that at the present time most students take biology in the tenth year and then take chemistry in the eleventh or twelfth year. It would be to the advantage of the biology department if these two courses could be switched in their sequence. There is much of biology that cannot be explained without using chemistry. The writer realizes that this change in sequence will probably not be made in the near future because of tradition. Recent curriculum study groups have found that there would be little objection to the change by high school chemistry teachers. Nevertheless, the statement is a fact, that in order to have the most thorough understanding of biology there must also be some understanding of certain chemical processes. The writer makes this statement at this time because of some of the facts of chemistry that should be applied to the above set of investigations. Maybe, as a result of recent study groups, biology teachers will see tradition discarded and the logical sequence of elective sciences become a reality.

Timely and well planned field trips always create good learning situations. The study of the life processes of biology becomes more effective when it becomes an integral part of the pupil's experiences. To explore

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[7]Morholt, Brandwein, and Joseph, pp. 13-26.

the plant and animal world, it is not necessary to seek out the redwood groves of California or take passage to Africa and arrange for a safari. The exploration may start in a vacant lot covered with a confused tangle of wild plants and young trees. If the area has not been subjected to applications of 2,4-D and other weed sprays there will be many kinds of animal life as well as a profusion of plant life. The instructor should plan for a class to do as much field work as possible. Collect live specimens and keep them in the laboratory for a few days. It is good for an instructor of high school biology to schedule a field trip during the first two weeks of the semester, even if it is only around three or four blocks to get the feel of observing trees, shrubs, and other living things. This is also a good time to gather grasshoppers, frogs, and crayfish in nearby fields, streams, and ponds for live observation. To get the students to really learn by doing, activities must be started early in the program. The writer has tried having the students plant oats in a large terrarium on the second or third day of school. By the time the class is ready to study grasshoppers (about the third or fourth week) the oats are several inches high. The living grasshoppers can then be put into the terrarium. This furnishes a suitable place for keeping the specimens for study. The students can observe the grasshoppers feed, breathe, move, and see the functioning of various systems. Similar things can be done with the crayfish, earthworms, and many of the other forms of lower animal life. The students can actually apply classification, description, habitat, economic importance, degree of specialization and the life processes. The life processes are made more real in dissecting when the organism's systems are studied carefully. Thus there are many worthwhile learning activities that can be brought about by the results of a field trip.

The class as a group may enjoy preparing models to illustrate certain ideas or structures. There are many models to use in class besides charts and commercial models. These models can be made by interested members of the class or they can be done as group projects. A very simple model of the cell can be constructed easily. The procedure is simple. Use a roll of cellophane, saran-wrap, or a clear plastic box for a cell model. The students should be able to supply their own information regarding the structures typical of cells. For instance, the students might use modeling clay for the nucleus of the cell, they can use one color for the nucleus, another color for the nuclear membrane, still another color for the nucleolus. They might use small balls of green clay for chloroplasts, or a ribbon of green blotting paper for the spiral chloroplast of Spirogyra. Of course, the students may come up with many other ideas of what to use in constructing the model. An attractive visual aids collection may be developed in a short time by the students. Instructors should be certain though that the student has a clear perception of what he is doing.

The laboratory can even be extended outside the school. Sometimes the students raise questions, or the teacher finds it desirable to extend the lesson outside of the classroom laboratory work. Several kinds of things can be done and can be useful to the student. However, the student does not have apparatus at home to carry on actual experimentation or self-demonstration. Therefore, experimentation at home will be limited. Collecting specimens is a good outside project. There are some pencil and paper procedures which stress various aspects of investigative procedures in science. A good example of pencil and paper investigations outside the classroom is one concerned with genetics. For instance, tracing the occurrence of a trait in the family of the student. The student can devise a key to show this trait over several generations. They will find it interesting while at the same time they will be using principles of genetics. There are many inventory-type projects that can be done in a unit on heredity or genetics. Students enjoy looking into the inheritance of maleness and femaleness, colorblindness, freckles, musical ability, shape of ears, attached or free ear lobes, blood types and ability to taste specific chemicals. One of these that works very well in high school is the phenylthiocarbamide taste test. About seven out of every ten human beings taste P.T.C. (phenylthiocarbamide) as a salt, sweet, sour, or bitter taste. To others, P.T.C. is tasteless. The paper soaked in the harmless chemical may be purchased or the teacher can prepare it. The paper can be used by the students to test themselves, their parents, and other relatives. The ability to taste P.T.C. seems to be a dominant trait and students can compile the data and make charts and thus many of the principles of genetics can be applied. With this simple test the concept of the pairing of factors and their segregation can be illustrated. Inventory-type projects may also be used in many other units of study.

The students can perhaps do simple projects at home with those things which can be devised by using apparatus of sorts from materials at hand. They can also make field-trip investigations on their own.

Clearly in one report even the most common patterns involving the use of all laboratory methods cannot be covered. But, in addition to the few techniques and procedures mentioned previously one must include the long-term projects and investigations.

In present day biology classes there is a definite trend toward laboratory experiences which run over a much longer period of time - perhaps several class periods or even several weeks to bring them to completion. Facilities should be provided which will permit this kind of educational experience. The biology laboratory should include enough space to provide for those student and teacher experiments and projects which will continue for the longer period of time.

