ENRICHMENT PROJECTS FOR GIFTED STUDENTS IN HIGH SCHOOL BIOLOGY

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IN HIGH SCHOOL BIOLOGY

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D. H.

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CHAPTER I

INTRODUCTION

Statement of the Problem

How may high school biology teachers stimulate and help gifted students in high school biology? This is one of the most important problems that we face today in teaching biology. It is a proven fact that teachers have more influence on teenage students than any other agency, as far as determining the choice of careers is concerned. In a study of young scientists entered in the Westinghouse Science Talent Search, it was found that the height of teacher inspiration was from the age of twelve to seventeen.[1] In other words, this age range extends from approximately grade six through high school and in the middle we find high school biology, so it is our duty to help these students to make their decisions, as to what career or vocation they will choose.

What is meant when we say "gifted student"? This is a question that provides fuel for many arguments. Usually, however, students are separated on the basis of I. Q. scores, reading scores, mathematics scores, direct observation and

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[1] The Sunday Oklahoman, May 29, 1960, P. 5.

by other means. Most of the methods listed above are helpful in determining the abilities of a student, but at the same time, it is felt that students who are somewhat lower in inherent ability, but are willing to work and work hard should be included in this group. Many times determination and effort overcome a certain lack of native ability.

In some schools, advanced students are placed in special classes in which emphasis is placed largely on laboratory work and freedom of the student. This is very desirable, but in many small schools it is impossible. In a recent study it was found that many schools in Oklahoma now have programs designed especially for gifted students, but a much greater number do not. To be more specific, only two hundred sixteen out of nine hundred high schools contacted were offering any kind of program for gifted students.[2] Some of the methods of enrichment were: giving additional assignments, putting more advanced students on their own for research projects, outside reading, skipping grades, educational television and more advanced courses. The second topic listed above is the one that will be dealt with in this study.

The project method of teaching is hard work on both the student and the teacher, but the end results cannot be matched for the feeling of satisfaction and accomplishment. This method offers the student the opportunity to learn by seeing, doing, and handling.

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[2] The Daily Oklahoman, November 21, 1959, p. 11.

The material in the body of this report and the projects listed may be used in any type of school system, but those schools not having a separate program for gifted students may find the projects challenging and it is hoped, useful. It is also hoped that the students will benefit from the basic ideas and principles of research outlined in the next few chapters.

Special classes have been organized by many schools which meet after school hours and work on various problems and projects. Many suggestions for organizing such groups and sources of material are listed in the Sponsor's Handbook, published by Science Service, 1719 N. St., N. W. Washington 6, D. C. Such groups are usually not selected on the basis of any test scores, but by a common interest in science. The science club offers the pupil an opportunity for specialization which he does not have in the classroom. In the classroom, his method of dealing with a problem is clearly outlined by teacher imposed restrictions, but in the club program the method is of his own devising.[3]

A distinctive feature of most science clubs is the fact that all work is done outside of regular class periods. No classroom time is sacrificed to work on projects. This, in itself, will eliminate those students whose only ideas are to get "something for nothing" or get out of classes occasionally.

This problem of providing for the needs of gifted students is especially intriguing because of the apparent lack of

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[3] E. D. Heiss, E. S. Osbourn, and C. W. Hoffman, Modern Science Teaching (New York, 1950), p. 30.

research at the high school level. This is just one of the many problems facing biology teachers across the nation today, but it is the most important one, as far as research and future development in the biological sciences is concerned. Students who are interested in research must begin somewhere, so why not provide them with ample opportunities in high school biology? It is hoped that through a study of this problem a working program for the enrichment of high school biology through research projects can be formulated.

Justification and Limitation of the Research

This study has been limited to one particular problem, because it is a vast area with many facets. It is felt, however, that this problem can be discussed enough that it may be somewhat clarified in the minds of high school students.

This study is considered necessary, because there has been too little research into this area of high school biology and the problems related thereto. This problem has also been examined because of its relation to the human problems of disease, nutrition, food production and conservation of the world's natural resources.

The increasing percentage of students taking biology in our high schools seems to point out the fact that biology is gaining in popularity with students. Along with the increase in the enrollment in high school biology, however, there has been a decrease in the amount of high school botany and zoology taught. There has been a tendency to combine these two into a course usually called general biology. Largely within the past ten years there has been a tendency to eliminate human physiology, as a separate course from the program of studies of the secondary school, and to teach the essentials of physiology as a part of the course in general biology.

Also, within the past decade there has been a growing and commendable trend toward the teaching of biology in terms of its relation to human welfare and human problems, so that now some schools offer courses in "civic biology."[4] Every indication seems to point out the stability of biology in the secondary school. From the early schools where no biology was taught, we have advanced to a point where high school biology no longer needs to fear extinction.

In this study, the term high school or secondary school refers to grades nine through twelve. Biology is generally assumed to be a high school course and in this study will be viewed as such.

Sources of Information

In preparing this report, the writer tried to obtain the latest information possible. The library books, magazine articles, biological journals, leaflets, newspapers, biological supply catalogs and other available materials were used to secure a wider understanding of the problems involved. Information was also obtained from members of the faculty of

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[4] William E. Cole, The Teaching of Biology (New York, 1934), p. 17.

Oklahoma State University, as well as individuals presently engaged in teaching high school biology.

Purpose of the Research

The purpose of this research is to reveal methods and ideas whereby students in high school biology may be encouraged and stimulated to go "beyond the call of duty." This report also attempts to summarize some of the principal ideas of basic research and make them understandable at the high school level. Various projects have been listed in the body of this report and it is hoped that these will be of help to the student in selecting a research project. The ultimate goal is to aid biology teachers in solving, or at least alleviating, the problem presented at the beginning of this chapter.

Method of Procedure

Information for this report was gathered from the material mentioned earlier under the title, Sources of Information. Facts and principles of any science are learned by three methods. One is by observing, experimenting and recording the observed results and comparing them with what others have learned. By a second method observation is also used, but we use the scientific or problem-solving method as a guide. The other method is to read what others have learned by the first two methods. In compiling this report, most of the material was obtained by the last named method above.

Chemical formulas, in addition to chemical names, have been included in the projects to aid the student in determining the exact chemicals needed.

The body of the report is composed of chapters on basic research, laboratory work, projects related to human anatomy and physiology, projects in botany and bacteriology, projects in zoology and a final chapter containing conclusions and recommendations. Some attention is given to procedures, but most of the experiments can be modified to suit the student.

CHAPTER II

BASIC PRINCIPLES OF SCIENTIFIC RESEARCH

Introduction to Research

Modern biology is far removed from the crude methods employed during its early stages. Today, biology enjoys an important place in the field of science. It has an almost limitless supply of material for study, since it is the study of all living things. Since humans are included in its scope, biology has even more significance, by all concerned. Altogether, there are more than a million known plants and animals, making it impossible for us to exhaust so great a supply, as far as study and research are concerned. As Aristotle has said, "All nature is marvellous."[5]

Before beginning a research project the student should rate himself on the list given below. If the answer is no to several of the traits of the ideal research worker, then the student should judge whether or not he is capable of doing a good job on the chosen research project. The ideal research worker should be:

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[5]Charles Singer, A History of Biology (New York, 1950), p. i.

1. Honest, sincere and integrious
2. Alert to vital problems and the truth
3. Poised
4. Accurate, thorough and exact
5. Inventive and constructive
6. Independent and self-confident, but open-minded
7. Industrious and energetic
8. Systematic
9. Persistent
10. Capable of using common sense
11. Introspective
12. Devoted to the truth[6]

It should be emphasized that these are traits of an ideal research worker, and not to be expected of the beginning student. Many other traits could be added to the list, but these are probably the most important.

The Scientific Method

The steps in the approach to and performance of a research problem have been stated as follows:

1. Definition of the problem
2. Gathering known facts related to the problem
3. Classification and organization of data

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[6] George H. Kelker, <u>Research Methods for the Beginner</u> (Logan, 1956), p. 3.

