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Title of Study: TEACHING METHODS IN THE BIOLOGICAL SCIENCES

Pages in Study: 43 Candidate for Degree of Master of Science

Major Field: Natural Science

Scope and Method of Study: The purpose of this report has been to attempt to present an "ideal" method of introducing the sciences to the high school students of today. One of the difficulties in trying to reach tenable conclusions regarding the aims of science instruction in the modern school lies in the fact that, at present, we have no means of evaluating such statements made by educators and others. The paper presents first, a review of the procedures used in organizing and constructing the ideal science classroom, the equipment, storage facilities, classroom arrangement, etc. Secondly, the paper presents a complete course in Botany, using this branch of science as a model course, in which the method of presentation is the important factor. It is presented in hopes that any of the sciences could be substituted and presented in the same manner.

Findings and Conclusions: The high school instructors of today are placing entirely too much emphasis on "cramming" terms and figures into the student or requiring extensive, unnecessary memorization of technical information. Instead, teachers should attempt to present the basic information, taking first, each part and becoming familiar with its structure and functions as a single unit and then as a part of a complete system.

If this job were done effectively by the present day high school teachers, and the technical training were left to the colleges and universities, our children would finish school with something more than just a diploma. They would finish with an understanding far superior to any educational system that has yet been devised.

ADVISER'S APPROVAL James H. Zant

TEACHING METHODS IN THE

BIOLOGICAL SCIENCES

By

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Bachelor of Science

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Stillwater, Oklahoma

1960

Submitted to the faculty of the Graduate School of
the Oklahoma State University
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
August, 1961

TEACHING METHODS IN THE

BIOLOGICAL SCIENCES

Report Approved:

Report Adviser

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PREFACE

Indebtedness is acknowledged to Dr. James H. Zant, Dr. L. Herbert Bruneau, and Dr. W. W. Hansen for their guidance in the writing of this report. Thanks also goes to Mrs. June Daniel, wife of a Musky, who performed the laborous task of typing this report.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER I

INTRODUCTION

When one begins to study and ponder the aims and objectives of science instruction in the schools, he is struck by the many statements which have been made from time to time and the manner in which recent statements have emerged from earlier points of view.

One of the difficulties of attempting to reach tenable conclusions regarding the aims of science instruction in the modern school lies in the fact that at present we have no means of evaluating such statements made by educators and others. Lists of aims and goals at their best are merely subjective judgments of opinions held by an individual or committee.

Many studies have been made in the past which have attempted to determine the importance of an objective on the basis of its frequency of occurrence in a number of such statements. Results from these studies obviously cannot be valid because of the lack of agreement among the writers on the definition of an objective. In reports which date back as far as 1920, one may read that science teaching should contribute to such ultimate goals as health, leisure time, vocation, ethical character, and others, as well as to the more immediate objectives of knowledges, havits, powers, interests and ideals. Obviously, even the goals in this statement called "immediate" are so very general as to be almost meaningless.

There have been, in recent years, attempts to approach the formulation of objectives through the synthesis of a variety of educational studies of interests, with accepted courses of study. These attempts have involved elaborate and, at times, questionable statistical procedures and in some instances were based upon studies of doubted validity. Such studies are almost valueless, when it comes to the all important matter of the determination of objectives for the science program. The outcomes of science instruction, because there is at present no valid means of testing them, should be based on the most logical terms that an individual or group of experts believe; and keeping this in mind we have to accept and shape our instruction in attempts to realize them.

It has been said many times by great and wise men that we are living in an age of science. There can be little doubt of this truth for the experiences of a day and hour are teeming with situations which have their problems deeply ingrained in science. Modern medicine, modern transportation, communication, modern agriculture, the modern home, all bespeak the implications and ramifications of science in the life of the present day.

Modern biology and medicine have lengthened the expectant life span of mankind as has modern chemistry in producing new medicines, as well as dyes, plastics, textiles, etc. Physics and engineering have eased the life of man and produced such things as the radio, the telephone and the automobile. Geology and archaeology are continuously opening the past of living things while the astronomers are building new instruments of research through which they will open, even more, the distant recesses of outer space. It is not difficult for one to become over-awed at the accomplishments of modern science and its potentialities for the future.

Present-day science education must find its justification, aims, and immediate learning goals in terms of the needs and interests of individuals living in a modern social order whose causal factors are at present, and likely to be in the future, drawn largely from technological implications.

It would seem that careful studies of individuals in their attempts to adjust to the myriad of science situations, both practical and intellectual which arise in modern life, would furnish us with valid and objective data from which to begin the refringement into the general aims of the science programs. Criteria for selecting and refining valid adjustments are as follows:

(1) The criteria should be universal in their application to life needs.

(2) The criteria should be in accord with the findings of science.

(3) The criteria should be disired by the pupils.

(4) The criteria should be essential to the making of other desirable adjustments.

After applying these or other criteria and arriving at a set of defensable adjustments, it becomes essential to discover the understanding, attitudes, habits, and skills which must be learned by the student to insure them. Further, after the selection of those knowledge factors, learning situations must be set up in the classroom which will approach as nearly as possible the real-life situation in which the adjustment is made.

In the following chapters the author has attempted to present a means for gathering material for an "ideal" science program. In obtaining this information, material must be collected from every possible source of scientific information. If this report were to cover all the possible aspects of science, it would be volumes long. The presentation of this paper is in two sections. The first section deals with the construction of the classroom itself and all the equipment needed to supply the science students. It is the author's belief that without sufficient facilities, which are used capably, an "ideal" program is impossible. The second section presents on phase of the science curriculum (Botany), and it is intended that this presentation would represent the methods and procedures that would be necessary in every phase of science. By taking only one phase, however, it will be possible to present more than merely an outline of all the sciences, rather to take one science and present details and demonstrations. It is not the material itself that needs to be put across, rather the manner in which any science can be presented to a student and permit that student to see and know and understand science, as we see it today.

It would seem then that the only valid method of building a set of defensible aims is to attack the problem, the analysis of behavior of individuals as they adjust to the situation in modern life which have science implications, and from these observations set up our aims and specific teaching objectives. These then can easily lead to the definition of defensible content and reliable methods of instruction.

CHAPTER II

CLASSROOM FACILITIES FOR AN ADEQUATE SCIENCE PROGRAM

This chapter examines some of the patterns of managing science classrooms and laboratories, and providing facilities for storing materials such as special shelves, cabinets, and closets. The main advantage in having facilities to permit storage and good housekeeping is that students can offer superior service as laboratory assistants for many kinds of work going on in the classrooms, and laboratories. Some of the possibilities for types of materials and kinds of activities in which students can share work in class and in laboratory under a teacher's supervision are as follows.

Space for Work

Where space is not readily available, the science program suffers greatly. Many of these problems can, however, be solved by the use of equipment which is easily transported. Some of these types of equipment are as follows:[1]

1. Propane gas cylinders with attached burners for rooms not equipped with gas. (Fig. 1).

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[1]Thomas M. Risk, <u>School Facilities for Science Instruction</u>, National Science Teachers Association, Washington 6, D. C., (1954), pp. 6-14.

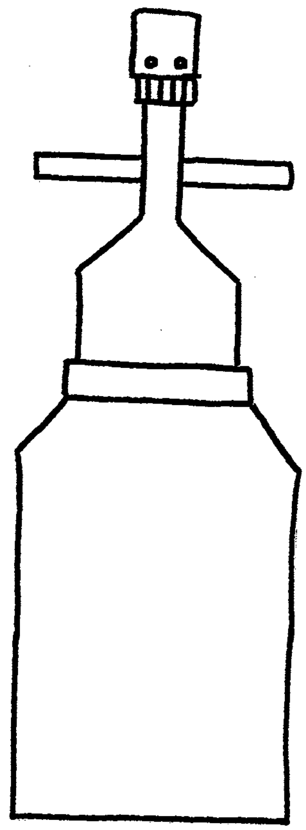

Fig. 1

Propane Burner

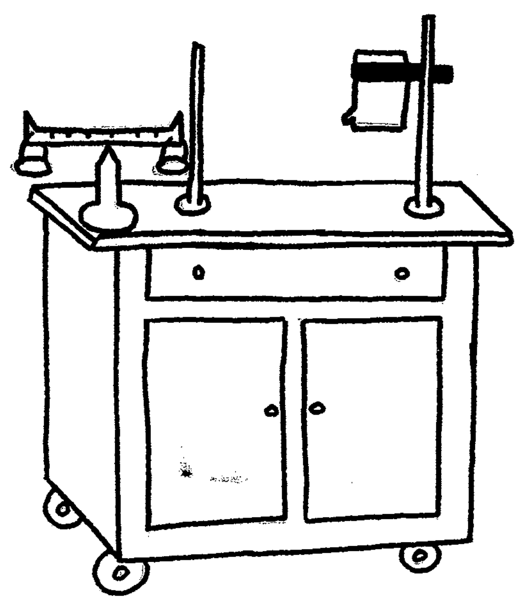

Fig. 2

Portable

Demonstration Table

2. A battery jar of a carboy of water with a rubber extension and clamp where water is not readily available. (Fig. 2).

3. A portable demonstration table which could easily be moved from room to room, thus eliminating the need for more than one demonstration setup. (Fig. 2).

