70-25,833

VOLKER, Roger Paul, 1934-
DEVELOPMENT OF MULTIMEDIA SYSTEM FOR TEACHING HIGH SCHOOL BIOLOGY.

Iowa State University, Ph.D., 1970
Education, theory and practice

University Microfilms, Inc., Ann Arbor, Michigan

DEVELOPMENT OF A MULTIMEDIA SYSTEM

FOR TEACHING HIGH SCHOOL BIOLOGY

by

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A Dissertation Submitted to the

Graduate Faculty in Partial Fulfillment of

The Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Major Subject: Education

Approved:

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1970

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INTRODUCTION

Audiovisual aids--those that transmitted either pictures or sound--arrived on the scene in the early part of this century. Photography was one of the first technological developments that found its way into the classroom. Many of the early teaching aids consisted of stereoscopic pictures, lantern slides, filmstrips, or motion pictures. In the 1930's disc recordings came into use in the classroom. Since World War II, audio tape, instructional television, teaching machines, and programmed instruction have been making an increasing impact on classroom and individualized instruction.

Even with these developments, instruction has remained teacher-oriented. Audiovisual materials have not been thought of as legitimate mechanisms of instruction. As Heinich (1965, p. 7) puts it:

> "Materials of instruction were more often afterthoughts of curriculum planning than results of the curriculum development process. Audio-visual materials usually entered the instructional process at the classroom application level, either when the teacher was casting about for materials that might 'aid' instruction, or when the audiovisual director instituted a search of catalogs for appropriate materials."

Kemp (1968, p. 3) agreed with Heinich when he said:

> "...16mm films--along with filmstrips, slides, recordings, and other typical audiovisual materials generally--have remained just aids to instruction. They have not reached a level of widespread acceptance and careful integration into present-day teaching and learning experiences."

Several problems may be identified as reasons for the lack of speed in the assimilation of technology into teaching and learning. The resistance to change on the part of educators and school assistants is one contributing factor. The type of person identified with an audio-visual program in a school system is another factor. As Thompson (1969, p. 225) states:

> "The audiovisual practitioner was service-oriented; he hovered on the fringes of instruction waiting for a summons to appear and perform. He did not mount a determined campaign for moving into instruction, and thus he failed to bring about a single important, generally accepted change in the education of teachers or in their practice."

Additional reasons for the slowness on the part of education to make technology a part of the teaching-learning process include the high cost of machines and materials to use with them. Probably one reason for widespread use of blackboards is their relatively low cost and infrequent maintenance. Overhead projectors, film projectors, tape recorders, teaching machines, and computer terminals not only cost more to begin with, but they need constant care. They frequently malfunction. If a teacher's presentation or a learner's activities are structured around a machine that may not always work, confidence in media is shattered.

Selection of appropriate media has been another problem. Industry has been quite willing to invent machinery it believes schools will buy. But an underlying educational rationale for the use of this equipment has not been used to guide its development. As Saettler (1968, p. 115) says:

> "...Media research has had little relevance to instructional

> design. Instructional design is still an unexplored theoretical and research frontier, and at this stage in the history of instructional technology the function of an 'educational designer' has yet to be clarified, let alone implemented in instructional practice beyond the most rudimentary beginnings. There are no texts or guidelines appropriate for use in designing instructional media messages, nor do we possess a sufficient body of experimental knowledge which can provide a basis for such design."

Despite these problems, it looks like educational media is becoming increasingly more significant as a legitimate form of instruction. Kemp (1968, p. 5) firmly believes this, when he says:

> "It should be evident that audiovisual and related educational media are proving to be far more than aids. Media of these kinds are often the vanguards of change in education and, when properly considered, can affect the development of curriculum and influence the learning process itself. They are essential to effective communication in group instruction; they are the only means of communication for direct instruction in many independent-learning programs."

While reasons for the slow inception of media as a form of instruction have been outlined above, there is an additional one. It is lack of proof of the effectiveness of instruction through media.

More evidence is needed to support these assumptions:

1. Gains in learning through media are greater and longer-lasting than through traditional methods
2. Teaching and learning time can be saved through media
3. Students enjoy learning through media to a greater extent than by traditional methods
4. Certain skills or subject matter areas are more effectively taught through media

Need for the Study

It is the need to create and test the effectiveness of multi-media instruction in biology, employing a wide variety of teaching techniques and materials, that prompted this study.

Research in media has generally been the "experimental-control group" type, with the experimental group receiving instruction primarily through media and the control group being instructed primarily by a teacher.

Studies of the type outlined above usually have shown no significant difference between the instruction through media and traditional, teacher-oriented classroom instruction. These studies have been called media comparison studies because they have attempted to determine differences in effectiveness between different modes of instruction. In a critical analysis of this type of research, Knowlton (1964) stated:

> "It was the addition of a medium, not the message variable which was considered to be the variable under investigation."

He did not believe these studies were research in media because they did not separate the physical characteristics of the medium from the content and its organization, which were transmitted by the medium.

Severin (1967) summarized the problem this way:

> "Over the decades, the combination of channels has been accomplished with no theory and few rules to guide it, and the products have varied greatly. These problems are probably among the most important ones that will have to be solved before we can work toward a full understanding of the communications process and more effective use of the media, both in general mass communications, and in education."

A specific example from the area of research on the effectiveness of teaching with television points up reasons why investigations in media have contributed little to the formulation of a distinct model or conceptual framework. In a comprehensive report Stickell (1963) analyzed 250 media comparison studies of televised instruction vs. face-to-face instruction by a live teacher. He classified 217 as uninterpretable as 23 as partially interpretable because of faulty experimental design. Of the 10 that were interpretable, all showed no significant difference in learning at the .05 level between televised and direct instruction.

Much of the research in teaching biology with media has been the media-comparison type. For example, in an experiment in visual communication Dwyer (1969) showed that black and white line drawings were as effective in teaching as full color natural photographs. Dwyer's contention was that realistic illustrations sometimes have too much additional information, which may interfere with transmission and understanding of the intended information.

An experiment by Skinner, (1968) using instructional television failed to turn up any differences in achievement in any of the four types of lessons over the same material. Two of these lessons used "direct explanation" television tapes, and two used "unanswered questions" tapes. Teachers followed up each tape with a "typical discussion" or "inquiry session." The unanswered question format for both typical discussion and inquiry session seemed to have a positive relationship to achievement, but Skinner recognized a number of interactions that made if difficult to pin down a specific reason for higher achievement in any situation. The subjects were elementary students.

Programmed materials have also been used to teach laboratory science. In a study with seventh grade students Carnes, et al. (1968) use non-programmed materials in a control group and programmed materials in an experimental group. She found the significant gains for both groups, but the control group, using non-programmed laboratory materials achieved significantly higher scores than those using programmed materials. She concluded that the effect of the teacher was important, and accounted for the difference.

Frequently a question arises about the value of direct laboratory experience. In a study to compare the effectiveness of laboratory and demonstration methods, Yager, et al. (1969) concluded (p. 82):

> "It is obvious...that many of the assumptions concerning the values of the laboratory cannot be demonstrated with the testing instruments used...In fact, the value of using a large quantity of biological material--even for demonstration--has not been illustrated. The only significant advantage found to using laboratory materials was increased skill in laboratory manipulations."

The results of this study provide encouragement to those who wish to explore the use of simulated or vicarious experiences in the teaching of biology. It may be possible for students to learn biology as effectively through non-laboratory means, involving 35mm slides, films, transparencies, and other media as through direct experience in the laboratory.

While it was not a study in biology, a multimedia system reported by Smith (1969) for teaching physics summarizes some important reasons for using a wide variety of learning materials. He states (p. 332):

> "Experience with this system suggests strongly that the

standard text should not be the central focus of learning activities in a course, and that distribution of instructional load across many media is desirable...The particular text, films, stations, and other media which are involved are not as important as the nature of the system passe."