4. Data tested mathematically, whenever possible, and results checked

5. Generalizations or conclusions formulated from the study

This, of course, is just a resumé of the steps of the scientific or problem-solving method. The steps in the scientific method have also been expressed in this way:

1. Find the facts
2. Filter the facts
3. Focus the facts
4. Face the facts
5. Follow the facts[7]

Stated either way it is clear that the study will be a systematic search for and assimilation of facts.

The scientist is always haunted by his acute awareness of the limited information he has. He never knows everything about anything, therefore his explanations and answers are phrased in terms of certain data, which themselves are limited in precision. A complication of the problem is the fact that future findings and data may considerably change earlier findings. Nevertheless, the high school student should have no fear of what the future may bring. Scientific work is a never ending process; it can always be extended and improved.

Choosing a Project

The student just beginning to do research is often bewildered by the huge number of problems that could be chosen

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[7]Ibid., p. 100.

for study, with the result that he doesn't know just what he should choose for a problem. The confusion may be due to the fact that the student has so many problems that he wants to work on all of them or he may just have the urge to be a "researcher", but he doesn't know how to start. Below are listed some guides in selecting a research project:

1. The student should take a mental inventory of that field of knowledge in which he is most interested.

2. Distinction should be made between what is definitely known and what is unknown about the chosen field.

3. Consult an expert in the chosen field of study. This should help clarify the problem and should be mentally stimulating to the student.

4. Read widely in relation to the general field. This is probably the key to a successful research project, not only at the high school level, but at any level.

5. Select a part of the field which will yield the best possibilities for research problems.

6. Timeliness and importance of the problem often aids in securing help from many sources.

7. Do not choose a problem which is not consistent with the preliminary survey of the field of study.

8. Never pose a problem in such a way as to suggest that you are trying to prove something. This is <u>not</u> what a research worker is trying to do.

9. Never attempt to solve a research problem by the trial and error method.

Choosing a title for the project is important if the final report is to be published, and in many cases this will be done. After the problem has been selected, then the student should choose a clear, concise, and complete title for the study and subsequent report. Don't try to be too generalized or all-inclusive with the title. Be sure that the title is clear and does not convey some unintended meaning to the reader. If scientific names are included in the title, be sure that they are correct and that they contain the name of the taxonomist.

Obtaining Information and Material

Obtaining information from literature is probably the chief means of carrying on most research projects. The student should read literature carefully to see if his work is original or if it parallels or is related to other efforts in that field. In many cases, research will be a continuation of other research projects in a given field. The high school student is likely to have difficulty in securing adequate literature and reference material unless he has access to a large library or other sources of information. This difficulty can be overcome in part by contacting people who can supply information or can suggest other sources of information. Much of the needed material and literature should be obtained before starting the project, if possible. This will eliminate some of the difficulties of securing material after the project is underway.

In regard to reading literature, the student should take careful, systematic notes over material which is relevant to the project. Notes should include: author, title, copyright date, publishing company, pages, tables, figures, charts, index, bibliography and cost. At first glance, this would seem unnecessary, but for quick easy reference many of the things listed above are necessary. Also, if the material is used as a reference, many of the above items will be needed in the footnotes. References serve four main purposes in a report. These are:

1. To give credit to the author of a method, theory, process or other innovation

2. To tell the reader where to find more information on the subject under discussion

3. To define the basis of published works on which inferences are drawn

4. To cite an authority as the premise to a certain line of reasoning.[8]

In examining a possible reference book, scan the table of contents or page headings to determine whether or not it contains material that you can use. If so, read the parts directly related to the project. Read critically. If the author is in error, a note should be made of this fact if there is certainty that the information is wrong. In note preparation always follow the correct rules of grammar and punctuation.

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[8] Ibid., p. 19.

The presentation of data in the form of tables and graphs is something that most students will eventually come in contact with. The student should keep in mind the fact that tables should be self-explanatory with appropriate labels showing how much, when, and where. Items in tables may be arranged in many ways, therefore the student must decide the logical way to present the data. The use of charts may also be included here. Statistical charts are of many and varied designs. A neat orderly chart is a complement to almost any type of project, however, the project should not be overshadowed by elaborate charts and graphs. Charts should also be self-explanatory. Also included under the heading of charts are pictures, maps, diagrams and graphs.

Conclusions, recommendations and a summary are important components of many, but not all, reports. Conclusions usually include facts revealed by the study with little elaboration. Again one must remember that a research worker is not trying to prove anything, merely looking for answers to certain questions. Recommendations do not usually belong in a paper on pure research, but they are appropriate in some studies. The summary is a brief review or abstract of the entire report. This should include the pertinent ideas revealed by the study and possibly suggestions for future study.

Fundamental Tools of Research

To summarize, the student should be in command of these fundamental tools of scientific research.

1. Language
    A. Vocabulary
    B. Grammar

2. Mathematics
    A. Arithmetic
    B. Algebra
    C. Geometry

3. Logic
    A. Propositions
    B. Facts
    C. Hypotheses

4. Ethics
    A. Integrity
    B. Sincerity
    C. Humility
    D. Thoroughness

5. Knowledge
    A. Basic or fundamental
    B. Professional or advanced
    C. Related fields

Many of these traits will be developed by the student during the time spent working on the project.

Any student research project, no matter how simple, affords the opportunity of learning true research methods. It involves planning the project, reading about it, development of controls and elimination of all possible errors and finally, drawing conclusions. Even if the whole project is a total loss, as far as scientific progress and achievement is concerned, it certainly will not be a complete loss from the student's viewpoint, because he will have learned many of the basic skills of true research.

CHAPTER III

THE LABORATORY AND ITS RELATION TO ENRICHMENT PROJECTS IN HIGH SCHOOL BIOLOGY

Value of Laboratory Work in Biology

Almost without exception, laboratory work is accepted as a desirable teaching method by high school biology teachers. There is probably no one method subscribed to more in the nation today than the laboratory method of teaching. There are certain distinct purposes and advantages of laboratory work which have been grouped as follows:

1. Laboratory work provides a basis for the pupil's learning and is itself a way of learning through the medium of self-activity.

2. Laboratory work provides for the development of laboratory techniques in biology.

3. Laboratory work offers opportunity for training in scientific methods and makes available a medium whereby students may determine, experimentally or otherwise, the solutions to their own problems.

4. Laboratory work also aids the student by clarifying facts not easily visualized without concrete illustration.

> 5. The data and principles of biology are made clearer and more meaningful through the medium of laboratory work.[9]

These five statements of purpose in the biology laboratory are stated quite clearly, so no further explanation is deemed necessary. The advantages of laboratory work just listed apply to regular biology classes and also to gifted students in high school biology. Item number two in the above list is very important to the future college student. Good skills and techniques are important in biology, as well as other sciences, such as chemistry and physics, where glass and equipment breakage is sometimes very costly and endangers the student as well. It is imperative that the student learn good laboratory techniques before entering college, if possible.

Repetition of material that is already familiar to the student is one sure way of creating boredom, and this is very likely to happen with gifted students who already have sufficient knowledge of fundamentals. What is known is no longer challenging, but that which is mysterious and unknown holds a fascination for the gifted individual. The teacher should see that a scientific atmosphere is created for the enrichment projects, not a "Buck Rogers" atmosphere, but a simple, straightforward approach to challenging problems.

One of the most common laboratory faults in high school biology is the tendency for the teacher to do too much work for the students. The teacher should be available to guide and

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[9] Cole, p. 94.

lead the gifted students, but not to drive them. This is <u>their</u> project and should be so considered. The teacher should see that material is made available for the gifted students for use with their projects, such as special library reference books, industrial material and laboratory equipment. The teacher, of course, must exercise his own judgment in regard to what and how much laboratory material should be made available to the students. In general, the projects will require only inexpensive equipment, much of which can be made or purchased cheaply by the student.