Classrooms

The trend in newer schools seems to be toward a combination classroom and laboratory so that the room serves multiple purposes. If space is limited, there is great advantage in having a laboratory arrangement at one side of the room and moveable tables and chairs on the other. In this manner, students may be grouped at either end of the room and the teacher and students do not have to speak loudly in order to be heard across the large room. A classroom of this type can include the classroom itself, storage shelves, laboratory, equipment lockers, darkroom (if photography equipment is available), a greenhouse, and a display section for projects done by the students. (Fig. 3).

Greenhouses

Many students find work in a school greenhouse an enriching experience. This work can be an extension of class activities as well as a means of supplying the classroom with living materials for study. In many schools over the country, a greenhouse is associated with student project work and field work activities on the school grounds. They may learn to grow algae, mosses, ferns and seed plants and some may go into soil-testing techniques, while others begin studies in plant physiology. There are unlimited opportunities available with the use of a greenhouse

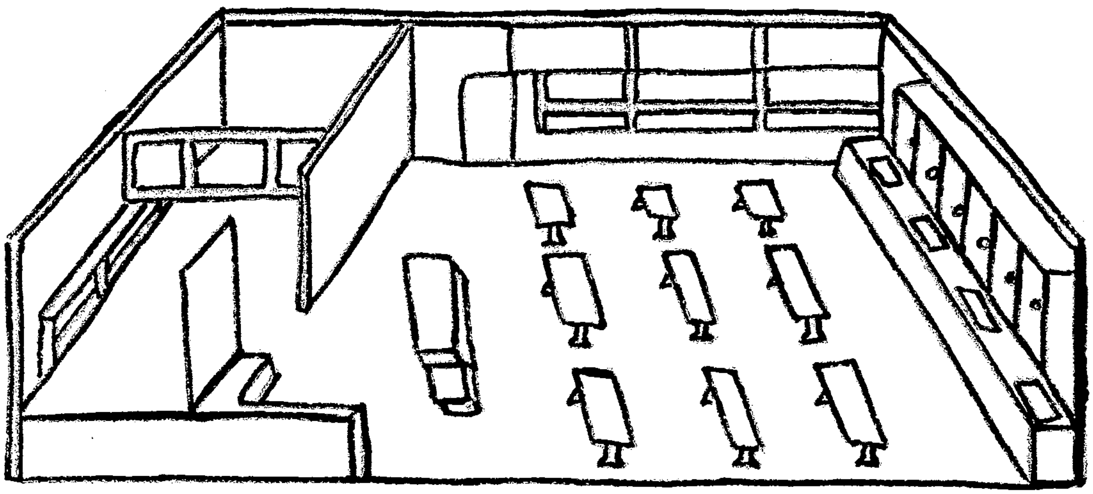

Fig. 3

Ideal Classroom

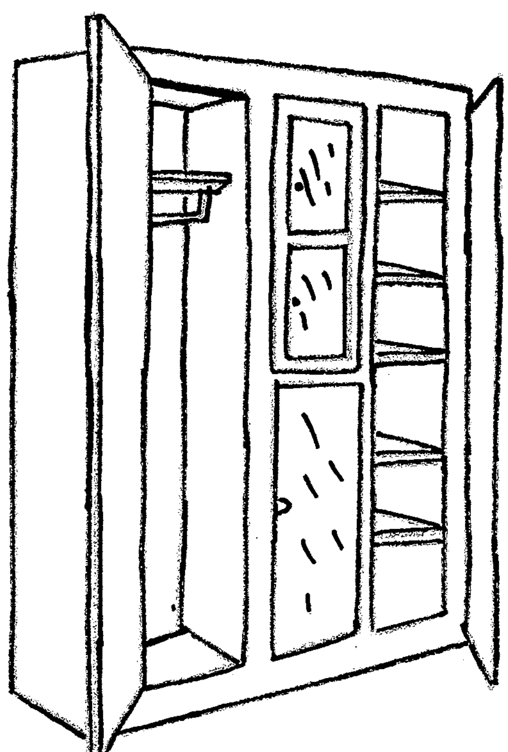

Fig. 4

Storage Cabinet

and it should be used in accordance with the capabilities and aspirations of the students.

Student Projects

Often teachers are asked to contribute ideas for landscaping the schoolgrounds or some job similar to this. When flowering trees and shrubs are specially selected for planting around the school, a teacher can conduct a short field trip to show how flowers function in plant reproduction. In some cases, teachers have laid out nature trails, built artificial lakes which have been stocked with plants and animals and have, in general, simulated the study of field biology.[2]

When both students and teachers pool their techniques, a small space can be found to exhibit living things for the whole school. Discussion of relationships and interesting facts concerning the plants and animals can be typed as legends on library cards, and placed on the exhibits. This area can grow into a permanent, living nature museum, which can be very valuable in that it will give a great many students a chance to watch nature in action. With this museum before them constantly, the students will not only get a better insight on nature in action, but will be encouraged to take an active part in collecting and caring for these plants and animals.

In some schools, teachers have set aside space for individual students to pursue an interest, a research problem, or a prolonged "original" experiment in science. Over a period of a year or two, these young people learn to use the methods of scientists. In searching for a solution to a

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[2]Brandwein and Joseph Morholt, A Sourcebook for the Biological Sciences, New York, (1959), pp. 410-450.

problem, they may also discover new information that would lead to the uncovering of new facts that would otherwise have been passed over.

Science Library and Committee Room

When space is not a limiting factor, there should be provided for the students a small science library and a separate place for conferences or committee work associated with their classroom work. This library should not compete with the school library, but should contain more advanced texts and magazines for the students engaged in individual research work.

Facilities for Storage

In the case of storing science equipment, closed storage space, such as cabinets and compact closets, are much better than open shelves. By storing the equipment and supplies in closed spaces, you cut down on the accumulation of dust and they are not exposed to fumes or to fluctuations in humidity and temperature. Facilities should be made available for such demonstration materials as models, skeletons, glassware, projectors, microscopes, etc. Many charts can be stored in a hanging position and in this manner, they are not exposed to wear. An ideal cabinet for general equipment and supply storage is shown in Fig. 4.

Equipment and Supplies

In attempting to coordinate a science program, the problem arises of how much, and what kind of equipment and supplies will be needed for the planning of an adequate program. This problem seems even larger when the responsibility of ordering these supplies falls upon the shoulders of the instructor. The quantity of material ordered depends upon what activities are to be carried on and how they are to be performed — as a classroom experiment by all students, by groups of four, by an individual as a project, or as a class demonstration. The amount of material also depends somewhat on the annual budget alloted for equipment and supplies.[3]

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[3]Ibid.

CHAPTER III

THE STUDY OF BOTANY

Botany may be defined as the branch of biology which deals with the structure, physiology, reproduction, evolution, diseases, economic uses, and other features of the plant kingdom. The word botany is traceable to ancient Greek words meaning "graze", "plants", or "cattle".

The History of Botany[4]

1. Ancient Period. Greek scientists laid the foundations of botanical study. They studied plants especially in relation to their uses as food and as sources of drugs. They also discovered mahy facts concerning the growth, distribution, and cultivation of plants. The Romans showed little interest in plants, aside from their use as drug and food plants.

2. Medieval Period. During the middle ages, most botanical study was carried on in monastaries and in the botanical gardens associated with universities. This study was often a mixture of scientific observations upon plant structure and behavior, with accounts of the superstitions about and the mythology of plants. The chief botanical books, called Herbals, frequently contained drawings or wood-cut illustrations

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[4]Ben DeLeon, A Graphic Survey of Biology, New York, (1959), pp. 45-49.

of the plants described. Attempts at classification were made during this period.