A large number of variables operate in any teaching situation. Learners react in different ways, and are affected by different stimuli. The influence of peers and teachers, the amount of need for structure, and differing abilities for learning through aural, visual, and verbal stimuli all have effects on how people learn. If a study is limited to one medium, such as audio tape, transparencies, or television, the complete spectrum of message transmission is ignored.

Research in multimedia instruction, while more complex than that of media comparison studies, may lead to a more complete understanding of the factors operating in a learning situation involving media. As Briggs (1968, p. 172) states:

"There is current interest among some educators and researchers in discovery of the unique patterns which may distinguish one student's style of learning from another's. The reviewer hazards the conjective, based on data such as the series of studies by Gagne and his associates...that if one were to design media to adapt media programs rigorously to the individual learner's general ability, special aptitudes, and entering competencies, most of the variance would be accounted for..."

Statement of the Problem

The problem was to compare a multimedia system for teaching high school biology with a conventional approach. Students exposed to both approaches were evaluated with achievement tests, attitude measures, and personality scales.

Purposes of the Study

The main purpose of the study was to develop and evaluate a multimedia system for teaching high school biology. Specifically, the following questions were asked:

1. Can achievement level be raised through a multimedia approach, when compared to conventional teaching?
2. Do students taking multimedia instruction have a different attitude toward the method, content, or their expectation of the course than students in classes where multimedia is not used?
3. Is there a relationship between achievement, attitudes, and selected personality traits that is different for students learning through multimedia when compared to students not learning through multimedia?

The purpose of employing a multimedia system was to provide a variety of means to explain concepts, clarify terms, and meet individual styles of learning. The student's role in the learning process was redefined to aid in accomplishing this purpose. Instead of passively listening to a lecture, observing a demonstration, or watching 35mm slides or a film the students were required to make overt responses to what they learned. Use of peer teaching and small group discussion techniques was integrated into the learning procedures. It was felt that individual differences in learning styles and rates should be complemented by a variety of teaching materials. There was an attempt to meet the needs for self-pacing, for viewing phenomena as well as hearing verbal descriptions, for increased time for personal contact between student and teacher, and an overall economy of time in teaching a given body of subject matter through a multimedia approach to instruction.

The teachers involved in this study performed a number of different functions in contrast to their former roles. They were involved in intensive planning meetings, making decisions on the behavioral objectives, types of media to be used, and evaluation procedures.

Briggs (1964, p. 274) outlined the teacher's role this way:

> "If, then, the teacher is no longer needed primarily for the telling and showing role, what role(s) should he adopt? Here are some possibilities. The teacher may become a counselor; a tutor; an evaluator of progress; an encourager of initiative; a rewarder of creativity; a designer of personal projects; a critic of student products; an aide in social development; a remedial loop to the program; an assigner of programs; a monitor of discipline; or a source of feedback to programmers."

The purpose of involving the teachers was to attempt to guarantee smooth teaching through the use of multimedia, and to insure that the learning activities were realistic in both depth and length. By closely examining the content and writing behavioral objectives it was possible for the teachers to play a major role in determining the direction the study should take.

Delimitations

A number of limiting factors prevent widespread conclusions to be drawn from a study of this type. Since the study ran only five weeks, and was administered to high school sophomores in a biology course, it was not possible to generalize the conclusions beyond these parameters. While teacher variables, because of the design, should not be a factor in influencing either experimental or control groups, the academic preparation and experience of the teachers undoubtedly influenced this study. The use of a number of new machines in the experimental group might have given rise to a Hawthorne Effect.

Every effort was made to delimit the conditions and educational objectives upon which this study was based. This is not an easy task, as Siegel and Siegel (1964) point out. They believe that four major classes of variables should be included in the conceptual scheme, which they term the Instructional Gestalt. These variables are 1) classroom environment, 2) instructor variables, 3) learner variables, 4) course variables. Each of these variables is defined more specifically in Chapter 3.

Definitions

For the purpose of this study these definitions were used:

1. Educational media - instruments, materials, or mechanisms of instruction, composed of hardware and software.
2. Hardware - machines such as an audio tape recorder, video tape recorder, projector, or dry-mount press.
3. Software - materials that may be used in conjunction with hardware, including transparencies, films, tapes, or slides. Software also includes maps, globes, charts, and a wide variety of printed materials

such as books, pamphlets, and programmed instruction.

4. <u>Multimedia teaching system</u> - an integrated cluster of hardware and software, plus a live teacher, creating a highly-structured learning environment. The system is based on carefully defined and sequenced behavioral objectives. Each component in the system is chosen because of its unique means of reaching a particular behavioral objective. The objectives provide a basis for evaluation of the effectiveness of the system.

5. <u>Individualized instruction</u> - a system through which individual students learn, employing audiovisual techniques and/or programmed instruction. Emphasis is on responsibility undertaken by the student himself. Use of peer interaction is employed, and frequent response to teacher queries is also called for.

6. <u>Audio-tutorial instruction</u> - a system employing audio tape, which serves as the basic guide to the instruction. Other media, such as, 35mm slides, film tapes, worksheets, drawings, or real objects are used as needed. The system may be used by individual students or small groups of students. The audio tape is recorded in a conversational style, with frequent encouragement to the student to repeat portions of the lesson or ask the teacher's help in carrying out instructions.

7. <u>Programmed instruction</u> - a sequence of concepts presented one at a time in short paragraphs called information frames. A question calling for an overt response from the student is asked after each frame. Responses may be multiple choice or short answer (constructed) response. (In this study the responses were constructed, and the program was linear).

REVIEW OF LITERATURE

In attempting to use educational media to determine if students learn more from it, the researcher often falls into the same trap as the classroom teacher. Teachers often use media because they intuitively feel that students will learn more, or that their interest level will be higher. In contrast to the teacher's lecture, blackboard notes, or teacher-centered class discussions, media does seem to offer a fresh approach. There is always a certain amount of enthusiasm if the students realize they are going to see a film, hear an audio tape, or view a videotape. Probably one important reason for the excitement is that these media are used so seldom, and the newness has not yet worn off. Like new toys, they have a great deal of appeal because they are novel.

Teachers may inadvertently choose media for other reasons. The teacher whose hobby is photography finds himself using 35mm slides a great deal. One who has experience in film production may make a number of films for teaching. Others who have a talent for drawing, or simply like to make transparencies may design a number of these materials for teaching. Audio tape, video tape, and various forms of commercial media such as filmstrips or study prints may be chosen by the teacher simply because of personal bias, and not because of a sound rationale.

The lack of systematic planning for the use of instructional media is only part of the problem. An equally important, or perhaps the most important step in the design should be construction of appropriate evaluation instruments that match behavioral objectives. Classroom teachers often do not write specific behavioral objectives for each unit, whether or not they use media. Consequently, when tests are constructed, there are no specific criteria for choosing the items. The teacher may leaf through the chapter, go over his notes, or simply reflect on what he said as he writes test items. A number of areas of the instruction are left out of a test because of this. Normally the test items do not go much beyond the recall stage. Little attempt is made to design test items to measure the student's ability to synthesize information or apply concepts to new situations in an evaluative or inductive process. Unless a classroom teacher has access to a computer program that can provide an item analysis of his tests, he has no idea of the test's reliability, or how it ranks in terms of item difficulty, or discrimination analysis.

There is need to establish some sort of sound theoretical basis for designing instruction, whether it be multimedia or not. Gilpin (1962, p. 81) emphasized the importance of base lines. He said:

> "...When an important instructional task is adequately specified, an instructional system is designed to meet the specifications, and...when the results are published...a base line will have been established. At present, when instructional objectives are almost never stated in detail, and when program tests are often constructed informally, it is usually not possible to produce an alternative instructional method with full confidence that its results are really comparable to the results of the original method."