Necessary Equipment and Storage Space

In general, a good high school biology laboratory should be equipped with water, gas, and electricity and, of course, adequate tables and seating facilities. Adequate space is desirable, but often lacking, for movement of students in the laboratory and especially for storage. Storage space is important for the projects after they are underway. Vandalism in a biology laboratory may prove costly, as valuable equipment and projects may be damaged. It is desirable that the unfinished projects be stored in a safe place, preferrably locked, if left at school. Of course, if the project is at home, then the student will have to provide for the safekeeping of the project. In some schools teachers have set aside space in the laboratory for students to work on their projects and have also provided them with storage space. A book shelf, book case or cabinet for science reference books in the same room is a welcome convenience for the students.[10]

Drawing, Workbooks, and Manuals

Drawing as an aid in these enrichment projects should be entirely optional with the student. Usually, too much emphasis is placed on the art of the drawing and not enough on the subject matter, which is more vital and important than any other phase.[11] Posters, charts, models, and other devices might possibly be used to good advantage if the project is to be displayed in the school, publicly, or at science fairs.

Dissection in a small high school biology laboratory is a rather rare occurrence, due to the prohibitive cost of most preserved materials. Dissection will often be important to a student engaged in biological work and therefore, a good dissecting kit is a necessity. These may be purchased as complete kits or may be assembled by the student from various household and toilet articles. For the student's future use, however, a good commercial dissecting kit is probably best for general use.

Workbooks, outlines, and manuals probably are good as guides in general laboratory work, but dependence on these will destroy the purpose of an enrichment project entirely. These materials do have a purpose, but they are not ends in themselves, but means to an end. Biology workbooks, as far as enrichment

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[10] E. Morholt, P. F. Brandwein, and A. Joseph, _A Source-Book for the Biological Sciences_ (New York, 1958), p. 428.

[11] Francis D. Curtiss, _A Digest of Investigations in the Teaching of Science_ (Philadelphia, 1926), p. 38.

projects are concerned, are not as essential as they may be for ordinary classroom use. These workbooks may suggest projects that can be used by the gifted students. "Most teachers use workbooks for a cook-book type of work in biology characterized by a slavish following of printed directions."[12] This is definitely not what is done with the enrichment projects.

Student notebooks are favored by some biology teachers and discredited by others. However, in the field of research, note taking is absolutely essential and an integral part of the research. This leaves no choice, but to take careful, systematic notes and keep them arranged so that they are available for immediate reference.

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[12] Victor H. Noll, _The Teaching of Science in the Elementary and Secondary Grades_ (New York, 1939), p. 53.

CHAPTER IV

PROJECTS IN HUMAN ANATOMY AND PHYSIOLOGY

Projects in human anatomy and physiology will probably evoke as much or more response than any other area. Humans, of course, are interested in their own bodies and experiments and projects in this field will probably prove to be quite interesting.

Blood Physiology Projects

Listed below are some facts about normal human blood that students may find useful in projects related to this field:

Coagulation time	3-5 minutes
Hemoglobin	90-100%
Red Blood cells	4.5-5.5 million/cc.
White blood cells	
Polymorphonuclear lymphocytes	60-70 %
Small lymphocytes	20-25 %
Large lymphocytes	5-8 %
Eosinophils	1-2 %
Basophils	1-2 %
Platelets	300,000/cc.[13]

A few precautions should be observed by the student when taking samples of blood. First, cleanse the area with alcohol that is to be pricked. The usual place to obtain

[13]Morholt, Brandwein, and Joseph, p. 76.

blood is from the tip of the finger, since this area is richly supplied with blood vessels. Sterilize the lancet, pin, or whatever is to be used, by passing it through a flame and then dipping it in alcohol. Sterilized needles wrapped in individual packets may be purchased from various biological supply houses if desired. After the blood is obtained, cleanse the area again with alcohol and apply a piece of sterile cotton. This sounds like a lot of unnecessary work to get blood, but serious complications may result from careless and hazardous practices.

Blood counts may appeal to some students. For this type of project a micropipette, a counting slide, a solution for diluting the blood and a microscope are the essential tools. To keep blood from clotting, 0.1 gm. of potassium or sodium oxalate ($K_2C_2O_4$ or $Na_2C_2O_4$) for every 100 cc. of blood is usually sufficient.

The hemoglobin content of human blood is another area that may yield worthwhile projects. A commonly used method for determining hemoglobin content is the Tallquist color scale method, which utilizes strips of red paper which are matched against white strips, which are used to absorb a drop of blood from a person being tested. Comparison of this strip with strips of known concentration, or standardized strips, gives the approximate hemoglobin content of the blood.[14]

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[14]Ibid., p. 77.

Blood typing is somewhat expensive due to the cost of the serums needed, but if these are available to the student in the school laboratory or if he wishes to purchase them himself, then possibly this could be used as a project. Another way to obtain these serums is to contact state civil defense headquarters. Most can supply the serum for training purposes and will probably cooperate to the fullest extent with students interested in this field. Other materials needed for blood typing are: common blank slides, a glass-marking crayon, alcohol, lancet, sterile cotton and toothpicks. This project could be enlarged, so as to type the blood of an entire class or an entire school. In fact, this would be a valuable service in case of an emergency. Some schools now offer this service to their pupils. A "dog tag" is sometimes worn or carried by certain students where a transfusion is needed quickly. Here is a summary of the major blood groups and the chemical substances they contain.

Blood Group	in red blood cells	in plasma
A	"A" chemical	Anti-B
B	"B" chemical	Anti-A
AB	"A" and "B" chemical	No anti-serum present
O	No chemical present	Both anti-A and anti-B serum present[15]

More complete information in regard to blood typing can be found in most human anatomy and physiology textbooks.

An interesting topic for a research project is the comparison of the color of oxygenated blood and de-oxygenated

[15] Ibid., p. 80.

blood. Several pints of blood will be needed for this project. A slaughterhouse or butcher shop is the logical place to secure the necessary blood. After the fresh blood is obtained, one part of sodium oxalate should be added to nine parts of blood to keep it from clotting. Other materials needed for this project are: two 250 ml. Erlenmeyer flasks; two 2-hole rubber stoppers (to fit flasks); rubber tubing; glass tubing and two generator flasks. One of the generating flasks should be used to produce oxygen and the other to produce carbon dioxide. These gases are bubbled through the blood, then the connections are reversed to observe what happens when oxygen is added to de-oxygenated blood and, vice versa. This at first glance, may seem to be too simple for the gifted student, but a great deal may be learned from this project. For instance, What chemicals are used to produce oxygen (O_2) and carbon dioxide (CO_2) for the experiment? Why does de-oxygenated blood become red when oxygen is added? A study of the complex ions formed within the red blood cells can make this project very meaningful to the student.

Oxidation in Muscle Tissue

Another project may be built around oxidation which occurs in muscle tissue in the human body. In order to illustrate this, the following materials are needed: one small frog, dissecting equipment, methylene blue in a 0.7 percent sodium chloride solution, blank slide, cover slip, and vaseline. This experiment is easily carried out by the student. Two muscles are dissected out of the back legs of the frog. These are stained with the methylene blue solution and then strips of these muscles are placed on the blank slide. The cover slip is then applied and a layer of vaseline around the edge to seal out the air. In a short while the blue color disappears due to the reduction which takes place in the muscle tissue. If the cover slip is removed the blue color returns. An interesting project can be built around this idea of oxidation-reduction in living tissues.[16]

Vitamin Deficiency Projects

Another field that might interest students is in the area of vitamin and mineral deficiencies. Since it is not practical to take humans and use them as test or experimental animals, rats and chickens can be substituted in many projects of this type and inferences drawn as to what would happen to humans under similar circumstances. The experiment listed below shows the effects of vitamin B_1 deficiency. A list of materials that will be needed for the experiment are as follows: six half-grown rats, enough cages to keep the experimental and control animals separate (at least two cages), balance scales, a marking pencil, and record sheets. Be sure that the rats are young, healthy and of as near the same weight and age as possible. Another factor to be considered is the sex of the rats. If they are of breeding age or nearing breeding age (six to seven weeks) do not mix males with females, but keep

[16] Ibid., p. 101.

both experimental and control groups of one sex, either all males or all females. To further clarify, do not make the control group all males and the experimental group all females, or vice versa. This would seriously affect the validity of the experiment, due to the tendency of most male mammals to be larger at maturity than the females of the same species. Keep a weight record of each animal each day from the beginning of the experiment. Mark each rat and each cage with the marking pencil and do not allow the controls and experimentals to become mixed up at any time. Keep the cages clean and supplied with fresh water at all times. The rats must not be handled or played with by unauthorized students. The foolishness and results of this are easily realized by most students. Handling the rats with heavy leather gloves is recommended. Any significant changes in weight should be noted on the day they occur. The deficient diet is as follows:

White flour	150 gm.
Butter (or oleomargarine)	30 gm.
Dried beef	15 gm.
Salt (NaCl)	3 gm.
Slaked lime (CaO)	3 gm.
Starch	100 gm.