3. Modern Period. The modern scientific study of the facts of plant life, divorced from superstition and mythology, began in the late seventeenth and early eighteenth centuries. Outstanding among the botanists of the early modern period was Swedish Carl Linnaeus, who established many of the fundamental principles of scientific plant classification and named many species of plants. The study of classification and of gross structure were the earliest branches of botany to develop, for they required no specialized tools or techniques from other sciences. The study of minute anatomy and the functional phases of plant life developed later, following the discovery of the basic principles of chemistry and physics and the perfection of magnifying lenses. Most of the details of the microscopic structure of plants and of the physiological activities of plants have been worked out within the past hundred years.[5]

The science of botany consists of several fairly distinct, though losely related, branches. Perhaps the best way to explain their small differences is simply to define each of the branches:

Plant Morphology - the study of plant structure.

Plant Anatomy ---- a phase of morphology dealing with the minute internal structure of plants, with reference to tissues.

Plant Taxonomy --- the study of plant classification and the principles of classification and identification.

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[5]Ibid.

Plant Pathology -- the study of the causes, control, and other features of plant diseases.

Plant Physiology - the study of the chemical and physical processes and behavior of plants.

Plant Ecology ---- the study of plants in relation to their environment.

Plant Geography -- a phase of plant ecology, dealing with the distribution of plants on the earth's surface.

Plant Genetics --- the study of inheritance and the breeding of plants.

Plant Cytology --- the study of the structure and physiology of individual cells, especially in relation to genetics.

There are various reasons for studying botany in the course of a liberal education. Since education consists essentially in the achievement of advantageous adjustment to one's environment and since plants constitute one of the most conspicuous features of human surroundings, a knowledge of the fundamental principles which govern plant life is an important part of a liberal education.

An awareness of man's complete dependence upon plants for food, textiles, rubber, dyes, lumber, and many other products increases man's appreciation of the activities of plants and of his place in nature.[6]

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[6]Harry J. Fuller, General Botany, Barnes and Noble, New York, (1955), pp. 2-3.

CHAPTER IV

THE APPLICATION OF BIOLOGICAL PRINCIPLES TO PLANTS

In considering the possibilities for the best curriculum arrangement for the high school student, it must be assumed that the student has had little or no previous instruction in this area. Assuming this makes it necessary to present the most basic information available concerning the physiological structure and function of each part of the plant. Each of the parts must first be considered and then related to the formation of the entire plant at the termination of the course. If this is done properly in every phase of science, the student will not only have a better picture of how each individual part comes into play, but how that one part fits into the complex organization of the whole system. This chapter is designed to present the parts of the plant as they function first as a single unit and then as a part of the entire system.

Unit 1

The Leaf

A leaf is a lateral outgrowth of a stem, arising at a node, and possessing a bud in its axil. Most leaves are flattened and expanded, but there are modified or specialized kinds of leaves which do not exhibit this flattened structure.[7]

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[7]Ibid, p. 61.

External Structure (Fig. 5).

The leaf generally consists of three parts. These are: (a) the blade, (b) the petiole, and (c) the veins. The blade, or the working part of the leaf, is generally broad or flat. The petiole attaches the leaf to the stem and holds the blade up to the light. The veins are branches of the midrib which form a network which supports the leaf and conveys liquids, sent through the petiole, to all parts of the blade. Leaves vary greatly in size, shape, thickness, and in texture. The veination in leaves is of two types. They are either "net-veined" or "parallel-veined". (Fig. 6). In net venation, the veins branch out many times from the midrib and form a complete network over the blade. There are two types of net-veined leaves: pinnate venation, in which there is one midrib from which the smaller veins branch; and palmate venation, in which there are several midribs of equal size branching into each of the blades of the leaves.

Most leaves have only one blade. Leaves of this type are termed simple. (Fig. 7a). Some plants have leaves in which the blade is divided into separate pieces, called leaflets. Such a leaf is termed compound. (Fig. 7b). When the leaflets are all attached at the tip of the petiole, the leaf is palmately compound. (Fig. 7c). If the leaflets are distributed at intervals along the extended petiole, the leaf is said to be pinnately compound. (Fig. 7d).[8]

Internal Structure (Fig. 8).

The epidermis is a single layer of cells forming the upper and lower

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[8] E. L. Moseley, Biology for Life, New York, (1952), pp. 25-35.