Several researchers have offered schemes for the design of instruction with media. In a rather detailed analysis of the psychological bases for instructional design, Glaser (1966) lists these four design components: 1) Analyzing the characteristics of subject matter competence. 2) Diagnosing pre-instructional behavior. 3) Carrying out the instructional process. 4) Measuring learning outcomes. Glasier goes on to describe each of these components more fully, and emphasizes the importance of full consideration of the ramifications and procedures for accomplishing each.

A broader view of educational research in general is offered by Siegel and Siegel (1964). They propose a conceptual framework and design for educational research called the Instructional Gestalt. Because data from media comparison studies or other typical educational research studies that attempt to show a difference between two methods of teaching is, they feel, not properly designed, resulting data may be grossly descriptive, but indicate little of what occurs during the teaching-learning process. They say (p. 20):

> "The time is long overdue when investigators stop inquiring whether one mode of presentation is as good as another and undertake instead the investigation of those conditions thought to optimize the realization of educational objectives under clearly specified and delimited conditions."

They specify more completely the four major classes of variables included in the conceptual scheme; classroom environments, instructor variables, learner variables, and course variables. Using instructional television, Siegel and Siegel applied the Instructional Gestalt model to an experimental situation. Three variables were investigated: manifest objectives, ability, and prior knowledge. All gave rise to significant main effects. The researchers stated that (p. 34):

> "These findings are typical of those resulting from what we have previously referred to as comparative studies and could have

> been derived without recourse to the Instructional Gestalt framework."

However, significant interactions between manifest objectives x ability, ability x prior knowledge, and manifest objectives x ability x prior knowledge were also found.

It appears that multimedia instruction can be individualized to maximize learning. Travers (1964) has listed several guidelines to assist in developing new techniques of presentation suitable for individualized instruction. They are:

"a. Pictorial material included with printed material does little to aid retention of the printed material.

b. In transmitting information through two sensory modalities, with redundant information, nothing is gained for learning.

c. Special effects were not found to enhance learning consistently.

d. Oversimplification can have a deleterious as well as a facilitating effect.

e. Some verbalization with a film presentation is better than none, but there is an optimal amount.

f. Verbalization of response and furnishing of knowledge of results appear to be the most effective participation techniques. Notetaking is of doubtful value for audiovisual presentations. Film-mediated processes such as the insertion of questions within a film still require further investigation.

g. It may well be that practice of responses to be learned during a film will be beneficial, partly due to added motivation; active participation is more helpful with more difficult material."

The need for research in multimedia instruction has been pointed up by others. Meierhenry (1962) has identified broad areas of research involving multimedia, the learner and his characteristics, and the teacher. He has suggested specific research projects involving interactions between the learner and media, interactions of teacher, student and media, multimedia characteristics, motivations and attitudes of the learner, systems analysis, and operational problems.

Design of Instructional Systems

The question, then, is not whether to use media, but how to use it. How can conceptual models based on what considerations, serve as a basis for designing an instructional system that uses a teacher and media and is individualized?

A logical starting point is to examine what the learner should be able to do when he is finished. Behavioral objectives, stated in terms of the learner's behavior, spell out what he should be able to do after he has learned. The objectives also contain a statement on the mechanism for evaluating the behavior.

One attempt to identify and classify behavioral objectives has been proposed by Bloom (1956). He lists six levels, arranged in order of ascending complexity:

1. Knowledge
2. Comprehension
3. Application
4. Analysis
5. Synthesis
6. Evaluation

The rationale for this hierarchy is discussed by Bloom, who says (p. 18-19):

"Our attempt to arrange educational behaviors from simple to complex was based on the idea that a particular simple behavior may become integrated with other equally simple behaviors to form a more complex behavior. Thus our classifications may be said to be in the form where behaviors of type A form one class, behaviors of type AB form another class, while behaviors of type ABC form still another class. If this is the real order from simple to complex, it should be related to an order of difficulty such that problems requiring behavior A alone should be answered correctly more frequently than problems requiring AB. We have studied a large number of problems occurring in our comprehensive examinations and have found some evidence to support this hypothesis. Thus, problems requiring knowledge of specific facts are generally answered correctly more frequently than problems requiring a knowledge of the universals and abstractions in a field. Problems requiring knowledge of principles and concepts are correctly answered more frequently than problems requiring both knowledge of the principle and some ability to apply it in new situations. Problems requiring analysis and synthesis are more difficult than problems requiring comprehension. Scatter plots of the performances of individuals on one test composed of items at a simple level in the taxonomy against their performances on another test composed of items at a more complex level in the taxonomy show that it is more common to find that individuals have low scores on complex problems and high scores on the less complex problems than the reverse."

Since Bloom, others have developed schemes for classifying learning. Gagne (1965, p. 58-59) outlined eight types of learning, each with its own criteria, and arranged them in a hierarchy from simple to complex. He assumed that each higher order learning category depends on the mastery of the one below it. The categories are:

Type 1. Signal learning

Type 2. Stimulus-response learning

Type 3. Chaining

Type 4. Verbal association

Type 5. Multiple discrimination

Type 6. Concept learning

Type 7. Principal learning

Type 8. Problem solving

Gagne feels that these learning types represent a hierarchy, with higher types dependent on those that are lower. In other words, a student must be able to make verbal associations before he can apply the principle of multiple discrimination.

This hierarchy of learning types can serve as a guideline for sequencing learning activities. In structuring a multimedia unit it is necessary to cause the learner to pass sequentially from one type to the next. The goal of such instruction should be to enable the student to solve problems or evaluate new situations.

Briggs and others (1967) have reviewed relevant research, including short-comings of present media research, and have made recommendations for future research. They believe the common media comparison study cannot result in improved instructional design. A more complex model is needed, in which variables involving the teacher, student, and media are considered. With such a model it should be possible to use a single medium or multimedia for the optimum length of time for the most appropriate set of objectives. It is necessary to weigh the alternatives of group instruction, individualized instruction, teacher-conducted instruction, and automated instruction.

Briggs (1967) presented an eight step sequence leading to a prescription of the media to be employed for the design of multimedia instruction. His eight steps are listed below (p. 228, 252):

"1. Selecting and defining the objectives of instruction and stating them in terms of behavioral outcomes expected for the students.

2. Sequencing the objectives in such a way that component or prerequisite knowledge is acquired prior to more complex learning.

3. Identifying for each objective the type of learning represented.

4. Listing for each objective the sequence of instructional events which would provide the general conditions of learning required for the type of learning represented by the objectives.

5. Identifying for each instructional event the nature of the stimuli (such as intensity, duration, and requirement for motion).

6. Identifying tentatively the optimum medium for presenting each stimulus described in the preceding step.

7. Reviewing sequences of objectives in an overall fashion in order to make media choices that would permit use of one medium of presentation for a reasonable length of time before changing to another medium during the instruction.

8. Writing specifications representing instructions to the specialist who will prepare material for each medium, such as for the programmer of automated instruction, the script writer for filmed instruction, etc."

The capabilities of the media are an important consideration in the design of multimedia instruction. Briggs believes the design should have these characteristics (p. 252).

"1. Capability of alternating rapidly among audio, static visual, and moving stimuli.

2. Capability of automatically turning on and off several mechanisms for presenting stimuli, such as motion pictures, tape recorders, and static displays.

3. Random access of the various stimulus materials.

4. Capability of preprogramming the instruction so that the

various devices are turned on and off in accordance with a prearranged schedule, with the added capability for modifying the program in a branching fashion.

5. Capability for instructor monitoring and override so that individual difficulties may be remedied with the assistance of the instructor."