This makes approximately three hundred grams of food, which should last the six rats several days. Always feed just a little more than will be eaten each day. Clean the feeding dishes regularly. Weigh the animals each day (or every two days). Look for the first indications of vitamin B_1 deficiency. Plot a weight curve for the experimentals and also a weight curve for the controls and compare the results. To the above diet, add any one of the following: ground wheat, 10 gm., or

30 gm. of middlings or wheat bran. This is to be fed to the positive controls. Any one of the three substances mentioned above will supply a sufficient amount of vitamin B_1 for the controls. When the animals that are fed the vitamin B_1 deficient diet have shown definite signs of the deficiency, start feeding them an addition of the wheat or bran to restore them to normal, and keep a complete record of the results.[17]

Mineral Deficiency Projects

A mineral deficiency experiment is listed below, along with a recommended diet. Select six young chicks or rats about twenty-five days old. Use half of the group for controls and half for experimentals. To the experimental group feed the following diet:

Flour	129 gm.
Dried beef	51 gm.
Butter	18 gm.
Lard	18 gm.
Dried potatoes	36 gm.
Sugar ($C_{12}H_{22}O_{11}$)	45 gm.
Table Salt (NaCl)	3 gm.

To the diet of the controls add bone meal (about 30 gm.). The above diet is fairly well balanced in most respects and there is little evidence externally for some time except weakness in the limbs and some effect upon stature. As soon as the observer is certain that the experimental animals have a marked defect, select the one which is most noticeably deficient and one of the controls, which has had additional bone meal and appears normal, and kill both animals. Thoroughly clean the

[17] David F. Miller and Glenn W. Blaydes, Methods and Materials for Teaching Biological Sciences (New York, 1938), p. 315.

skeletons and assemble the bones in an approximate position for comparison. Compare the skeletal weights of the two. The most marked results of this test, of course, are in the skeletons. If chicks are used in this experiment, thoroughly grind and mix all ingredients. Feed just what will be eaten and keep the excess in a refrigerator or prepare fresh food every second day. It should be remembered that this experiment is one dealing with mineral deficiency and not vitamin deficiency.[18]

Preparation of Skeletons

The preceeding experiment could be further enlarged to include the preparation of complete skeletons of the two animals. Detailed information is available from most biological supply houses for this type of work, but in general the steps are as follows:

1. Cut away as much flesh as possible and allow the bones to dry.
2. Scrape the bones clean, removing cartilage, tendons, etc., and place in an ammonia bath for several days. (NH_4OH solution)
3. Bleach the skeleton in a sodium hypochlorite ($NaHSO_3$) solution and allow it to dry.
4. Treat the skeleton with carbon tetrachloride (CCl_4), so the oils will be removed from the bones.[19]

All of the work listed above should be done under a draft hood or in a well ventilated room to avoid the danger

[18] Ibid., p. 315.

[19] Morholt, Brandwein, and Joseph, p. 410.

of poisonous fumes. After the skeleton is bleached and dried, then the real job of articulating the skeleton begins.

Enzyme Projects

A challenging experiment is this one in the field of enzyme research. Obtain from a butcher shop a sheep or pig pancreas with all possible fat removed and grind this in a meat chopper. Put the ground pancreas in a 500 cc. flask, add 150 cc. of 30 percent ethyl alcohol (C_2H_5OH) and let it stand for 24 hours, shaking it occasionally. Strain and filter the alcoholic extract through cheesecloth. Begin to neutralize the filtrate with potassium hydroxide (KOH dissolved in water). Use litmus paper as an indicator. Near the endpoint (when the solution is almost neutral, pH 7) slow down, by using 0.5 percent sodium carbonate solution (Na_2CO_3) and continue until the endpoint is reached. The pancreatic juice extract may be added to hard-boiled egg white or albumin solution to test whether or not it has retained its potency.[20] Other projects somewhat similar to this one could be worked out using insectivorous plants and their enzymes. The venus fly-trap, pitcher plant and sundew are all good examples of insectivorous plants.

Standard Tests and Solutions

Several solutions are listed below along with methods of preparation. Many of these can be used in the projects listed in this report.

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[20] Ibid., p. 65.

Benedict's solution, used to test for sugar, as in urine, consists of the following materials:

Sodium or Potassium Citrate ($Na_3C_6H_5O_7$) or ($K_3C_6H_5O_7$)	173.0 gm.
Sodium Carbonate (Na_2CO_3)	200.0 gm.
Copper Sulfate ($CuSO_4$)	17.3 gm.

Dissolve the carbonate and citrate in 700 cc. of water, warm and then filter. Dissolve the copper sulfate in 100 cc. of water and then add slowly to the first solution, stirring constantly. Add enough distilled water to make one liter of solution.

Hayem's solution, used in diluting blood for blood counts, contains the following salts dissolved in 100 cc. of water:

Mercuric Chloride ($HgCl_2$)	.25 gm.
Sodium Sulfate (Na_2SO_4)	2.50 gm.
Sodium Chloride (NaCl)	.50 gm.

Limewater is sometimes used in the laboratory and is one of the most easily prepared solutions found in the laboratory. Add an excess of calcium oxide (CaO) to a container of distilled water. Shake or mix thoroughly and let stand, then filter off the clear solution. Keep this solution well stoppered to prevent the carbon dioxide (CO_2) in the atmosphere from reacting with the limewater to form the insoluble precipitate, calcium carbonate ($CaCO_3$).

Physiological saline solution, for cold blooded animals, is made by dissolving 0.7 gm. of sodium chloride in 100 cc. of distilled water. A similar solution for warm blooded animals is made by dissolving 0.9 gm. of sodium chloride in 100 cc. of distilled water.

Ringer's solution for mammalian tissue is made by dissolving the following salts in one liter (1000 cc.) of distilled water:

Potassium Chloride (KCl)	.42 gm.
Sodium Chloride (NaCl)	9.00 gm.
Calcium Chloride ($CaCl_2$)	.24 gm.
Sodium Bicarbonate ($NaHCO_3$)	.20 gm.

This is a mounting fluid for examination of living tissues.[21]

A few simple tests are also needed for much of the work in anatomy and physiology. Most of the tests are simple and require little equipment.

Starch Test. The test for starch consists of adding a few drops of an iodine solution to the substance to be tested for starch. A change in color from normal to blue-black indicates the presence of starch.

Sugar Test. The test for reducing sugars (glucose, fructose) consists of boiling 5 cc. of either Benedict's or Fehling's solution with a sample of the unknown in a test tube. If either of the simple sugars are present a series of color changes from green to yellow to orange will result.

Protein Test. The common test for proteins is called the xanthoproteic test. Concentrated nitric acid (HNO_3) is added to an unknown solution. If proteins are present, the solution will become yellow in color. As a further test, pour off the nitric acid and add a small amount of ammonium hydroxide (NH_4OH). The yellow color should change to deep orange.