The long-term investigation should be "original" in the high school meaning of the word. The students should begin with a simple technique which helps resolve a relatevely simple problem and then evolve the problem into a full scale investigation.

The investigation will be or should be in an area in which the stuent is deeply interested. For example, in previous years of teaching experience this writer has found that many students want to do projects in the areas which relate to vocations in which they are interested. One tenth grade student who enrolled in the writer's class chose to do a project called "Hematology: The Science of Blood". Items in the project on hematology covered approximately ten areas. They were: an artificial heart constructed from clay and paper mache; a map of the United States showing the main blood donation centers denoted by use of flashing lights; the rapid administration of blood; blood transfusions; blood as a fertilizer; blood as a medicine; an electronic stethoscope, which the student actually constructed; blood and a future war; the heart; and the heart and how it works. This student's special interest was medicine and he wanted to become a doctor.

Another student chose a project which she called "The Effects of Vitamins on Growth of Animals". She used chickens, rats, and guinea pigs to show the effects of deficiencies of certain vitamins.

Another student did some research on heredity. He used chickens, rats, beans, and peas in his project to show inherited characteristics.

These special projects averaged about three or four months in duration.

These long term projects or investigations may be so basic that they have been done by thousands of students or they may be original. Nevertheless, in either category the student learns by doing. Some of these student's are tomorrow's scientists. Most people agree that the inspiration for a career come during formative days of early schooling. In a survey of 89 biological scientists it was reported that 42.7 per cent of them had been influenced into that career by the time that they had completed high school. 23.2 per cent of them had been influenced by a high school teacher.[8]

The best projects are usually done by those who develop their own ideas and materialize them. Scientists obtain satisfaction in attempting to solve problems, even if the results are often inconclusive and lead to further experimentation. So it is with long-term investigations in biology and projects in which students engage. They are beginnings, not ends in themselves. Each investigation whether an individual project or a class project will lead to more knowledge and appreciation of some concept or phase of biology.

Many good ideas for individual projects for students are listed in a publication by the Science Clubs of America entitled "Thousands of Science Projects". Again, many of the titles are so basic that they have

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[8]Donald R. Miller, "A Study of Influencing Factors Identified as Pertinent in Career Selection by a Random Sample of 231 Physical and Biological Scientists", (unpub. M.S. report, Oklahoma State University, 1958), p. 7.

been done by thousands of students and some are original and have been done by only one student. The list includes titles of exhibits shown at science fairs and projects produced for the Annual Science Talent Search. The titles are classified by subject matter. The directions and plans for the projects are not available. But the student may get an idea from these titles and can then devise his own methods of research.[9]

If a teacher has a student in his tenth year, the student might even start an investigation that would last over the rest of his high school days. The student should not start an investigation that he would not have time to complete, neither should the instructor start class projects that cannot be completed in time for the students to grasp the knowledge and application to be obtained from the investigation.

Students with biological interests can be discovered. Not all of them, of course, will become biologists. Some of them will never develop much interest in biology, but teachers can get across certain basic ideas and concepts for daily living. Some of the students who become interested will change their minds when they find greener pastures or other areas of study which suit them or fit them better.

Students who turn out the best science projects usually arrive at the system used by professional scientists. They must learn to "think through" experiments before attempting to perform them in the laboratory. They must learn to use their own training and experience, the training and experience of the instructor and other associates, and they must study books, technical papers and magazines which contain references to the problem. In other words, the student must read widely; question others,

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[9]Margaret Patterson and Joseph H. Kraus, Thousands of Science Projects, (Washington, D. C., 1957).

and plan carefully.

Although the long-term investigations usually appeal more to the above-average, there are many projects for all levels of ability and instructors must realize that adequate biological instruction is a necessary component for all liberally educated people whether college bound or not.

CHAPTER VII

CONCLUSION

Today's biology classes pose many new problems for the teacher. The major divisions of biology have not changed, but the ever-increasing knowledge of the biological field have caused changes. The ever-widening of experience and abilities among students in the same classes and the increasing need for specific information about man himself are presenting a challenge.

While the writer has been trying to indicate as P. W. Bridgman once said, "Science means doing one's damnedest with one's mind, no holds barred," the concepts of biology are developed in hard work and creative activity.[1] Brain and muscle, mind and hands must be in constant collaboration.

Biology is an experience in search of the meaning of living things. The study of biology is for all. The elements of biology are the fundamental facts essential to the knowledge of man living in today's world. The presentation of these elements through narrative, review, illustration, thought-questions, problem-solving, and stimulating projects should make the objectives of biology courses become a reality. The elements of biology can be combined in the classroom, in the laboratory, out of the classroom to meet the varying needs of all students.

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[1] P. W. Bridgman, Yale Review, XXXIV (1945), pp. 444-461.

To meet the varying needs of all students the teacher must carefully plan time, methods of approach and useful materials.

The function of the high school biology teacher is to attempt to instill fundamental knowledge in the limited, develop basic skills among the average, and inspire complex creative activities in the gifted.

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