Briggs' basic design for multimedia instruction was implemented by Smith, Schagrin, and Poorman (1967) when they did a study using multimedia to teach a unit of the Harvard Project Physics. They designed their multimedia system in hope that the traditional role of the teacher could be changed from that of a lecturer/demonstrator to that of tutor and guide. They found increased instructional effectiveness, especially in individualized instruction. The emphasis in their study was on student activity and providing students with demonstrations spurring them to deeper thought on problems and problem situations. The multimedia system as they designed it does not attempt to wrap up each concept in neat packages before going on. The appearance of a multimedia class changed from day to day, with emphasis on student activity and the guidance-tutorial role for the teacher. They state (p. 363) that:

> "Over a period of days, one observes variety in the type of presentation, from films to laboratory stations to small group discussions to programmed instruction. Later units of the course use role-playing, debates, and other class activities designed to bring out the historical and philosophical dimensions of physics more strongly. The multimedia group takes seriously the implications of contemporary research in teacher effectiveness: that employing a wide range of techniques, rather than using any one technique, makes for successful teaching."

Learner Variables

While Bloom, Gagne, and Briggs have provided a conceptual framework for considering the design of cognitive teaching, other factors are also important. Snow and Salomon (1968), urge media specialists to consider the inclusion of aptitude variables in their thinking and in their work. They state (p. 354) that:

> "...Most previous research has pitted instructional media and methods against one another without concern for individual differences. While one cannot really argue that none of the treatment variables studied thus far produced general effects across all students, it is appropriate to ask how many such studies have masked real and important interactions by averaging in overall comparisons. Truly general effects will never be separated from important special effects till the possibility of interaction is directly investigated."

Edling (1963) feels that techniques employed by behavioral scientists can make a significant contribution to development of more effective instructional materials. The analysis of characteristics of learners can assist in structuring the content of materials.

Need for consideration of the learner and his characteristics is further emphasized by Hilgard (1955, p. 3), who states:

> "It is surprising that, after all these years of doing it, we know so very little about effective teaching. It is surprising that studies of class size, discussion vs. lecture, and teaching aids such as motion pictures and TV point to so few differences in the effectiveness of teaching. My guess is that they fail, however, to understand the subtle differences made by kind of student, kind of teaching setting, and kind of long-range goals that are operative."

Cronbach (1957, p. 681) stated that:

> "...we should design treatments, not to fit the average person, but to fit groups of students with particular aptitude patterns. Conversely, we should seek out the aptitudes which correspond to and interact with modifiable aspects of this treatment."

"Aptitude" is a general term that implies a large number of characteristics. Snow and Salomon (1968, p. 347-348) define aptitude as:

> "...Any individual difference variable which functions selectively with respect to learning, and which appears to facilitate learning in some students and some instructional treatments limiting or interfering with learning in other students and other instructional treatments. The term does not mean general mental ability."

In a study designed to look at interaction of selected aptitudes with achievement, Snow, Tiffin, and Seibert (1965) found that highly active, self-assured, assertive individuals receive live instruction best, while students characterized as passive observers, lacking self-confidence, and dependent on others received instruction from films best. They also found that low responsibility students, those unable to stick to tasks that did not interest them, and who were flightly or irresponsible, seemed to profit more from live than from filmed demonstrations.

It has already been shown that studies on the relationship of achievement to the use of various forms of media does not always conclusively indicate a significant higher level of achievement when media are used. However, other components of the instructional process in addition to achievement alone have been considered by a number of investigators. One of these concerns the relationship of interest and attitude in traditional, teacher-centered instruction.

The question of interest in media instruction was investigated by Becker (1964). While he admits that interest is a complex factor, he believes it is made up of two components: fixation on a stimulus, and level of tension. He believes optimal learning from a program should be facilitated when a tension is focused on the desired part of the field and when a learner is in a relatively high state of tension. While he believes that interest may raise achievement levels and increase retention of information, his results were inclusive.

Measurement of Learner Variables

Studies indicate that fruitful research might be done in the attempt to relate personality variables to achievement through multi-media instruction. One of the main problems, of course, is adequate measure of the personality variables for each individual learner. The need for achievement, anxiety, introversion-extroversion tendencies, and other personality factors may vary depending on the instrument used in measuring.

Using response profiles of interest in instructional TV programs and galvanic skin response, Becker (1963) measured retention and attitude change. He concluded that whether members of the audience retain information from the program has very little to do with whether they think the program is interesting, or whether the program increased tension in the audience.

An attempt to measure longitudinal changes in attitude toward learning involving various kinds of media has been studied by Neidt (1964). A 26 point scale was constructed to measure attitudes toward programmed instruction, television, small class instruction, and large class instruction. The scale used 13 favorable or positive items, and 13 unfavorable or negative items. Sixteen statements pertained to the area of method, five to expectation, and five to content. Some sample statements were: "I am satisfied with the methods used for teaching this class (method)"; "This class exceeds my highest expectation (expectation)"; and "The subject matter of this class is interesting (content)." In using the attitude scale five times during each of the four instructional procedures, the investigators found a decline in attitude, but attitudes towards the four methods were widely separated. The most favorable attitude was toward programmed instruction, with a marked decrease for television instruction, and even lower attitude for small class instruction, and the lowest attitude toward large class instruction. The investigators offered one possible explanation for this striking difference in attitudes. They believed that both programmed and television instruction were relatively newer methods for most of the students than small or large group instruction, and the novelty or Hawthorne Effect might account for the high attitude. However, since programmed instruction and television instruction attitudes did not decline to the point of the small and large group instruction attitudes, they believe a simple relationship between novelty and attitude is not adequate to explain the results.

The 26-item attitude scale developed by Neidt was used in this study to measure attitude toward expectation, content, and method.

Programmed Instruction, Attitudes and Achievement

While it was pointed out in the introduction that research on the effectiveness of multimedia systems in relation to achievement, student attitudes, and learner variables is indeed lacking, studies of individual media may provide some guidelines for the design of certain components of an individualized multimedia teaching system.

Of all forms of media, programmed instruction, films, and educational television have stimulated the most research. Traditional films, those designed for classroom use, have most often been used as group teaching devices. The same is true for educational television. Neither of these two media is individualized in the sense that the learner can obtain knowledge of correct results, recycle through the program in remedial loops, or move at his own pace. Since the thrust of this study is toward individualized instruction, programmed instruction will be reviewed more carefully.

In an excellent review of the literature on programmed instruction up to 1963, Schramm (1964) was interested primarily in the question, "Do students learn from programmed instruction?" The research was reviewed on the basis of characteristic variables of ordered sequence, short steps and few errors, constructed response, immediate knowledge of results, working at the learner's own pace, and reinforcement of correct response. His annotated bibliography of 195 references provides sources for answers to the above question, but it is difficult to say "yes" or "no" without qualifying it. Age of student, branched or linear instruction, size of step, length of remedial loops, and type of subject matter all must be spelled out. Some of the variables to consider are discussed below.

Lindvall (1964) investigated changes in attitude and interest through the use of programmed instruction. He found that students were significantly more attentive when studying programs, and concluded that programmed materials can be more effective than non-programmed materials in holding student attention. He believed the data indicated that students do not necessarily become less attentive as they use programs over a period of time. As far as attitude was concerned, he found that it did not seem to be a factor in determining how well a student learned from a program.

The evidence seems conflicting on this point, however. Frey, et al. (1967) studied attitude change in programmed instruction related to achievement and performance, and found that negative attitude change toward programmed instruction was accompanied by a marked decline in achievement. These researchers concluded that the intensive use of programmed materials over a long period of time without relief through other modes of instruction should not be recommended. Instructional procedures should be varied frequently. Programmed instruction offers no means for an easy solution to the variation in instructional patterns. On the other hand, they point out this is no more true for programmed instruction than for films, lectures, television, textbooks, and workbooks. They concluded that a variety of materials, in other words a multimedia approach to teaching probably would have the great advantage of maintaining student interest.