The Leaf

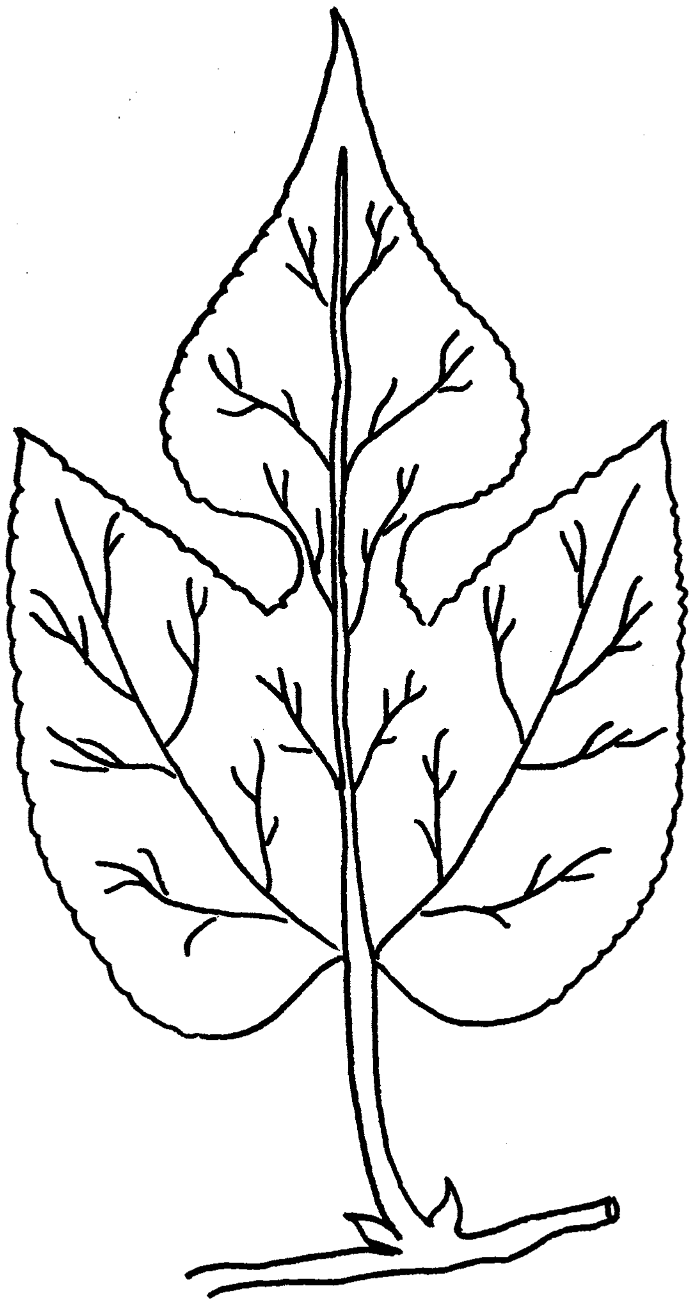


Fig. 5

Venation

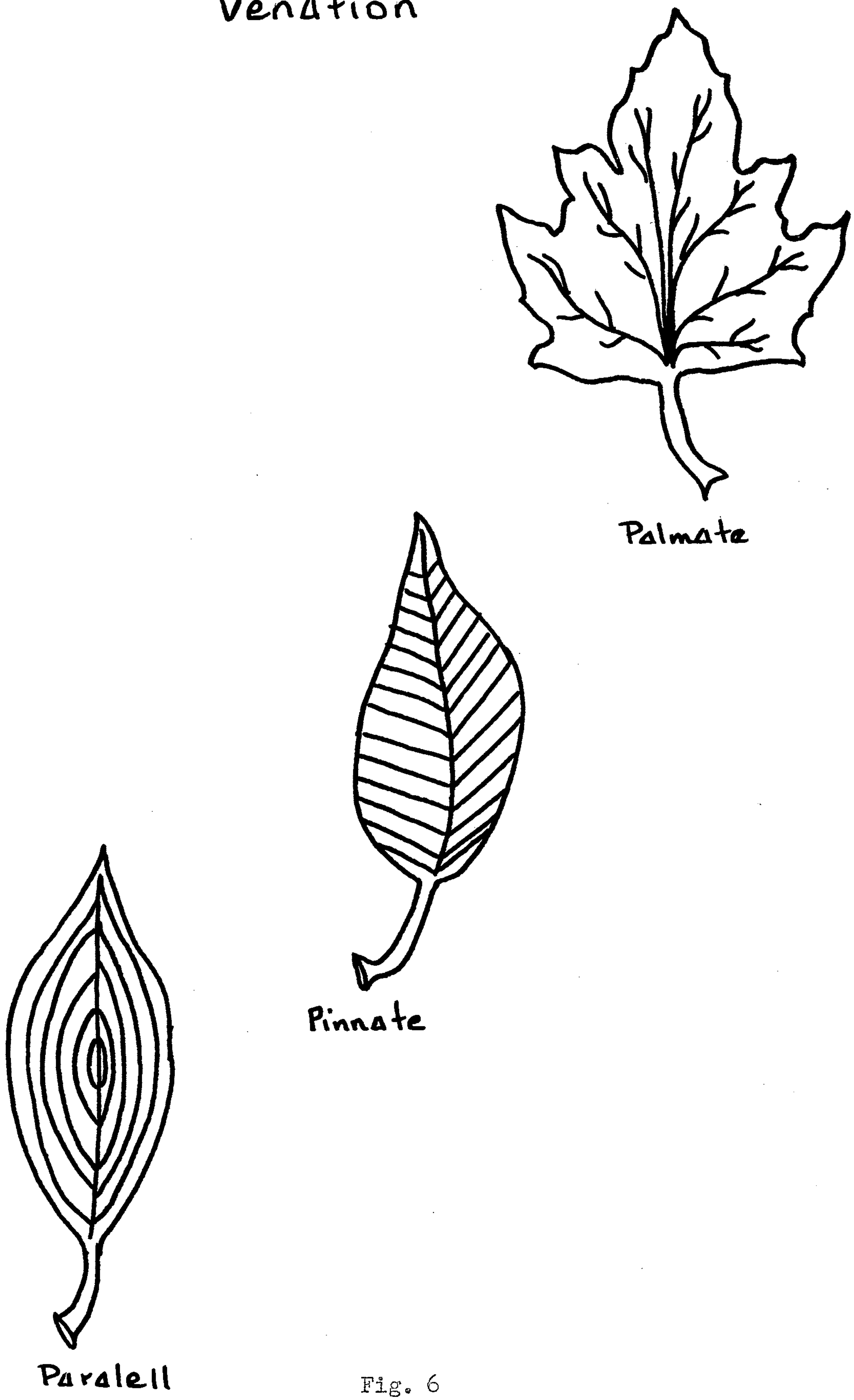
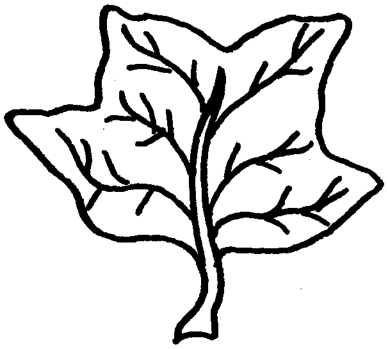


Fig. 6

Types of Leaves

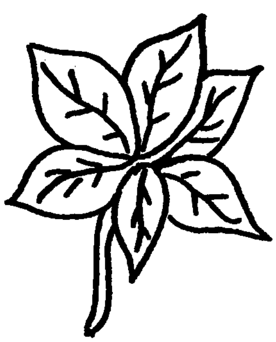


(a)

Simple

(b)

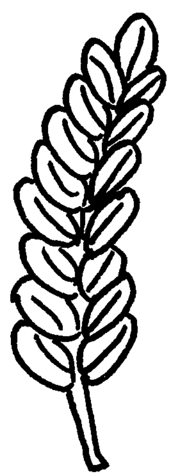
Compound



(c)

Palmately Compound

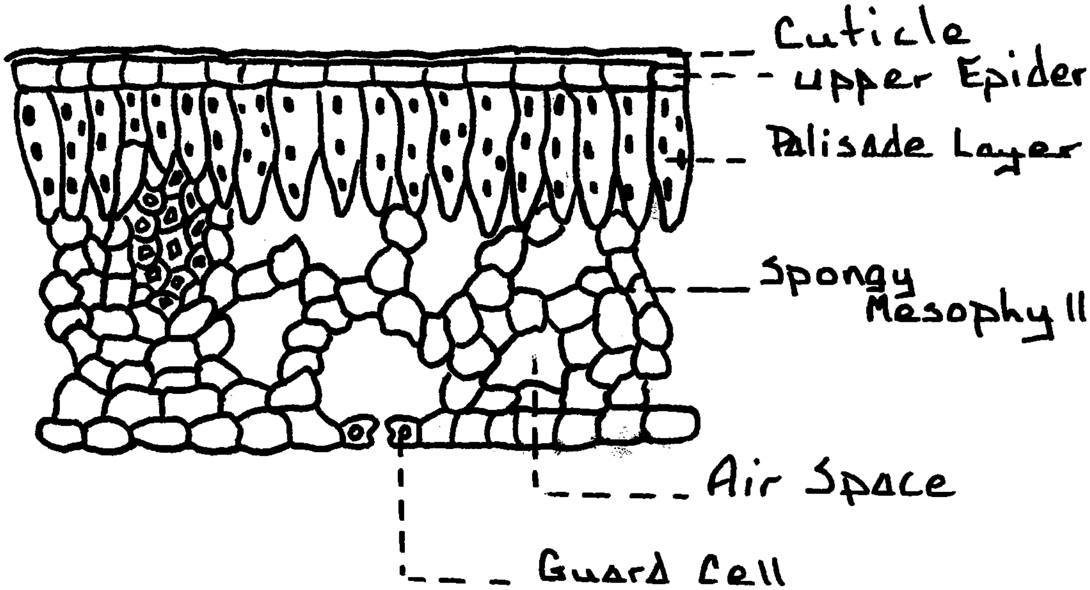
Fig. 7

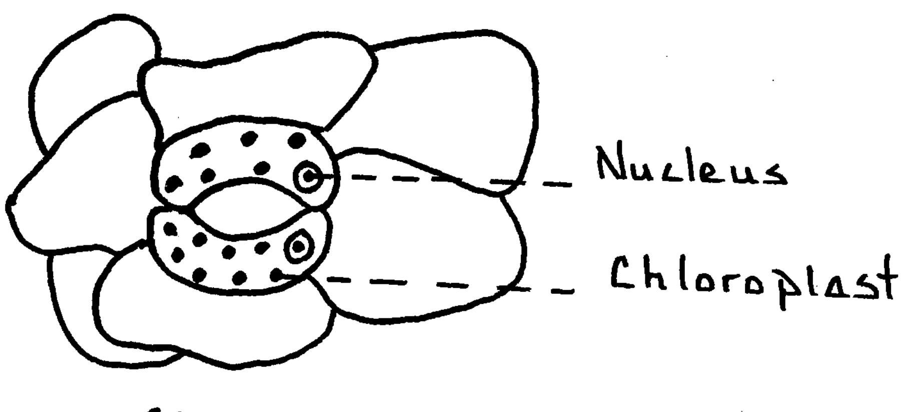


(d)

Pinnately Compound

The Leaf (Internal)





Stomate

Fig. 8

surface of the leaf. These cells fit tightly together and are of two types: ordinary epidermal cells, and green, crescent-shaped guard cells, which occur in pairs, with a minute opening, or stoma, enclosed by each pair. The ordinary epidermal cells function to protect the inner tissues from dessication, mechanical injury, and, to some extent, from the entrance of parasites. These cells often secrete a waxy substance, cutin, on their outer surfaces. The cutin layer, or cuticle, which is waterproof, varies in thickness in different species and is effective in reducing evaporation. The stomata are avenues of exchange of carbon dioxide and of oxygen and water vapor between the interior of the leaf and the external atmosphere. The opening and closing of the stomata is regulated by changes in the water pressure in the guard cells. This pressure increases when light falls on the guard cells and decreases when darkness comes. Light causes an increase in the sugar content and thus in the osmotic concentration of the guard cells, and water enters, supplying the pressure which expands the guard cells.