Fats and Oils Test. One of the simplest tests is that for detecting the presence of fats and oils. Simply place some

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[21] Ibid., p. 265.

of the unknown substance on a piece of wrapping paper. If a translucent spot appears that does not evaporate quickly, this usually indicates the presence of an oily substance.

Water Test. The test for water is even more simple than that for fats and oils. Place the unknown substance in a pyrex test tube and heat gently. If droplets of moisture condense on the sides of the test tube, this is a positive test for water.

Minerals Test. Minerals may be tested for by heating an unknown substance in a pyrex test tube or an evaporating dish. If a whitish ash results, this indicates the presence of minerals and qualitative chemical tests may be used to identify these minerals.

CHAPTER V

PROJECTS IN BOTANY AND BACTERIOLOGY

There are many projects available in these two fields and one of the major reasons is because nature has provided us with an abundance of plant life, as well as animal life, which will be discussed in the next chapter. Approximately one-half of this chapter will be devoted to botany and the other half to bacteriology, although a complete report could be written on either, with scarcely any of the available material covered.

Botany probably should be classified as the most important branch of biology, since photosynthesis is one of the major functions. Without this remarkable process devised in nature, life long ago would have ceased to exist. Since this is the most important process on earth, this chapter should begin looking at some of the projects worthy of study in this area.

Extraction and Analysis of Chlorophyll

Prepare an alcohol solution of chlorophyll by heating a beaker of denatured ethyl alcohol (C_2H_5OH) with a small quantity of green leaves. Heat slowly and be careful not to ignite the alcohol in the beaker or the fumes above the beaker. This danger may be avoided by using a steam bath or an electric hotplate. After the chlorophyll has been extracted, allow the liquid to cool and pour the alcoholic extract into a large test tube. Pour off half of the solution in the test tube and replace with an equal quantity of benzene (C_6H_6). Shake the mixture well and allow it to stand. The two liquids will gradually separate, the benzene going to the top and the alcohol to the bottom. Which of the two solvents has extracted chlorophyll _a_ and _b_? Which has extracted carotin and xanthophyll? Another possibility for continuation of this project is the analysis and separation of chlorophyll _a_, chlorophyll _b_, carotin and xanthophyll, but this may possibly involve too much chemistry for even the better high school student. Chlorophyll solutions may also be analyzed by the paper chromotography method, which depends on the size, speed and movement of molecules. Instructions for this method of analysis may be found in a recent sourcebook for biological science[22] and in many modern chemistry textbooks.

Other projects involving photosynthesis may be built around the ideas of: release of oxygen during photosynthesis, effect of different colors of light on photosynthesis, and the effect of carbon dioxide on photosynthesis.

Plant Physiology and Radioactive Compounds

The use of radioactive compounds in the study of transportation and diffusion in plants is coming into wide usage in

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[22] Morholt, Brandwein, and Joseph, p. 17.

laboratories today. Much of the equipment for this type of work may be lacking in many high school laboratories, so no attempt will be made to outline specific projects in this area. Uranium nitrate ($UO_2[NO_3]_2$) can be purchased from chemical supply houses and is an excellent "tracer" in this field. A 10 percent solution may be added to plants and in a very few hours a Geiger Counter should reveal the presence of uranium in the leaves. X-ray or ordinary photographic film may then be used to make radioautographs of the radioactive leaves. Lines should appear on the negatives, corresponding to the veins in the leaf which contain the uranium. The United States Atomic Energy Commission can and will supply certain radioactive chemicals to high schools. For more information, write to: U. S. Atomic Energy Commission, Washington, D. C.[23] It probably should be stated that these compounds are harmless if the precautions are observed that are included with the radioactive salts. Ten micro curies are available to all biology teachers at the Oak Ridge Center.

Release of Carbon Dioxide During Seed Germination

A project that is somewhat simpler than the preceeding ones is that of testing for carbon dioxide released by seeds during germination. There are several possible ways to do this experiment, but probably the simplest way is to fill a jar or bottle one-third full of soaked seeds, such as beans, peas, corn, oats, wheat or barley. Connect this jar or bottle to

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[23] Ibid., p. 45.

one approximately two-thirds full of limewater by means of glass tubing through one-hole rubber stoppers. Arrange the delivery tube so that the carbon dioxide evolved must pass up through the limewater. After a few days the limewater should become cloudy and then a little later a precipitate should form. What is the chemical compound that is being precipitated? Evidently, this is a rather simple experiment, but perhaps a good student can add something that will make it more challenging, such as measuring the amount of carbon dioxide given off by a certain volume or weight of germinating seeds.

Heat of Germination Projects

Another idea, similar to the one above, is testing the amount of heat given off by germinating seeds enclosed in a vacuum bottle. An interesting project could be worked out by using the same weight of different seeds and keeping an hourly record of temperature changes. Plotting a curve for different seeds should reveal whether or not there is any appreciable difference in the heat of germination of different seeds. Materials needed for the above project are: a 0°-120° centigrade thermometer, vacuum bottle, one-hole rubber stopper (to fit vacuum bottle), seeds, record sheets for recording temperature changes, and graph paper.

Seed Viability Test

A project that may be of particular interest to students who live on farms or are interested in agriculture is the seed viability test. In the past the "rag-doll" method of testing was used, whereby seeds were wrapped in a moist towel or cloth and allowed to germinate. Now, however, there is a much quicker method for determining seed viability by using 2, 3, 5-triphenyl tetrazoleum chloride. This reduces the test time to 24 hours or less, compared to 10 days for the "rag-doll" method. The procedure: Soak 100 seeds in water for about 18 hours, then germinate 50 of these seeds on moist filter paper in petri dishes and then add 0.1 to 1.0 percent tetrazoleum chloride until the seeds are just covered. Place these halves in the dark for 2 to 4 hours at a temperature of 20° centigrade. As germination proceeds the tetrazoleum chloride is changed to an insoluble red dye. The viable seeds may be identified by the staining of at least half of the scutellum, all of the shoot, and all of the radicle. As a follow-up and as a control, check the other seeds that have been allowed to germinate and compare the results of each test.[24]

Hydroponics and Nutrient Solutions

Hydroponics is another area that may yield suitable projects for botanical work. This type of soil-less farming will probably appeal to students, since they are accustomed to seeing plants growing only in soil. Several methods of preparing the equipment and plants are possible and there are also many different nutrient solutions that have been prescribed by

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[24] Ibid., p. 109.

different workers in this field. It would be useless to try and cover all the possible projects, so only one experiment and two nutrient solutions will be included in this report. One of the nutrient solutions supplies trace minerals which are thought to be absolutely necessary by most botanists. One common method is to prepare a bed of glass wool in a shallow pan made from paraffin-covered or asphalt-covered wire mesh. Seeds are embedded in this and are then placed over the nutrient solution in a suitable container. As the seeds germinate, the roots will grow down into the solution through the wire mesh. The mesh will give some protection and support to the plants, but a layer of sterile sand can be placed in the bottom of the nutrient container if desired.

Knop's solution is used as an example of a nutrient solution.[25] Add the following chemicals to one liter of distilled water.

Calcium Nitrate ($Ca[NO_3]_2$)	0.8 gm.
Potassium Nitrate (KNO_3)	0.2 gm.
Potassium Phosphate (KH_2PO_4)	0.2 gm.
Magnesium Sulfate ($MgSO_4$)	0.2 gm.
Ferric Phosphate ($FePO_4$)	trace

Haas' and Reed's "A to Z" solution is included, since it fulfills most of the trace mineral requirements of plants. Weigh out the following chemicals and add them to one liter of distilled water.[26]

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[25]Ibid., p. 113.

[26]Ibid.