In a study to determine whether pupil anxiety and creativity were related to achievement in a programmed instruction unit on geography, O'Reilly and Ripple (1967) found that anxiety contributed negatively to achievement. They were unable to measure conclusively the value of creativity. Of equal importance in achievement in programmed instruction they found intelligence and pre-instructional achievement were the main factors.

Using a scrambled book programmed text in genetics, Burmester and Lawson (1963) found that students in three different ability groups reacted differently to programmed instruction. Those in the lowest group prospered the most, and those in the most able group profited least.

The relationship of attitude and achievement in programmed instruction was investigated by Eigen (1963). He found that high ability students were favorable toward the use of programmed material, especially if it was presented by a machine. However, student attitude toward the material or the method of presentation was not shown to have an influence on achievement.

In comparing programmed instruction with other methods of presentation, Ripple (1963) found that those receiving programmed instruction produced significantly higher results on a post-test when compared to students doing conventional reading or attending a conventional lecture. He found that programmed instruction produced an increase of seven to 16 percent in learning efficiency over conventional reading of the same material.

Researchers frequently find programmed instruction to be an efficient, time-saving method of instruction. Diamond (1968) found that the use of programmed instruction in teaching biology saved enough time to make it possible to add new objectives to the laboratory work.

Postlethwait, Novak, Murray (1964) found a direct relationship between amount of time spent in individualized instruction and achievement. Their conclusion was that the more time a student spent in individualized instruction, the more he learns. Their results showed a positive correlation between time and achievement for high, middle, and low ability students.

Campbell (1963) investigated the use of by-passing in linear programmed instruction, and found that there was a slight tendency for high ability students to finish the program sooner. In other words, by-passing was a time saving device. This indicates that programmed instruction, while it may not account for difference in achievement, may allow a student to complete a program sooner, and thus go on to new information. The student may be able to explore a greater breadth or depth of a subject.

The consensus of research on programmed instruction seems to be that outcomes depend to some extent on student variables, sequencing, size of information frame, and format (linear or branched). Perhaps the mechanics of the program are not as important as content. Payne and Krathwohl (1967) found that scrambling of frames did not interfere with topics having logical development. They found no confirmation for the hypothesis that students with high ability might be able to overcome the effect of scrambling more than low ability students.

Niedermeyer (1968, p. 315) contends that:

"...a programmer manipulating frames in search of an optimal sequence is wasting his time if those frames do not contain instruction pertaining to all subordinate tasks that the learner must be able to perform in order to acquire the final task."

In a review of literature relating to the design and evaluation of multimedia instruction the following considerations emerge:

1. Systematic planning (pre-testing, writing behavioral objectives, choosing media appropriate for the learning task, and post-testing) is important for a system to be successful.
2. Instruction should be individualized so that learners can move at their own pace and re-cycle when necessary.
3. Learning activities should require a range of skills, including learning of terms, synthesis and evaluation of new information, and problem solving.
4. A wide variety of learning activities should be incorporated into the system to provide for a large number of learning styles.
5. Provision should be made for measuring a number of learner variables such as attitudes, aptitudes, and personality characteristics in addition to achievement.
6. Interactions as well as main effects should be considered in the analysis of the effectiveness of a multimedia system.

METHODS OF PROCEDURE

The purpose of this study was to compare a multimedia system for teaching high school biology with a traditional, non-media approach. Students exposed to both approaches were evaluated with achievement tests, attitude measures, and personality scales.

Objectives

1. To determine if achievement as measured by test scores could be increased in high school biology through the use of programmed instruction, film loops, slides, audio tape, and other forms of media, as compared to achievement through traditional instruction. The instruction was student-centered rather than teacher-centered. Students could pace themselves, reworking material they did not learn completely the first time.
2. To determine how students felt about instruction through media. A 26-item attitude scale developed by Neidt (1964) was used to measure student attitude toward expectation, content, and teaching method (Appendix H).
3. To determine what relationship existed between personality traits, achievement, and attitude. Four scales to measure aspects of personality were constructed, based in part on Rotter's theories of personality dealing with internalizers or externalizers.

Hypotheses

Three general hypotheses are listed below, with evaluations stated for each. Differences were considered significant if the calculated F value was larger than the value from an F table (Snedecor and Cochran, 1969), measured by a 2-tailed test at the .05 level. The F value for a highly significant difference was taken from the F-table at the .01 level.

1. There is no significant difference in achievement between students receiving traditional instruction in high school biology and those receiving instruction through educational media, as measured by these achievement tests:

   a. Pre-test

   b. Test on photosynthesis

   c. Test on lower plants

   d. Test on vascular plants

   e. Post-test

2. There is no significant difference in attitude toward types of instruction between students receiving traditional instruction in biology and those receiving instruction through media, as measured by an attitude scale to determine attitude toward:

   a. expectation

   b. method of teaching

   c. content

3. There is no significant difference in personality traits between students receiving traditional instruction in high school biology

and those receiving instruction through educational media, as measured by a scale to indicate:

a. Social locus of control

b. Academic locus of control

c. Need for structure

d. Social desirability

Assumptions

Students were normally and independently distributed in both the experimental and control groups with respect to IQ, grade point average, ITED composite scores, and ability in biology, as explained in the section on Selection of the Sample.

Teacher characteristics had approximately equal effects in both experimental and control groups, since each teacher taught some sections of both experimental and control groups. The usual assumptions underlying analysis of co-variance and regression were assumed.

Selection of the Sample

The sample for this study consisted of students enrolled in 12 sections of biology in the Ames High School. The study was conducted from November 17 to December 19, 1969. The total number of students involved was 311. Of these, 159 were in the experimental group and 152 in the control group. Most of the students were sophomores, although some were juniors and a few were seniors. While there was no reason to believe the students were assigned to sections by ability or because of other criteria, neither was a conscious attempt made at the high school to make assignment to sections by a table of random numbers. Thus, even though they were not specifically chosen at random, the distribution approached randomization.

It was decided to use all of the students taking biology to make up the experimental and control groups, rather than draw a sample. Six sections were arbitrarily designated as the experimental group, and six as the control group.

The high school used two identical classrooms for teaching biology. The rooms were side by side, with a preparation room and greenhouse shared between them.

Assignment of Teachers

The three biology teachers at the high school were involved in the study. They were assigned the following sections:

Table 1. Assignment of teachers to sections

Section Number	Experimental Section Teachers	Number of Students	Control Section Teachers	Number of Students
1	Teacher A	29	Teacher B	28
2	Teacher B	28	Teacher A	30
3	Teacher C	28	Teacher A	29
4	Teacher B	27	Teacher C	26
5	Teacher A	24	Teacher B	23
6	Teacher C	29	Teacher A	28
	Total	165	Total	164

Because of other teaching assignments it was not possible to insure that each teacher taught the same number of experimental and control sections. Insofar as possible each teacher was assigned equal numbers of experimental and control sections.

Because certain data was unavailable on IQ, grade point average, or ITED scores for some students by the time analysis was made, these students were dropped from the study. Six students were dropped from the experimental group, and 12 from the control group.

Selection of Content

The following considerations were made in designing the learning experiences for the students.

1. Opportunities should be provided for non-directive teaching. Teachers should use a variety of techniques that employ students ideas, asking students to work out solutions to questions, problems, and procedures that are posed, in contrast to direct lectures.
2. Opportunities should be provided for students to assume responsibility for learning. Programmed instruction, worksheets, laboratory instructions, and projects that require the student to make specific responses should be utilized wherever possible. Students should make responses to each other or to the entire class as well as responding to the teacher only.
3. Learning experiences should be realistic. Since the study of biology utilizes living and preserved plants and animals, it

was considered important for any media substitution of these real objects to be as realistic as possible. This principle guided selection of the films, slides, transparencies and drawings used in the student materials.