The mesophyll, occupying the central portion of the leaf, is composed of two distinct tissues: the palisade tissue, consisting of vertically elongated, cylindrical cells; below the one or two palisade layers is the spongy tissue, composed of loosely-packed cells of variable form. Both layers are rich in chlorophyll and constitute the food-making tissues of the leaf. The numerous intercellular spaces make possible the ready diffusion of gases to all cells. Within the spongy layer lie the veins or vascular bundles. These are branched continuations in the mesophyll of the vascular bundles of the petiole. A vein consists of xylem cells which conduct water up from the roots, and phloem cells which conduct food substances in solution downward. In most leaves, the xylem cells are the upper part of the veins, and the phloem cells are the lower part.[9]

Physiology of Leaves

The main physiological function performed by the plant is the process known as photosynthesis. This process may be defined as the manufacture of carbohydrates from carbon dioxide and water in the presence of light through the mechanism of chlorophyll. It is the basic process of food manufacture in nature and all animals and plants (except a few fungi) depend on it. It is also a major source of oxygen in the air. The end product of photosynthesis is starch and the waste material given off is oxygen. In this manner, photosynthesis is beneficial to animals in that they use the starch for food and the oxygen in respiration. Plants benefit from photosynthesis in using the starch for food for themselves. The following experiments are presented to show that during photosynthesis, carbon dioxide, chlorophyll, and sunlight are necessary and that oxygen is given off as a waste product.[10]

Experiment 1.

Object - to show that sunlight is necessary for photosynthesis.

Method - select a geranium plant which has been in the dark for at least 24 hours. Cover a portion of several of the leaves by pinning a piece of cork or black paper to both the upper and the lower sides of the leaf. Expose the plant to sunlight for a few days. Remove the leaves and boil first in water for five minutes and

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[9]Ibid, pp. 35-40.

[10]W. Summerson, Practical Physiological Botany, New York, (1954), pp. 5-20.

then heat in alcohol to remove the chlorophyll. Spread the leaves out on a flat surface and apply iodine.

Observation - the part that was not covered turned blue-black, indicative of the presence of starch, while the part which was not exposed to sunlight remained white.

Conclusion - sunlight is necessary for the manufacturing of starch in leaves.

Experiment 2.

Object - to demonstrate the necessity of chlorophyll in photosynthesis.

Method - select a plant whose leaves contain both white and green parts. Expose to sunlight for a few hours and then remove chlorophyll by boiling in alcohol. Apply iodine to the surface of the leaf.

Observation - those parts of the leaf which were green (contained chlorophyll) turned blue-black, indicative of the presence of starch, while those parts which were originally white (no chlorophyll) did not turn blue.

Conclusion - Chlorophyll is necessary for photosynthesis.

Experiment 3.

Object - to demonstrate the liberation of oxygen during photosynthesis.

Method - fill a jar with water, at the bottom of which is a green water plant such as elodea. Cover the plant with a funnel and place a test tube filled with water over the funnel and expose the plant to sunlight for several days.

Observation - bubbles were seen rising in the test tube and displacing the water there. After the gas was collected, a glowing splint was inserted and the splint burst into flame.

Conclusion - Since oxygen supports combustion, the gas in the test tube, which was given off by the plant during photosynthesis, must have been oxygen.

Experiment 4.

Object - To demonstrate that carbon dioxide is necessary for photosynthesis.

Method - place a healthy geranium plant on a sheet of glass with a beaker of potassium or sodium hydroxide pellets. Cover the apparatus with a bell jar and seal it to the glass with vaseline to make it air tight. (The potassium hydroxide will remove the carbon dioxide from the jar). Set up a similar demonstration, omitting the hydroxide and place both preparations in moderate sunlight. Text for starch.

Observation - the plant with the carbon dioxide absorbent will show little or no starch, while the plant with no carbon dioxide absorbent will show a positive starch content.

Conclusion - carbon dioxide is necessary for starch production in photosynthesis.

Unit 2

The Stem

Aerial stems are commonly classified into two types: (1) herbaceous and (2) woody stems. These type stems differ chiefly in the following ways:

Herbaceous Stems	Woody Stems
a. Soft and green	a. Tough and not green
b. Little growth in diameter	b. Much growth in diameter

c. Tissues chiefly primary	c. Tissues chiefly secondary
d. Chiefly annual	d. Chiefly perennial
e. Covered by an epidermis	e. Covered by a corky bark
f. Buds mostly naked	f. Buds covered by scales

External Structure

Upon examination of a young shoot from a tree, (Fig. 9), it can be seen that the large bud is at the end of the twig. This is called the terminal bud. The terminal bud is a leaf bud which will develop, during the following spring, into a new branch or shoot and leaves. Covering the terminal bud are bud scales which protect the bud from external injury. On the side of the stem there will be moon-shaped scars known as leaf scars, each of these indicating where a leaf fell off the twig. Within the leaf scars there are small dot-like marks which are the severed ends of the veins which pass into the leaves. These are known as bundle scars. Somewhere on the stem you will come upon a circle of scars which extends all the way around the stem. These are called bud-scale scars, and were formed when the scales of the terminal buds fell off the previous spring. The ring, therefore, indicates where growth started the previous spring; thus, the distance between any two bud-scale scars shows the growth of the twig for one year.

The chief functions of the stem are: (1) The conduction of substances up from the roots to the leaves and down from the leaves to the roots, (2) the production and support of leaves and reproductive structures, and (3) the storage of food. There are some stems which perform secondary functions, including photosynthesis (in young green stems), and respiration (which takes place through openings known as lenticels,