Boric Acid (H_3BO_3)	0.6 gm.
Manganese Chloride ($MnCl_2$)	0.4 gm.
Zinc Sulfate ($ZnSO_4$)	0.05 gm.
Copper Sulfate ($CuSO_4$)	0.05 gm.
Aluminum Sulfate ($Al_2[SO_4]_3$)	0.05 gm.
Potassium Iodide (KI)	0.03 gm.
Potassium Bromide (KBr)	0.03 gm.
Cobalt Nitrate ($Co[NO_3]_2$)	0.03 gm.
Lithium Chloride (LiCl)	0.03 gm.
Titanium Dioxide (TiO_2)	0.03 gm.
Stannous Chloride ($SnCl_2$)	0.03 gm.
Nickel Sulfate ($NiSO_4$)	0.03 gm.

These two nutrient solutions are not necessarily the best ones, but they should do the job in most cases. The pH of the nutrient solutions should be checked occasionally. Most plants grow best in the pH range of 4.5 to 6.5 (acid). Variations in this experiment can be brought about by changing the pH of the solution or by having entirely different groups of like plants in different solutions. Tolerance levels may be established for different plants by carefully regulating the pH of the solutions. A kit for conducting these experiments is available from Science Service, 1719 N. Street, N. W. Washington D. C., at a cost of $4.95.[27]

Auxins and Suggested Experiments

This is the last section for botany then bacteriology will follow. No better topic could be chosen for a research project than growth hormones or auxins. Much work has been done in this area in the last few years and much work will be done in the future.

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[27] Unesco Source Book for Science Teaching (Amsterdam, 1956), p. 50.

In 1880, Charles and Francis Darwin showed that a substance is transmitted from the top of a stem to the basal regions and in 1910 Boysen-Jensen proved that this was a chemical substance, since it could not pass through a mica barrier. On the basis of this work by the Darwins and Boysen-Jensen, as well as others, the study of auxins or plant hormones has arisen.

An interesting original study was made in 1926 by F. W. Went on the collection of plant hormones in agar blocks. In the original experiment, Went removed the tips of oat seedlings and placed these in contact with small agar blocks. He then observed that if these agar blocks were placed on the original decapitated shoots the usual curvatures were observed.[28]

Several growth promoting substances have been isolated and are available from chemical supply houses. Among the better known auxins are: Indoleacetic acid, beta-indolebutyric acid and alpha-naphthaleneacetic acid. 2, 4-D is available as a weed killer at most drugstores.

Original projects in this field could be developed by students by obtaining auxins that have been isolated and purified by chemical supply houses. All sorts of projects could be developed, such as the effect of auxins on fruit drop, their influence on the shedding of leaves, the effect on cuttings, the effect on stems, and the effect on seeds. This is an interesting field and one in which much research is needed. Why do

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[28] Mordecai L. Gabriel and Seymour Fogel, Great Experiments in Biology (Englewood Cliffs, 1955), p. 148.

auxins affect different types of plant tissues in different ways? Why do auxins behave as they do? Why do some of the auxins cause plants to absorb water against an osmotic gradient? These are just a few of the questions about auxins that have not been answered completely by the botanist.

Introduction to Bacteriology

Bacteriology is a wide-open field as far as research and study is concerned. Ever since Leuwenhoek discovered bacteria in 1683, man has tried to tame these "wild little beasts" of the plant kingdom and to see what makes them tick. A great deal has been learned, but a greater amount remains to be learned about these strange little plants. Many men have contributed much to this field, but Leuwenhoek, Schroeder, Dusch, Lister, Koch, and many others will be long remembered for their outstanding contributions and research.

Why study bacteria? First of all, because bacteria cause many serious and crippling diseases in man; second, they cause many diseases in cultivated plants; third, they cause the spoilage of large quantities of foodstuffs; fourth, they cause many diseases of domesticated animals and fifth, denitrifying bacteria break down nitrates and deplete the nitrogen content of soils. On the other side of the ledger, we find some of their useful characteristics, which far outweigh their damaging characteristics. Some of these are: the manufacture of cheese, the tanning of leather, decomposition of proteins, fats and carbohydrates and fixation of nitrogen.

Improvisation of Bacteriology Equipment

One of the first questions that comes to the mind of a student interested in this field is: How much equipment will I need? Luckily, most of the needed equipment can be improvised if necessary. One of the drawbacks, as far as student research is concerned, is the lack of equipment in the high school laboratory. If an oil immersion microscope isn't available and certain necessary stains, then the student will have to confine the projects to areas in which visible colonies are produced. If the student can arrange to use hospital or clinic laboratory facilities then this would alleviate this problem. Basically, the only equipment students will need is: pyrex test tubes, petri dishes, culture media, and an autoclave.

Petri dishes may be improvised by cutting heavy aluminum foil into six inch squares and then molding one of these squares inside a petri dish. To make the cover, mold another aluminum square around the outside of the petri dish. In both cases, mold the foil tightly with the fingers and then trim off the excess foil around the top with scissors or shears. These aluminum petri dishes have several advantages over the normal glass petri dishes, such as: no breakage, inexpensive, withstand sterilization in an autoclave or hot air oven, may be cleaned and reused many times and they can easily be made by students.[29]

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[29] David L. Fagle, "Another Use for Aluminum Foil," *American Biology Teacher*, XVIII (1956), 196.

An important item that could be turned into a project is the construction of an incubator for use in bacteriology experiments. Several methods and ideas are available, such as constructing an incubator from an old refrigerator cabinet or from a five gallon can. The necessary materials are listed below and the student's own ideas will determine how the incubator will be constructed. The student will need: a heavy metal five gallon can, electrical wire, two lamp sockets, one plug, two light bulbs, a suitable stand, a centigrade thermometer, a bi-metal strip thermostat.[30] This will be a useful piece of equipment in the classroom and especially useful to the student interested in doing research in bacteriology.

Nutrient Media for Bacteria

Nutrient broth can be purchased in dehydrated form or can be made from the following ingredients:

Peptone	5 gm.
Beef extract	3 gm.
Salt (NaCl)	5 gm.
Water	1000 ml.

If a solid culture medium is desired, nutrient agar can be prepared by adding 15 gm. of agar to the solution above. This medium liquefies at about 100° centigrade, but does not solidify until cooled to about 45° centigrade. The culture materials listed above may be obtained from Difco Laboratories, Detroit 1, Michigan, or from Baltimore Biological Laboratories,

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[30] David L. Fagle, "Improvisation of Bacteriological Equipment," <u>American Biology Teacher</u>, XX (1958), 252.

1640 Gorsuch Avenue, Baltimore, Maryland.[31] If a catalog is desired write to either of the two sources mentioned above. If necessary, other materials such as sterilized milk, boullion cubes, potatoes, carrots, plain gelatin and oatmeal may be used as culture media, but for observation and study the two previous media are best.

Sterilization of Equipment

An important fact to remember in bacteriology experiments is the fact that all work must be done under sterile conditions. Contamination of a plate can cause poor or misleading results. Glassware, such as glass rods, test tubes and petri dishes may be sterilized by heating three to four hours in an oven at 340° Fahrenheit. Do not try to sterilize rubber, cotton or plastic goods in the oven at this temperature as charring will result. Glassware should be wrapped in heavy paper before sterilization. If the package is wrapped and sealed securely the enclosed material should remain sterile for quite some time. Many sterile materials can be purchased at drugstores, such as cotton, cotton swabs, gauze, and other materials. Culture media may be sterilized by heating at a temperature of 120° centigrade for 15-20 minutes. This may be done in an autoclave or ordinary pressure cooker.

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[31] W. R. Lockhart, "Experiments in Bacteriology for High School Science Classes" (unpub. leaflet, Iowa State College), p. 1.

Obtaining Pure Cultures of Bacteria

Pure bacterial cultures may be obtained from many colleges and universities free of charge or from biological supply houses. It should be noted that pathogenic bacteria should not be used by the high school student and in many states this is prohibited by law. Some of the available sources of bacteria are: water, air, soil, and milk. Probably the simplest way to obtain bacteria is from decaying organic matter. Pure cultures may be obtained from soil by adding a small quantity of soil to a small quantity of water. Using platinum or nichrome loops, streak some of the liquid on a nutrient agar plate and allow this to incubate. After small colonies have formed on the plate, transfer some of the bacteria from a colony to another plate and allow this to incubate. This process may have to be repeated several times before a pure culture is obtained.