Because of limitations of time and equipment, it has traditionally not been possible for the classroom teacher to show many unusual phenomena, or to have students see or use much unique apparatus. Through films, slides, and transparencies, the students were brought closer to these important experiences than if they merely heard a verbal explanation.

4. Behavioral objectives should be made clear to students. The importance of specifying behavioral objectives and evaluation criteria has been a recurring theme in all of the research on media. Many studies are considered by researchers to be of little value because behavioral objectives and evaluation criteria for them have not been clearly specified in the studies. Furthermore, students frequently are kept in the dark in regard to behavioral objectives. Specific behavioral objectives (Appendix A) were designed for this study, and were carefully explained to the students. The behavioral objectives were a part of the student's study material, and furnished them with guidelines around which they could organize their learning through the programmed instruction text material, and the audio-tutorial laboratory work.

5. Preplanning involving the teachers is a necessary requisite. Studies in media often are set up by the researcher independent

from the classroom teacher, yet it is the teacher who must deal with the students and the subject matter for which the study was designed. An important guideline for designing media research is that of involving the participating teachers in as many phases of the planning of the study as possible. This step was stressed. Teachers participating in the study were a part of the planning team and helped develop each day's lesson. They assisted in the writing and sequencing of the behavioral objectives, made suggestions regarding the media to be used, and helped write the tests. They also aided in the selection and scheduling of topics as well as developing lesson plans (Appendices B and C).

The subject matter was selected from three chapters and laboratory work from a forthcoming biology text (Trump and Volker, ca. 1970). The content is summarized below:

Text	Laboratory Work
Photosynthesis (Chapter 8)	Leaf structure
Lower Plants (Chapter 9)	Exercises on photosynthesis
Vascular Plants (Chapter 10)	Bryophytes
	Algae
	Stems and roots

The materials represented a cross-section of biology, and were appropriate for the high school biology course. By late November, when the study began, students were accustomed to the class work, to their teacher, and to the classroom.

The gross characteristics of the instructional systems for the experimental and control sections were as follows:

	Control sections	Experimental sections[1]
Text	Mimeographed, in traditional paragraph form	Spirit duplicated, in linear format programmed instruction; constructed responses.
Teacher	Lectured, performed demonstrations, conducted laboratory work from time to time	Acted as tutor to individual groups during laboratory work or during discussion periods.
Laboratory	Large group instruction, with students doing exercises, filling out worksheets, making observations through the microscope from time to time	Individualized, with students working in small groups. Instruction through multimedia, audio-tutorial lessons.

Both the experimental and control groups had certain elements in common, in addition to studying the same content. The three teachers each taught experimental and control sections. The same evaluation instruments were used in both. The only media common to both were five 16mm sound films.

[1]Samples of the programmed instruction used are included in Appendix D. A list of specific media for each laboratory exercise is included in Appendix E. Laboratory exercises are in Appendix F.

Programmed Instruction

The text material had been used by the three teachers at the Ames High School for the past three years, in field-testing Foundations of Life Science. The control sections continued to use 8½ x 11, single-spaced, mimeographed copies. Each chapter contained about 15 pages of material. There were no illustrations, although additional references, such as periodicals and other biology texts were available.

The experimental sections used copies of spirit duplicated materials, in booklets consisting of about 40 pages. The program was linear. Each page contained the answer to the previous frame, a new frame of information, and a question about that frame. Students constructed short answer responses on the page, then turned to the succeeding page for the answer.

The information frames paralleled the control group materials paragraph by paragraph, and only minor changes were made in writing style. There were 36 frames in the chapter on photosynthesis, 44 in the chapter on lower plants, and 46 in the chapter on vascular plants. Principles of writing programmed instruction (Markle, 1964, p. 21) were followed.

To insure that the students actually completed their programs, the instructors collected the programs prior to each achievement test.

Audio tapes were used to acquaint students with the procedures of working through each program. Each student, prior to starting each chapter, listened to a five minute audio tape, using headphones. Important aspects of the chapter were pointed out, and the student was also asked to look over the accompanying laboratory work. Ten tape recorders were used, and passed from student to student during one class period. Both cassette and reel-to-reel tape recorders were used. For review, or for students who missed class that day, the orientation tape was left in the classroom for several more days to be used as needed.

Laboratory Work

In the experimental sections formal laboratory work took the form of small group audio-tutorial lessons. Because there was not enough equipment to set up 25 or more individual stations, four or five clusters of equipment were used. Each cluster consisted of a tape recorder, a listening station with eight headphones, a super-8 film loop projector, and a slide projector. Two tables were pushed together and students arranged their chairs around the equipment in a semi-circle.

Laboratory exercises were duplicated, and handed out with the programmed instruction. The laboratory work was not programmed. However, there were drawings to label, diagrams to construct, and spaces to record data and summarize answers.

The audio tape served as the guide to the laboratory work. Students were asked to reverse it at any time if they wanted to review, or to turn it off if they wanted to discuss a point. At several places in each tape the students were told to stop and discuss within their group certain questions regarding the laboratory work.

Little traditional biology apparatus was called for, though it was available for demonstration purposes. For example, in studying stem structure, 35mm slides were used by the students. However, they could observe microscope slides of the same materials if they wished.

In one exercise dealing with photosynthesis the audio-tutorial format was not used. This exercise involved a great deal of apparatus, and it was felt that, because of the specific content of this exercise, it was more profitable for groups of two or three students to work directly with the apparatus.

The control sections received traditional instruction in laboratory work, but it was less structured. Some worksheets were used, and live cultures of algae were available. There was little interaction between teacher and student, however, or between students. Infrequent small group discussion was required, and students were not often asked to observe and record data, then interact with others to determine its significance.

The Role of the Teacher

Teachers of the control sections were asked to continue teaching in their usual way. They performed demonstrations, showed films, directed laboratory work, discussed each section of the chapter, and answered questions when students asked them.

In contrast to the teaching activities described above, there was an attempt to change the teachers' role in the experimental sections. The teacher was asked to serve as a tutor, or discussion leader, in counseling with the small groups as they worked through laboratory exercises.

Since the laboratory exercises and use of programmed instruction required more class time, there was less time in the experimental sections for the teacher to give formal lectures, or lecture demonstrations.

As mentioned previously, 16mm films were used in both experimental and control groups. However, in the experimental sections guide sheets were prepared as study aids to the students. These guide sheets were adapted from the film guides available with the commercial films, and included terms, an overview of the film in outline form, and discussion questions for follow-up.

Method of Collecting Data

Several evaluations were used to gather data on both the experimental and control group. These consisted of a pre-test, three achievement tests on content, a post-test, an attitude scale measuring three types of attitudes, and four measures of personality variables.

Pre-test To assess progress up to the point just prior to the study, a 40-item test was given over the immediately preceding chapter. The pre-test was used to provide an index of each student's ability in both the experimental and control sections. It was also thought that pre-test scores could act as a co-variate if differences between the experimental and control groups were not equalized on the basis of the three scores (IQ, grade point, ITED composite) designated as co-variates.

Achievement tests Student achievement from instruction in each of the three units in the study (photosynthesis, lower plants, vascular plants) was measured by a 40-item achievement test. The testing schedule is in Appendix B.

The items, in as far as possible, were written to evaluate the behavioral objectives. The answers were entered on IBM 5-choice answer sheets and item analyzed to produce class means, variance, standard deviation, average item difficulty, reliability, error variance, and error of measurement for both raw scores and T-scores.

Post-test The post-test, was given a month after completion of instruction as a part of the first semester final exam. The first 30 items of the final were used as the post-test. Ten questions were taken at random from each of the three unit tests to make up that section of the final.