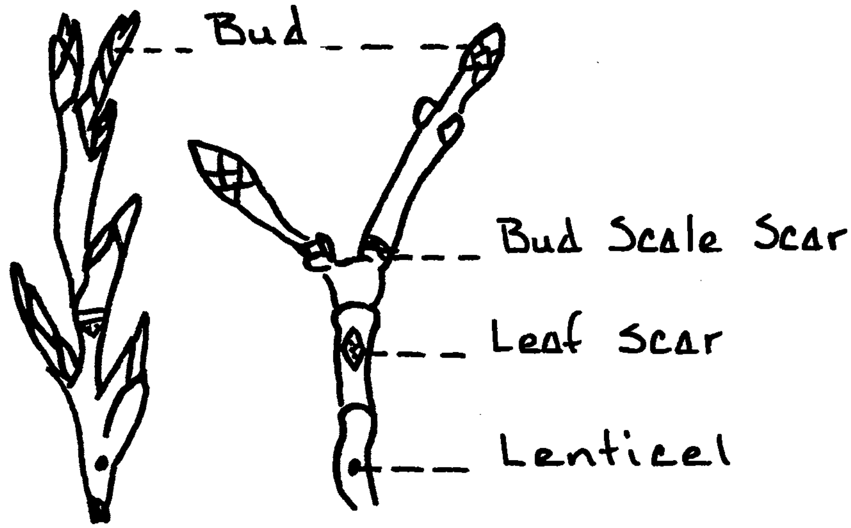
Bud
Bud Scale Scar
Leaf Scar
Lenticel

Fig. 9

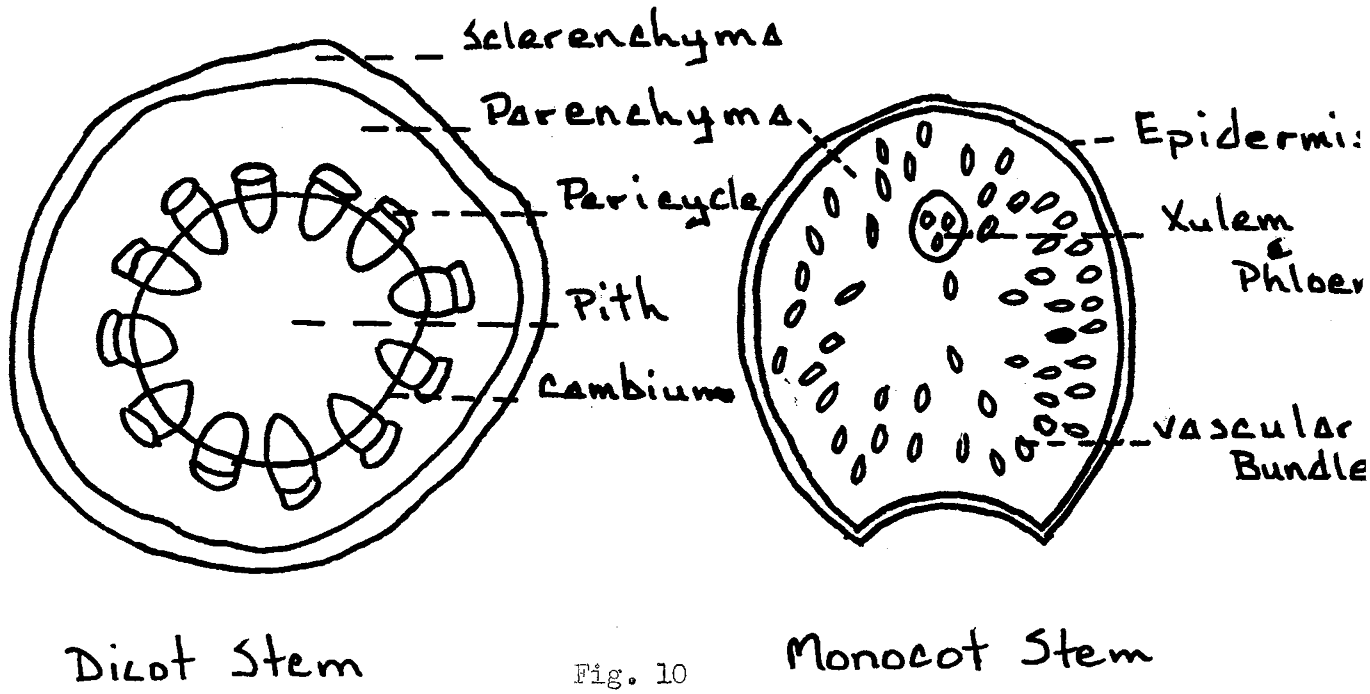
Sclerenchyma
Parenchyma
Pericycle
Pith
Cambium
Epidermi
Xylem
&
Phloe
Vascular
Bundle
Dicot Stem
Monocot Stem

Fig. 10

in the bark of older stems).[11]

Internal Structure (Fig. 10)

The internal structure involves two types of stems; monocotylendons and dicotyledons. The monocotyledenous stem is one produced from a seed that has but one cotyledon, while the dicotyledonous stem has developed from a seed that has two cotyledons. In the dicot stem, the outermost portion is known as bark. This bark is composed of three layers. The outer surface is known as the cork layer which protects the stems against water loss. Below this is the cortex and below the cortex lie the phloem cells, which convoy food, manufactured in the leaves, down the stem. Just under the bark, there is a region known as the cambium layer which is the region of growth. The innermost portion of the stem is known as the pith, which serves as a storage place for food. Between the pith and cambium lies an area called the wood. The outer wood ring, next to the cambium, contains the xylem tubes which conduct the water in the plant. In the monocot stem, the functions of the tissues are similar to those of the dicot stem. A monocot stem, however, does not produce a cambium, so that all of its cells are primary and not secondary tissues. In this type of stem the fibrovascular bundles, (containing the xylem and phloem cells) scattered throughout the pith, carry soil water up the stem and food material down toward the roots. These bundles also give strength and support to the stem itself. In the monocot, the outer covering is called the rind and the direction of growth is in height rather than in both height and width as in the dicot.[12]

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[11] Theodore Colen, Biology, New York, (1949), pp. 121-125.

[12] Ibid, pp. 125-129.

Unit 3

Roots

Plants are in close contact with the soil through their root systems. Most roots grow beneath the surface of the soil and their functions are as follows:

(1) Anchorage of the plant in the soil

(2) Absorption of water and dissolved minerals from the soil

(3) Conduction of water and minerals upward into the stem

(4) Conduction of foods manufactured in leaves downward to growth and storage regions of the roots

(5) Food storage.

Roots are adapted for carrying out their primary functions by their general structure which is a long central root and many smaller roots branching out from it. The roots anchor the plant by sinking a strong foundation and by the presence of root hairs with their delicate outside membranes which permit osmosis to take place and the soil water, with dissolved mineral matter, enters the roots.[13]

Root Structure (Fig. 11)

The epidermis is a layer of cells which, together with root hairs, absorbs soil water. The cortex is made up of thin walled cells in which food is stored. The central cylinder contains the woody (or xylem) tissue and the bast (or phloem) cells. The sieve tubes convey food down from the leaves through the fibrous bark of the stem and the cortical

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[13] R. O. Alexander, An Outline of General Biology, New York, (1950), pp. 11-12.

The Root

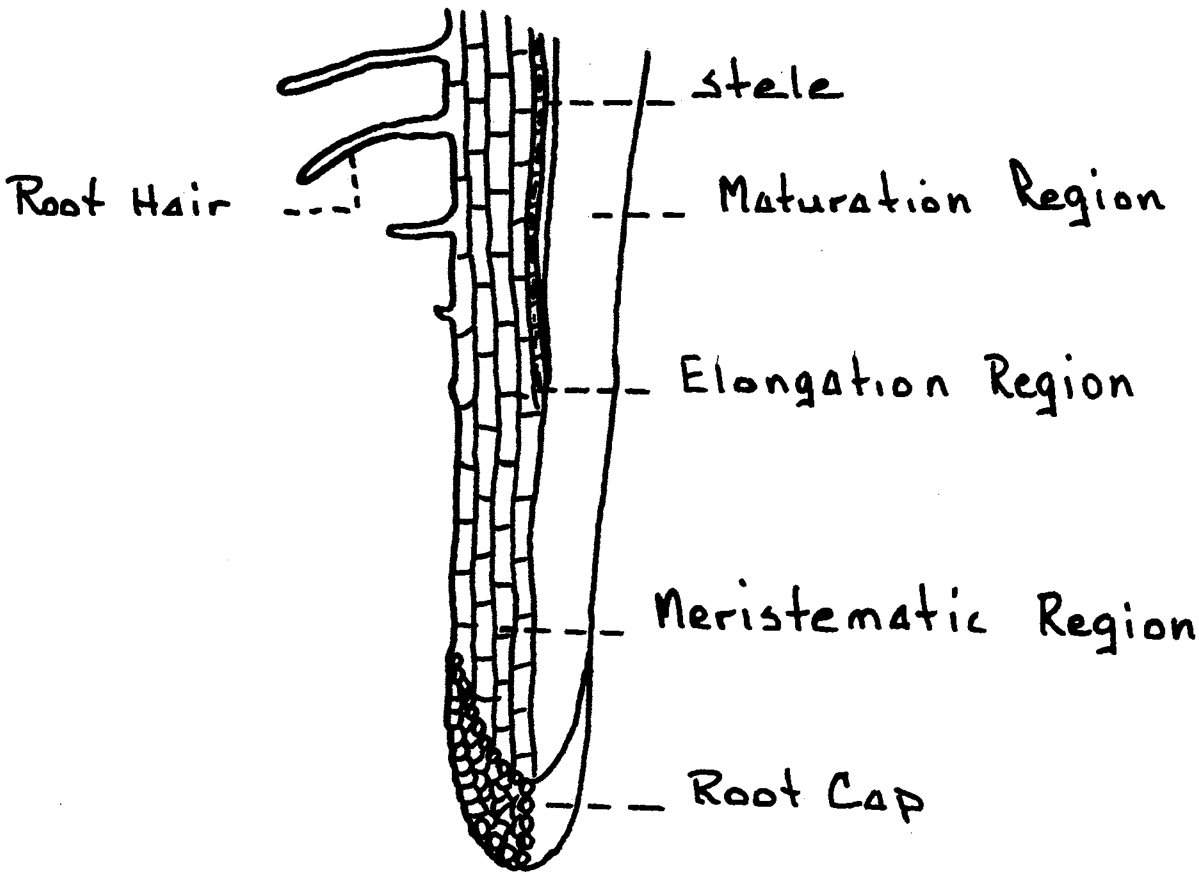

Fig. 11

layer of the root. The growing or cambium region produces new cells which are protected by several layers of dead cells known as the root cap.[14]

Experiments Associated With Roots[15]

Experiment 1.