Bacteriology Projects

In doing research in bacteriology, the student may wish to study bacteria from the throat and mouth of humans. A blood agar plate is needed for this project and can be made by adding 5 cc. of citrated blood to 95 cc. of nutrient agar. Allow the blood agar to cool to about 50° centigrade, then pour into a sterile petri dish, then quickly replace the petri dish cover. After the agar hardens, swab the throat with sterile cotton and touch lightly to the blood agar. Replace the cover and allow this plate to incubate for 16-32 hours in a warm place. In some cases there should be evidence of hemolysis (breakdown of red blood cells). What causes hemolysis? Why do some bacteria grow on blood agar and not on nutrient agar? At what temperature do throat and mouth bacteria grow best? These are all questions that can be woven into a research project of this nature.

Bacterial genetics is a field that is relatively new and unexplored. In this type of work, it is possible to work with large numbers of organisms that would be impossible in other fields of biology. Spontaneous mutation in bacteria is an excellent area for study. All types of mutations have been observed, such as the type of colonies formed on agar, the color of colonies, ability to synthesize certain materials, resistance to antibiotics, resistance to ultraviolet light and resistance to bacteriophages. These mutations can be induced by various mutagens. Some of these are: x-rays, ultraviolet rays, gamma rays and chemicals. Acriflavin, nitrogen-mustard gas, manganese chloride and various peroxides are all chemicals that cause bacterial mutations.

Other areas that need to be studied in bacterial genetics are: phenotypic lag, photo-recovery, transformation, transduction, recombination, and conjugation.

In short, bacteriology is a tremendous field with unlimited possibilities for research by high school students.

CHAPTER VI

PROJECTS IN ZOOLOGY

The abundance of animals makes this area one of the most favorable of all fields of biology for research projects. Almost everywhere we look there are animals--from the arctic regions to the tropics.

Animal Genetics

The field of genetics is especially challenging, since the future depends so much on improved plants and animals to feed a rapidly expanding population. Much of our plant and animal breeding is simple genetics. No longer is the breeding of plants and animals a hit or miss proposition. Genetics is a comparitively new and undeveloped science as far as biology is concerned. Gregor Mendel established some of the basic principles of genetics in the 1800's, but not until the 1900's did genetics gain widespread attention.

One of the annoying things about genetic research is the fact that many plants and animals do not reach maturity for several months or even years in some cases. As a result of this, reproduction is delayed for long periods of time. A good point for the student to remember in this field is not to select a plant or animal that requires a long period of time to mature and reproduce. Fruit flies of the genus Drosophila are widely used in the field of genetic research, mainly because of the two week life cycle, which makes for convenience in studying these little flies. These flies may be purchased from various biological supply houses. The distinctive feature of Drosophila is the presence of large chromosomes which can be studied under the microscope.

If a hospital or clinic is available, the student could study the effects of various dosages of x-rays on Drosophila. In addition, a high-power microscope and suitable stains will be needed in the study of the giant chromosomes.

The United States Atomic Energy Commission and other agencies are spending large sums of money each year on this and effects of other types of radiation. More detailed information can be obtained from: United States Atomic Energy Commission, Washington 25, D. C.[32] Free information concerning atomic radiation can also be obtained from the National Academy of Sciences, 2101 Constitution Ave., Washington 25, D. C.[33]

Raising and keeping fruit flies is relatively simple. Several stock cultures can be made, but one of the easiest to prepare is to dip a section of a banana in a yeast solution and place in a clean glass vial or jar. Soft grapes, plums, apples, yeast and fermenting solutions are all good sources of

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[32] Morholt, Brandwein, and Joseph, p. 477.

[33] Ibid., p. 476.

food for fruit flies and also serve to attract fruit flies in season. Another culture medium is the cornmeal-molasses-rolled oats mixture. This is prepared by mixing together the following ingredients: 73 cc. of water, 11 cc. of molasses or syrup, 15 gm. of cornmeal and 2 gm. of uncooked rolled oats. Cook this mixture until a thick viscous solution is formed. Agar can be added if a somewhat thicker medium is desired.

Guinea pigs, tropical fish, and white rats are also adaptable for genetic research and observation.

Digestion and Enzyme Projects

Digestion in animals can be studied, as well as the action of specific enzymes. An interesting project related to the digestion of proteins by pepsin can be carried out in the following manner or may be modified as the student sees fit. The material needed: hard-boiled egg white, eight test tubes, labels for test tubes, 100 cc. of distilled water, 100 cc. of 0.5 percent commercial pepsin suspension, and 50 cc. of 0.2 percent hydrochloric acid (HCl) solution. Label the test tubes and proceed as follows: (1) chop the egg white and add equal amounts to each of the eight test tubes; (2) in two test tubes add 10 cc. of water; (3) in two test tubes add 10 cc. of the commercial pepsin suspension; (4) in two more test tubes add 10 cc. of the hydrochloric acid solution; (5) in the last two test tubes add 10 cc. of the pepsin suspension and two drops of the hydrochloric acid solution, which will give a solution somewhat similar to gastric juice. Place all the test tubes in an incubator or water bath at a temperature of 37-40° centigrade for a period of 24 hours. Examine the tubes and observe in which tubes digestion has taken place. How does temperature affect the digestive process? How does hydrochloric acid affect the reaction? How does hydrochloric acid affect the digestive process? How does a change in pH from acidic to basic affect the reaction? These are just a few of the questions that can be related to this project.

Digestion of fat by lipase in the small intestine can be demonstrated by the following project. The material needed: three test tubes, 50 cc. of distilled water, 5 cc. of olive oil, 10 cc. of ordinary soap solution, 100 cc. of artificial intestinal juice. The artificial intestinal juice can be prepared by adding the following chemicals to 100 cc. of distilled water.

Pancreatin	1 gm.
Calcium Chloride ($CaCl_2$) (1% sol.)	1 cc.
Potassium Biphosphate (K_2HPO_4) (0.2 M solution)	25 cc.
Sodium hydroxide (NaOH) (0.2 M solution)	11.8 cc.

The procedure for the experiment is as follows: (a) add 10 cc. of water to each of the three test tubes along with five drops of olive oil; (b) to two of these tubes add 2 cc. of the soap solution; (c) add 5 cc. of the artificial intestinal juice to one of the test tubes containing the soap solution and 5 cc. to the one tube not containing the soap solution. If carried out in this manner we have three different solutions. Check the pH of the three solutions and be sure that they are all neutral. The solutions may be heated in a water bath to observe the effect of temperature on the enzyme, lipase or they may be cooled to see if this has any effect on enzyme action. Other variations are also possible, such as changing the pH from neutral to either basic or acidic.

Adrenalin and its Effect on the Heart of a Frog

Circulation in animals can be turned into research projects in many ways, but one of the most effective methods is to anesthetize a frog and then open the body cavity to expose the heart. Remove the pericardial sac and bathe the heart throughout the experiment with Ringer's solution. The heart, if bathed in this solution, will continue to beat for several hours. Variations in the heart activity can be induced by bathing the frog's heart with warm water (about 40° centigrade), then with ice water. Another possibility is the addition of a very small quantity of adrenalin to the Ringer's solution. How does the adrenalin affect the heartbeat rate? How do warm and cold water affect the heart's activity? How does a weak electric current affect the heart when applied directly to it?

Circulation in Daphnia

Water fleas of the genus Daphnia can also be used to study circulation in animals. A binocular microscope is excellent for studying these tiny little animals. Material needed: blank glass slides, cotton fibers, methyl-cellulose solution, microscope (preferrably binocular type), glass or plastic cover slips. On a blank slide, make a ring with the methyl-cellulose, then place a water flea in the center, along with two or three drops of water and several cotton fibers. As the methyl-cellulose hardens, the fibers become entangled and should hold the water flea securely, so it may be studied. Apply a glass cover slip. Warm the slide slightly. Is there any appreciable difference in the heartbeat rate? The heart should be quite easy to identify, since it will be beating quite rapidly. Add one drop of 0.01 percent adrenalin solution to the solution in which the water flea is entangled. This is a relatively simple project that can be expanded in many ways by a clever student.