The pre-test, three achievement tests, and post-test are in Appendix G.

Measurement of attitudes An attitude scale was administered to both experimental and control groups at the time the final exam was given. It was the assumption that attitudes in the control group did not change because the instructional process was not altered during the study. By contrast, any changes in attitudes of the experimental group could be ascribed to the effect of multimedia instruction.

The 26-item attitude scale developed by Neidt (1964) was used to determine attitude toward expectation, content, and teaching method. The items were arranged in the Likert format (1932), and a set of directions prepared. Students recorded responses on a continuum on a 10-choice IBM answer sheet. Results were hand scored, since it was considered impractical to use machine scoring. Some items were weighted positively and some negatively. Table 2 indicates the positive and

Table 2. Positive and negative loading for each of three attitudes measured by the 26-item attitude scale

Expectation	Content	Method
2-	5-	1+
7+	9-	3-
12-	13+	4+
19+	23+	6-
24-	26+	8-
		10-
		11+
		14-
		15+
		16-
		17-
		18+
		20-
		21+
		22-
		25-

negative items. Appendix H includes the attitude scale.

Three attitudes were measured; expectation, content, and method. Five items were included on the expectation, five on content, and 16 on method.

Attitude toward expectation was determined with questions like, "This class exceeds my highest expectation," or "I am disappointed with this class." It was a gross measure of the students' general feeling of well-being toward the course in biology.

Attitude toward content was determined with questions like, "Too much emphasis has been placed on topics that are unimportant," or "The subject matter of this class is interesting." It was a measure of how students felt about the subject matter.

Attitude toward method was determined with questions like, "I am satisfied with the methods used in teaching this class," or "I can see no advantage of this method of teaching over other methods."

The attitude scale was administered to both experimental and control groups at the same time as the post-test.

<u>Personality scales</u> A series of four personality scales was administered to establish if any relationship might exist between attitude, achievement, and personality.

A large number of personality evaluating instruments exist, providing a measure of many aspects of personality. Several considerations prompted the use of the four scales used in this study. For one thing, it was felt that some students or their parents might object on the basis of invasion of privacy if lengthy and involved personality tests were given. In addition, several of the commercially available personality inventories were expensive to purchase and to score. No local computer programs or answer machines were available to score and analyze the results, because the tests used unique answer sheets.

Through the cooperation of a staff member of the Department of Psychology at Iowa State University four personality scales were developed. These scales were adapted from Dissinger (1968), who used them to study college students. A number of the items were re-written to make them applicable to high school students.

To clarify for the students the fact that the personality scales used in this study were not extensive personality inventories, they were entitled Student Opinion Surveys.

Student Opinion Survey I was based on Rotter's (1966) Internal-External Locus of Control Scale, the I-E. The subject is considered to be external with respect to reinforcement if he believes his behavior leads to no specific consequences. He is classified as an internal if he believes his behavior determines consequences. Survey I was a 29-item scale, presenting pairs of statements in which the student was required to make a forced choice. It was hand scored as a true-false test, with the external-type items considered "true".

Student Opinion Survey II was a forced-choice scale of 35 items as a measure of preference for a structured vs. unstructured learning environment. It was hand scored as a true-false test, with the high need for structure items considered "true". Students expressing a need for structure preferred a highly structured classroom, a directive teacher, definite weekly assignments, and frequent quizzes.

Student Opinion Survey III was similar to Scale I, except that students responded to items with respect to controllability of reinforcement. Internal-type students believed that grades were contingent on study behavior, while the externalist believed reinforcement was due to uncontrollable sources, unrelated to his own behavior. Survey III was a 33-item scale hand scored as a true-false test, with the external-type items considered "true".

Student Opinion Survey IV was a 33-item social desirability scale patterned after the Marlowe-Crowne Social Desirability Scale (1964). It was hand scored as a true-false test, with the socially desirable items considered "true".

Three co-variates were selected for each student. These were furnished by the high school guidance department, and represented the best measures of each student's general academic ability. The measures were Iowa Tests of Education Development composite standard score (ITED) the grade point average, and IQ score as measured by the Otis-Lennon test. In most cases these data were collected during 1969 through the testing program at the Ames High School.

In all, 15 measures were gathered for each student; 5 achievement tests, 3 attitude measures, 4 personality tests, and 3 co-variates.

Statistical Design

The design selected was the nonequivalent control group design (Campbell and Stanley, 1963). As they explain, in discussing the applicability of this design (p. 47):

> "One of the most widespread experimental designs in educational research involves an experimental group and a control group both given a pretest and a posttest, but in which the control group and the experimental group do not have pre-experimental sampling equivalence. Rather, the groups constitute naturally assembled collectives such as classrooms, as similar as availability permits but yet not so similar that one can dispense with the pretest. The assignment of X to one group or the other is assumed to be random and under the experimenter's

control.

$$\frac{0}{0} \text{— — } X \text{ — — } \frac{0}{0}$$

> ...The more similar the experimental and control groups are in their recruitment, and the more this similarity is confirmed by the scores on the pretest, the more effective this control becomes."

As stated previously, two-tailed F-tests at the .05 and .01 levels of significance were used. The following co-variance model was used:

$$Y_{ij} = u + \alpha_i + B_1 (\bar{X}_{1ij} - \bar{X}_1) + B_2 (\bar{X}_{2ij} - \bar{X}_2) + B_3 (\bar{X}_{3ij} - \bar{X}_3) + E_{ij}$$

where Y_{ij} = the j^{th} observation of classrooms subjected to the i^{th} treatment

$i = 1, 2$

$j = 1, 6$

u = overall mean

$_i$ = effect of the i^{th} treatment

B_1, B_2, B_3 = coefficients

X_{1ij} = measures on first co-variate (grade point average) for the j^{th} classrooms in the i^{th} treatment

X_{3ij} = measures on the third co-variate (ITED scores) for the j^{th} classrooms in the i^{th} treatment.

FINDINGS

In addition to analyzing the data by co-variance techniques to determine if there were significant differences between the experimental and control groups in achievement, attitudes, and personality factors, two other findings are reported here: item analyses of achievement tests, and correlation matrices of all variables for the experimental and control groups.

In order to analyze the data, scores were coded into 80-column IBM code sheets and cards were punched from the coded sheets. Table 3 summarizes the field sizes and type of data punched into cards for the master data deck. This deck was used to generate data for the co-variance analyses and correlation matrices described below.

The item analysis of the achievement tests, reported in Table 4, was taken directly from the original answer sheets turned in by each student. Sixteen students were excluded from the master data deck because certain information on them was lacking. Therefore the total number of students in each group in the item analysis does not necessarily agree with the total in each group appearing in the master deck, because certain of the 15 measures for each student were not available when the master code sheets were made up. The missing data usually were scores for grade point average, ITED composite standard scores, or IQ scores. When any data were missing for any student, the entire set of data for that student were discarded. There were no more than one or two students omitted from any one section, and it appeared that none was extremely high or extremely low, so there was some assurance that the students who were omitted did

Table 3. Key to field sizes of master data deck

Field	Significance
1-3	Identification number
4	Experimental or control group Experimental = 1 Control = 2
5	Class period Period 1 = 1 Period 2 = 2 Period 3 = 3 Period 4 = 4 Period 5 = 5 Period 6 = 6
6	Sex Boy = 1 Girl = 2
7-8	Test score: Pre-test
9-10	Test score: Chapter 8
11-12	Test score: Chapter 9
13-14	Test score: Chapter 10
15-16	Test score: Post-test
17-18	Attitude score: expectation
19-20	Attitude score: content
21-23	Attitude score: method
24-25	Personality score: Social reaction internal-external scale
26-27	Personality score: Need for structure
28-29	Personality score: Academic internal-external scale
30-31	Personality score: Social desirability
32-33	Grade point - IMPLIED DECIMAL BETWEEN 32 and 33
34-36	IQ
37-38	ITED composite standard score