Object - to show the region of the root through which liquids arise

Method - place a tap root such as the carrot in a red ink solution and set aside for several hours. Remove the carrot and cut a lengthwise section.

Observation - the central cylinder of the root stained red.

Conclusion - liquid arises (through ducts) in the central cylinder of the root.

Experiment 2.

Object - to show the response of roots to gravity.

Method - germinate some radish seeds on moist cotton and when the roots are about one-half inch long, place the seeds between two glass plates. Now turn the plates so that the tips of the roots point upward. After several days turn the plate so that the tips once more point upward.

Observation - each time the tips of the roots were pointed upward, they were later seen to curve around and grow downward.

Conclusion - the direction of growth of roots is influenced by gravity.

Experiment 3.

Object - to show the response of roots to moisture.

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[14]Theodore Colen, Biology - Questions and Answers, New York, (1950), pp. 130-132.

[15]Arthur G. Hoff, Secondary School Science Teaching, Philadelphia, (1947), pp. 47-49.

Method - fill a wooden box with sawdust and divide the box into two parts by means of a partition. Keep one side moist and the other side dry. Place some bean seeds that have germinated on the dry sawdust and set aside for several days.

Observation - the roots will grow toward the moist sawdust.

Conclusion - roots respond to the influence of moisture.

Unit 4

Flowers

A flower is the reproductive part of the plant; its function being to produce seeds. A flower (Fig. 12) consists of two types of organs: the essential, which includes the stamen and the pistil; the accessory, which includes the calyx and the corolla. The stamen are made up of slender stalks called filaments, which support the anthers. These anthers are box-like and are filled with pollen grains. The pistil, as a rule, consists of three distinct parts: the stigma, the style, and the ovary. The stigma is somewhat enlarged and contains a sticky substance to catch and hold the pollen grains. The style is the neck-like portion, down which the pollen tube will travel. The ovary is the expanded base of the pistil and contains the ovules or the undeveloped seeds. The sepals are green and leaf-like, and together, make up the calyx which protects the flower. The petals, also leaf-like, constitute the corolla. They are usually highly colored and thus attract insects. The essential and accessory organs are attached to the receptacle and this recepatcle later becomes a part of the fruit.

The stages in the reproductive process of the flower are as follows:

pollination, germination, and fertilization.[16]

Pollination (Fig. 12)

Pollination is the transfer of pollen from a stamen to a stigma. It is brought about by wind, water and by animals and insects. Self-pollination is the transfer of pollen to the stigma from the stamen of the same flower or to another flower on the same plant. Cross-pollination is the transfer of pollen from an anther to a stigma on another plant.

Germination (Fig. 12)

The development of pollen grains and ovules is as follows:

1. Pollen mother cells are produced in the anther sacs. Each mother cell forms four pollen grains. Meiosis, or reduction division, occurs when pollen grains are formed from pollen mother cells. Each nucleus in a pollen grain thus has half the number of chromosomes of the body cells. Each pollen grain has a tube nucleus and a generative nucleus.

2. An ovule develops inside the ovary, to the inside of which is attached by a placenta and by a stalk, or funiculus. The ovules extend into the cavity or cavities (locules) of the ovary. An ovule ready for fertilization has several layers of cells on its surface. Inside the integuments is the embryo sac, which at maturity usually contains eight nuclei, three at one end, two in the center, and three at the other end. Reduction division occurs in the spore mother cell in the ovule. One of

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[16]Ben DeLeon, A Graphic Survey of Biology, New York, (1959), pp. 258-260.

The Flower

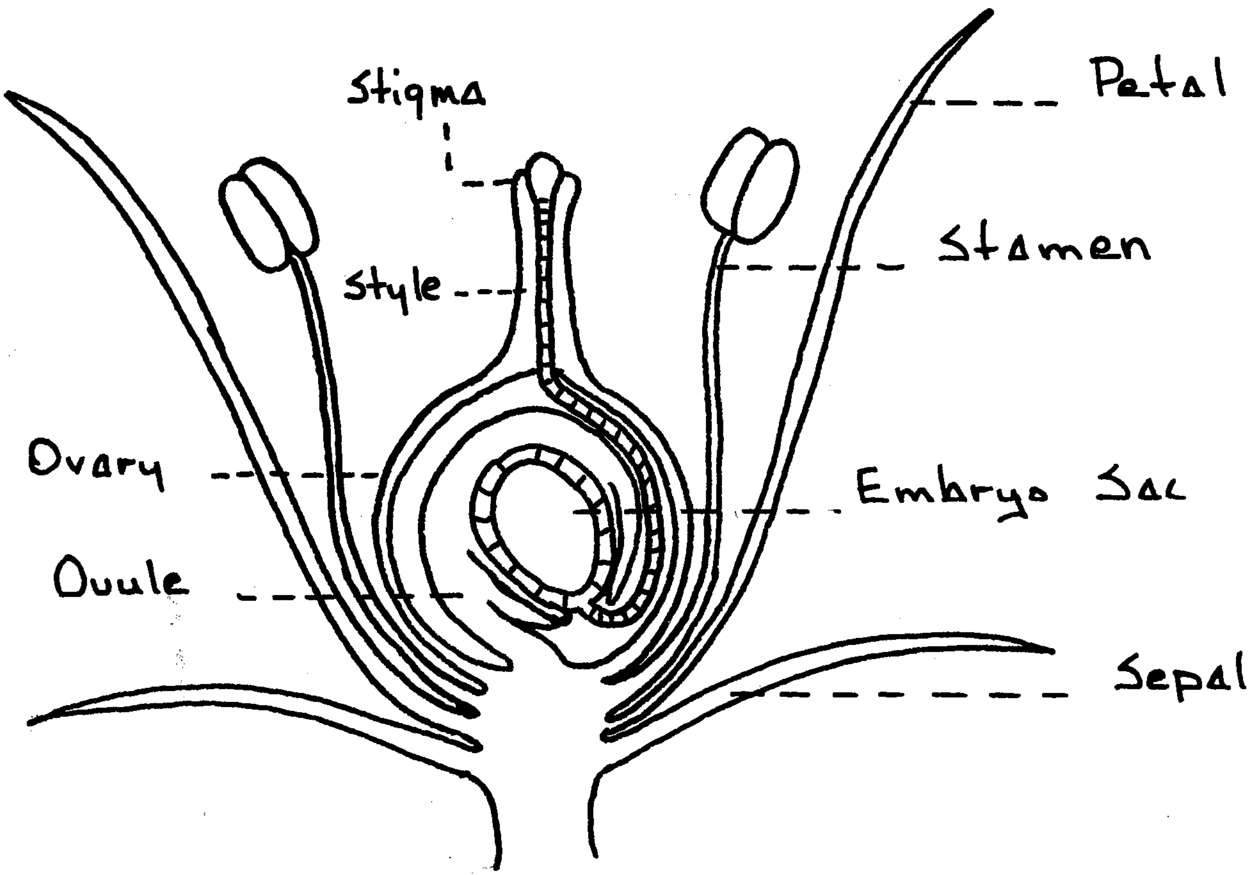

Fig. 12

the spores formed from a spore mother cell develops into the embryo sac. At the end of the ovule opposite the funiculus end is a pore (micropyle), an opening where the integuments have not closed. One of the nuclei at the micro-pylar end of the embryo sac is the egg; the other two at this end are the synergids. The two nuclei at the center of the embryo sac are the polar nuclei. The other three at the other end of the embryo sac are the antipodals.[17]

Fertilization

After the landing of a pollen grain on a stigma, which is often covered by a sticky fluid, hairs, or roughened protuberances which hold the pollen grains, these incidents occur in order:

1. The pollen grains swell, germinate, and form a pollen tube, which grows down through the style by digesting some of the stylar cells or by growing through a stylar canal, and which enters the ovary. The growth of the pollen tube is controlled by the tube nucleus.

2. A pollen tube enters the micropyle of an ovule in the ovary and discharges into the embryo sac two sperm nuclei, which develop from the division of the generative nucleus.

3. One sperm fuses with the egg nucleus, thus forming a zygote, or fertilized egg.

4. The other sperm fuses with the two polar nuclei to form the endosperm nucleus. This behavior of both sperms is known as double fertilization.

5. The tube nucleus, synergids, and antipodals disintegrate.

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[17]Harry J. Fuller, General Botany, New York, (1955), pp. 88-91.