Responses of *Planaria* to Various Stimuli

Planarian worms are easily obtained from the underside of rocks in fresh water streams and can be used to study responses in animals. These are small worms, ranging in length from one-fourth to one inch long and most are either dark gray or brown in color. After obtaining several of these worms, test their response to light by directing a beam of light on one end of their container. Chemicals, such as hydrochloric acid (HCl) and sodium hydroxide (NaOH) in various concentrations can be used to study their reactions to chemicals. Be careful not to make the solutions too strong or you may kill the flatworms. Usually a few drops of a solution in one end of the container is sufficient to test their reaction. Another variation in this project can be affected by removing the small eyespots on the anterior end of the planarian's body with a razor blade or sharp knife. In most planarian's there are only two lightly colored eyespots present, but some have as many as seven, so this may complicate matters somewhat. Do planarians respond differently to light when the eyespots are removed? This project may be carried a step farther by the student. Do the eyespots grow back after a period of time? These little animals have great powers of regeneration, so it would not be too surprising if they did, but investigation in this area would probably prove to be quite interesting.

Parthenogenesis in Frog Eggs

Artificial parthenogenesis in frog eggs is one of the most challenging projects in this area of biology. This is the phenomena of eggs developing without being fertilized by sperm cells. Frog eggs may be obtained by gently holding an ovulating female frog and pressing gently in the direction of the cloaca. Strip the eggs into large, sterile, dry dishes and be sure that all dishes are free of sperm. Wash the eggs with a 0.1 percent Ringer's solution, then strip the eggs in single file on clean glass slides. Keep the eggs moist until a blood-coelomic fluid can be obtained from a non-ovulating female frog by cutting the tip off the ventricle of the heart and allowing the blood to flow into the coelomic fluid. Next, take a small camel hair brush and streak the blood-coelomic fluid on each egg, then take a sterile glass or platinum needle and prick the small black area just off the center of the egg. As a final step, immerse the eggs in spring or distilled water, keep these in a cool place and check hourly or every two hours with a binocular microscope for signs of cleavage in the eggs.[34] Why does artificial stimulation cause the eggs to develop? A lot of scientists would like to know the exact answer to that question.

Projects in Entomology

Before closing, a section of this chapter should be devoted to entomology, since these animals make up approximately 80 percent of the animal kingdom. Insects are found in all sizes, ranging from 1/100 of an inch to 10 inches long and even more impressive is the fact that there are over 650,000 known species of insects.[35]

A well prepared insect collection is a most rewarding accomplishment. The collecting itself is enjoyable and an extensive knowledge of insects may be gained as well. In many cases, insect collections may be used in connection with 4-H and FFA work, which is an additional incentive.

A word of caution is probably in order for the beginning entomologist, since many insects can inflict painful bites, stings and stabs. In addition, some of the true bugs and beetles emit foul smelling fluids as a defense mechanism.

Most of the material needed in insect collecting can be quite easily improvised. A minimum essentials list should probably include the following items: a long-handled cheesecloth or small-mesh net, a wire mesh net (for collecting aquatic

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[34] Ibid., p. 172.

[35] D. E. Howell, "Insects and Man" (unpub. lecture, Oklahoma State University), section 8-2.

insects), a killing jar, insect pins of various sizes, a spreading board, storage boxes, insect repellants (moth balls or paradichlorobenzene), 90 percent ethyl alcohol, waterproof labels, India ink, quill or fine-point pen, small plastic vials with stoppers or screw-on caps, small boxes, tweezers, pipette, and a hand lens.

A few words in regard to the equipment just listed. Don't expect a lightweight net to stand up under the rigors of aquatic collecting or brush beating. For aquatic collecting a wire mesh net should have a strong metal hoop for a frame and a handle not more than four feet long. Aquatic insects should be placed in water after they are collected to prevent them from drying out and dying.

A lighter weight cloth net can be used for flying insects, such as moths and butterflies. These insects should be handled carefully to avoid damage to the wings and body. These may be killed immediately or placed in jars until after the collecting is done, however some wing damage is likely to occur if they are left in the jars too long.

Large killing jars are necessary for butterflies and moths. Potassium cyanide (KCN) is used in some killing jars, but this chemical should probably not be used by high school students. This is a deadly poison and could cause death if swallowed or the vapors inhaled. Carbon tetrachloride (CCl_4) does a good job and isn't nearly so poisonous as potassium cyanide. Pack rubber bands or pieces of a rubber inner tube into the bottom of a large glass jar; soak the rubber with carbon tetrachloride; cover the rubber with absorbent cotton and finally; cover this with a circle of cardboard to prevent the insects from becoming entangled in the cotton. The carbon tetrachloride will evaporate, so the killing jar should be recharged from time to time.

Instructions for pinning, labeling and identifying insects can be found in most high school biology books, entomology textbooks, and leaflets distributed by agricultural agencies, so no further discussion of this is deemed necessary.

Soft bodied insects should be preserved first in a 50 percent ethyl alcohol solution, then transferred to a 70 percent solution and finally, preserved permanently in 90 percent ethyl alcohol. Formaldehyde can be used, but it tends to make the insects somewhat brittle.

Protecting the insect collection is very important after preparation and labeling. Small insects can and will ruin insect collections if necessary precautions aren't observed. Moth balls may be used, but paradichlorobenzene is more effective as an insect killer. To prepare moth balls, heat the heads of insect pins and push firmly into the moth balls. These may then be mounted in the insect boxes. Paradichlorobenzene may be melted and poured along the inside of insect boxes.

Special research projects in entomology can be devised in such areas as: the effect of various sprays and poisons on flies, honeybees, mosquitos; the life cycle of a selected insect; a collection of all members of a selected order of insects in a given area (don't make the area too large); observation of metamorphic changes in butterflies and moths; an ecological study of insects in a given area; and finally, the effect of temperature in regard to the estivation of certain insects. Material may be obtained by contacting most state universities or local agricultural extension offices.

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

One of the major conclusions of this study is the realization of the inadequateness of one report to cover this topic. Any one of the areas would have provided sufficient material for a report in itself, but this was not intended to be an encyclopedia of projects, whereby a student could select a topic and turn to a certain page and begin a "cookbook" project. This report does not pretend to cover even a small percentage of the available research projects, but it is hoped that it will give students an insight into the basic principles of research and stimulate them to do some creative thinking. Basic research is needed in many areas and high school students should investigate these areas and avail themselves of modern techniques and information.

Another important point to be remembered is that the average and below average students should not be neglected by the teacher. The teacher has an obligation to these students which should not be overlooked in the search for talented students.

The following are recommendations that are an outgrowth of this study.

1. Enrichment projects can and should be used in high school biology.

2. All work on research projects should be done outside the classroom and no class period should be sacrificed in favor of enrichment projects.

3. As much equipment and reference material should be made available as possible to students engaged in research projects.

4. Clinics and hospitals should be contacted for help in certain research projects.

5. Students should be helped, but not pushed in the performance of research projects.

6. Participation of qualified students should be entirely voluntary.

7. Approved laboratory techniques should be used extensively in the performance of the selected project.

8. Workbooks and manuals should be used moderately in selecting and carrying out these enrichment projects.

9. The scientific or problem-solving method should be used extensively by students engaged in research projects, never the trial and error method.

10. Careful records and notes should be kept on all phases of the research project.

11. Special precautions should be observed in dealing with bacteriology projects, as well as projects involving blood physiology, to avoid infection.

12. Improvise equipment, whenever possible, and avoid purchasing expensive equipment, unless absolutely necessary.

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