6. The zygote by numerous cell divisions develops into the embryo of the seed.

7. The endosperm nucleus develops into the endosperm (food storage) tissue of the seed.

8. The integuments become the seed coats of the seed.

9. Following fertilization, the ovary and its ovules increase in size. In some plants, fruits develop without fertilization, a condition known as parthenocarpy.[18]

Unit 5

Variation and Heredity

One of the striking characteristics of living organisms is their reproduction of similar offspring, which are not merely of the same species as their parents but which often resemble their parents more than other individuals of the same species. However, offspring are never exact duplicates of their parents. The tendency of offspring to be like their parents is called heredity. The tendency of offspring to differ among themselves and from their parents is called variation.

Variation

Variations within a species are of three common kinds:

1. Environmental Modifications, which are differences brought about by differing environments which may surround individuals of the same species. Individuals of the same plant species growing in different types of soils, under different rainfall and temperature conditions, etc. show

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[18]Ibid, pp. 91-92.

differences in size, rate of growth, leaf size, and vigor. These environmentally induced modifications are not inherited, except possibly if the differences in the environment continue for thousands of years.

2. Mutations, which are sudden variations of genetic makeup which is entirely unpredictable in nature. They are caused by changes in chromosome arrangement. Mutations are heritable and are usually passed on from generation to generation. Mutations may develop in seeds or in buds.

3. Combinations, which are variations in the offspring of parents which possess heritable differences. These parental differences combine in various ways in the offspring and are heritable. An offspring of parents with heritable differences is termed a hybrid.

Heredity

The fundamental laws of heredity were discovered by Gregor Mendel, an Austrian monk, who in 1866 published his work on inheritance in garden peas. At first it was thought that all hereditary phenomena followed the laws discovered by Mendel, but more recently many exceptions to these laws have been found. Mendel's work was with monohybrid and dihybrid crosses. A monohybrid cross is one between parents differing in a single character. A dihybrid cross is one between parents differing in two characters. From Mendel's work on mono- and dihybrid crosses, four laws may be stated:[19]

1. The Law of Dominance - some hereditary factors dominate or control others in the offspring, thus concealing the presence of the recessive

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[19] E. R. Frank, Everyday Problems in Biology, Chicago, (1954), pp. 36-42.

factor.

2. The Law of Segregation - hereditary determiners may come together in one generation (F_1) and may then separate when that generation reproduces and forms offspring (F_2).

3. The Law of Unit Characters - each hereditary determiner is an independent unit in a cell and behaves independently of other determiners.

4. The Law of Independent Assortment - the hereditary determiners which come together in one generation may separate and combine in various ways in the next generation.

Since Mendel's work, great steps have been made in furthering the knowledge of heredity and its components. The following is a look at the problems encountered in determining the physical basis of heredity:

1. Chromosomes are the largest identifiable rod-like masses of chromatin in the nucleus at mitosis. Chromatin is organized into units, several of which are borne in linear fashion on a chromosome. Each of these units (hereditary determiners or genes) influences a single trait of an organism. Each chromosome bears numerous genes.

2. The hereditary connection between one generation and another is by means of the chromosomes of the sex cells which fuse in pairs at fertilization.

3. All of the body cells of plants and animals have two sets of paired chromosomes; one set is a descendant of the chromosomes which come from the parental sperm and is made up of chromosomes like those of the sperm; the other set is a descendent of chromosomes which came from the parental egg. These chromosomes are paired; that is, for every chromosome, of the male set, there is a chromosome of the female set bearing similar genes in similar order. In organisma with odd chromosome numbers

in their body cells, all of the chromosomes except one are usually paired. Thus, every body cell contains a number of paired (homologous) chromosomes; this is called the diploid number. This number is usually constant for every body cell of the species.[20]

It is conceivable that our knowledge of heredity will some day develop to such an extent that a eugenics program will seem to have more practical value than it does now. At the present time, however, it is the virtually unanimous opinion of biologists and social scientists that the only hope of improving the human race lies in improving its environment, in the broadest sense of the word.

Unit 6

Classification

The objects of plant classification are to arrange plants in groups for identification and to indicate, whereever possible, relationships among plants. The exact total number of the kinds of (species) plants on the earth is not known; about 350,000 species are known at the present. The science of classification is known as taxonomy.

At present, reproductive structures and behavior are the chief basis of classification, and vegetative characters are of secondary importance. Emphasis is placed on reproductive features because these are less susceptible to the influence of environmental factors than are vegetative parts of plants and are consequently more stable.

A system of classification is a complete arrangement of the major groups of plants or of all plants into a unified scheme. Different

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[20] Ibid, pp. 43-46.

botanists have proposed different systems of classification, because accurate knowledge of true relationships among certain plants is lacking and consequently opinions as to such relationships vary. A natural system attempts to classify organisms on the basis of their true relationships. A natural system is the goal of taxonomy. As more facts about relationships are discovered, artificial systems are replaced by natural systems.

Plants are classified in the following manner: Kingdom, Sub-kingdom, Phylum, Class, Order, Family, Genus, and Species. A species may be defined as the smallest unit in the classification system. It is a group of individuals of the same ancestory, of similar structure and behavior, and retain their characteristic features through many generations under natural conditions. A genus is a collection of closely related species. A family is a group of closely related genera and an order is a group of closely related families which have certain common traits but which differ in certain respects. A class is a group of related orders and a phylum is a group of related classes.

The following system of classification is most commonly used, because it is the most nearly natural system:[21]

KINGDOM ---- Plant
Sub-kingdom ---- Thallophyta (plants not forming embryos)
Phylum 1 ---- Cyanophyta (blue-green algae)
Phylum 2 ---- Euglenophyta (euglenoids)
Phylum 3 ---- Chlorophyta (green algae)
Phylum 4 ---- Chrysophyta (yellow-green and brown algae)
Phylum 5 ---- Pyrrophyta (cryptomonads, dinoflagellates)
Phylum 6 ---- Phaeophyta (brown algae)
Phylum 7 ---- Rhodophyta (red algae)
Phylum 8 ---- Schizomycophyta (bacteria)
Phylum 9 ---- Myxomycophyta (slime molds)
Phylum 10 --- Eumycophyta (true fungi)

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[21]George E. Nichols, The General Biology Course and The Teaching of Elementary Botany and Zoology in American Colleges and Universities, Science, Vols. 501, 509, 517, (1949).

Sub-kingdom ----- Embryophyta (plants forming embryos)
  Phylum 11 ---- Bryophyta (plants lacking vascular tissue)
    Class ----- Musci (mosses)
    Class ----- Hepaticae (liverworts)
    Class ----- Anthoceratae (hornworts)
  Phylum 12 ---- Tracheophyta (plants with vascular tissues)
    Sub-phylum --- Psilopsida (psilopsida)
    Sub-phylum --- Lycopsida (club mosses)
    Sub-phylum --- Spenopsida (horsetails)
    Sub-phylum --- Pteropsida (ferns and seed plants)
      Class ----- Filicineae (ferns)
      Class ----- Gymnospermae (cone-bearing plants)
      Class ----- Angiospermae (true flowering plants)
        Sub-class --- Dicotyledonae
        Sub-class --- Monocotyledonae

Each species of plant has a scientific name composed of two words; the first, which is capitalized, is the name of the genus; the second, not capitalized, is the name of the species. This system of naming is called the "binomial system". It was invented in the seventeenth century and was first used by the Swedish taxonomist, Carl Linnaeus. Following each scientific name is an initial or abbreviation which indicates the man who named that species. For example: Rhizopus nigricans, Linn. (bread mold).

CHAPTER V

SUMMARY AND CONCLUSIONS

The objective of this report has been to try to present an "ideal" method of presenting the sciences to the high school students of today. It is true that today we are living in a so-called technical world and it becomes more so each and every day. However, in the author's opinion, high school science is not the place for all this technical training. What our high school students need is a broad, comprehensive background on which to build a stronger one if the student decides to further his education in a university.

The high school instructors of today are placing entirely too much emphasis on "cramming" terms and figures into the student or requiring extensive, unnecessary memorization of technical information. Instead, teachers should attempt to present the basic information, taking first, each part and becoming familiar with its structure and functions as a single unit and then as a part of a complete system.

If this job were done effectively by the present-day high school teachers, and the technical training were left to the colleges and universities, our children would finish school with something more than just a diploma. They would finish with an understanding far superior to any educational system that has yet been devised.

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