Table 4. Item analysis of achievement tests

PRE-TEST

Section	Number taking test	Mean	Variance	Standard deviation	Average item difficulty	Reliabilty	Error variance	ERROR OF MEASUREMENT Raw scores	T-scores
Experimental Group									
1	29	20.45	31.54	5.62	0.46	0.78	6.81	2.61	46.46
2	25	20.92	29.99	5.48	0.45	0.76	7.34	2.71	49.48
3	23	20.00	30.73	5.54	0.47	0.77	7.20	2.68	48.39
4	24	22.50	44.43	6.67	0.41	0.85	6.66	2.58	38.70
5	23	21.57	51.08	7.15	0.43	0.86	7.16	2.68	37.44
6	26	19.42	34.33	5.86	0.49	0.78	7.50	2.74	46.73
Control Group									
1	26	18.31	21.74	4.66	0.52	0.68	6.96	2.64	56.57
2	30	19.93	27.31	5.23	0.48	0.72	7.60	2.76	52.77
3	29	21.48	36.33	6.03	0.43	0.80	7.17	2.68	44.43
4	25	18.00	33.33	5.77	0.53	0.78	7.21	2.68	46.50
5	23	20.13	39.66	6.30	0.47	0.81	7.43	2.73	43.28
6	27	21.11	38.41	6.20	0.44	0.80	7.51	2.74	44.23

Table 4. (Continued)

								ERROR OF MEASUREMENT	
Section	Number taking test	Mean	Variance	Standard deviation	Average item difficulty	Reliability	Error variance	Raw scores	T-scores
TEST ON PHOTOSYNTHESIS				Experimental Group					
1	29	24.14	41.34	6.43	0.40	0.83	7.23	2.69	41.82
2	28	20.29	29.77	5.46	0.49	0.74	7.63	2.76	50.63
3	28	23.00	24.96	5.00	0.43	0.69	7.86	2.80	56.12
4	25	22.56	21.26	4.61	0.44	0.66	7.24	2.69	58.38
5	24	22.13	26.98	6.08	0.45	0.79	7.61	2.76	45.35
6	26	24.27	23.32	4.83	0.39	0.69	7.30	2.7	55.93
				Control Group					
1	27	19.78	36.56	6.05	0.51	0.78	7.89	2.81	46.47
2	29	20.48	25.26	5.03	0.49	0.69	7.89	2.81	55.89
3	28	22.82	44.52	6.67	0.43	0.82	7.90	2.81	42.11
4	22	20.32	22.89	4.78	0.49	0.67	7.53	2.74	57.33
5	21	20.95	35.65	5.97	0.48	0.78	7.93	2.82	47.17
6	28	20.36	50.46	7.10	0.49	0.84	8.22	2.87	40.36

Table 4. (Continued)

Section	Number taking test	Mean	Variance	Standard deviation	Average item difficulty	Reliability	Error variance	ERROR OF MEASUREMENT Raw scores	T-scores
TEST ON LOWER PLANTS				Experimental Group					
1	28	27.36	35.72	5.98	0.32	0.81	6.63	2.57	43.08
2	26	25.58	48.33	6.95	0.36	0.85	7.08	2.66	38.27
3	25	24.44	30.17	5.49	0.39	0.77	7.02	2.65	48.24
4	26	27.04	29.40	5.42	0.32	0.79	6.22	2.49	46.01
5	24	25.63	23.03	4.80	0.36	0.71	6.66	2.58	53.77
6	27	27.15	35.98	6.00	0.32	0.82	6.57	2.56	42.74
				Control Group					
1	28	24.07	48.07	6.93	0.40	0.84	7.55	2.75	39.63
2	30	22.23	39.56	6.29	0.44	0.80	7.97	2.82	44.89
3	28	23.96	41.89	6.47	0.40	0.81	8.06	2.84	43.86
4	23	26.43	31.80	5.64	0.34	0.77	7.43	2.73	48.34
5	22	25.14	46.69	6.83	0.37	0.85	6.96	2.64	38.61
6	28	25.57	52.33	7.23	0.36	0.85	7.62	2.76	38.16

Table 4. (Continued)

TEST ON VASCULAR PLANTS					Experimental Group				
Section	Number taking test	Mean	Variance	Standard deviation	Average item difficulty	Reliability	Error variance	ERROR OR MEASUREMENT Raw scores	T-scores
1	29	22.76	61.76	7.86	.43	.87	8.31	2.88	36.68
2	28	21.57	39.44	6.28	.46	.80	8.02	2.83	45.09
3	26	22.42	26.57	5.15	.44	.70	7.95	2.82	54.68
4	26	24.19	24.64	4.96	.40	.71	7.24	2.69	54.22
5	24	20.00	32.43	5.70	.50	.75	8.15	2.85	50.11
6	27	23.96	36.65	6.05	.40	.80	7.43	2.73	45.04
					Control Group				
1	28	21.82	24.74	4.97	.45	.70	7.48	2.73	54.97
2	30	19.63	49.76	7.05	.51	.82	8.72	2.95	41.86
3	28	21.39	39.28	6.27	.47	.79	8.43	2.90	46.34
4	24	22.63	39.81	6.31	.43	.80	8.02	2.83	44.88
5	22	22.95	33.09	5.75	.43	.76	7.86	2.80	48.73
6	27	20.44	66.95	8.18	.49	.87	8.66	2.94	35.97

Table 4. (Continued)

POST-TEST				Experimental Group					
Sec-tion	Number taking test	Mean	Variance	Standard deviation	Average item difficulty	Reli-ability	Error variance	ERROR OF MEASUREMENT Raw scores	T-scores
1	29	18.48	37.97	6.16	.38	.85	5.67	2.38	38.65
2	27	16.93	22.38	4.73	.44	.74	5.83	2.41	51.03
3	28	19.07	15.70	3.96	.36	.67	5.15	2.27	57.27
4	25	18.32	21.73	4.66	.39	.75	5.42	2.33	49.95
5	24	15.71	43.87	6.62	.48	.86	6.10	2.47	37.28
6	26	19.88	23.23	4.82	.34	.77	5.32	2.31	47.85
				Control Group					
1	27	15.89	28.79	5.37	.47	.79	5.93	2.44	45.40
2	28	14.82	18.30	4.28	.51	.67	6.13	2.47	57.85
3	28	15.86	37.16	6.10	.47	.83	6.23	2.50	40.93
4	25	6.96	34.79	5.90	.43	.83	6.00	2.45	41.52
5	23	16.61	35.70	5.98	.45	.84	5.75	2.40	40.14
6	28	15.43	35.66	5.97	.49	.82	6.36	2.52	42.25

not distort the analysis.

The total point score, representing the sum of achievement tests for the chapters covering photosynthesis, lower plants, vascular plants, and the post-test was generated by the computer program for use during the processing. For this reason the total point score did not occupy a field on any data cards.

As the results of the item analysis indicate, the range of item difficulty was 0.32 to 0.53, with a mean of 0.4345. According to Warman (1968, p. 5) the ideal average item difficulty should be about 0.40.

Reliability fell in the range of 0.66 to 0.86, with a mean of 0.7805. This fell slightly below the 0.80 level which, according to Menne (1968) must be reached if the test is to be used as a part of the basic decision process for ascertaining letter grades of students.

In addition to the achievement tests, other measures, such as evaluation of reports, laboratory work, and special projects were used by the teachers to assign letter grades to students. For this reason a higher reliability on the achievement tests, and a lower error of measurement, were not as critical. If the achievement tests alone had been used to assign letter grades, the reliability should have exceeded 0.80.

Content validity, was judged to be high by the three teachers participating in the study. In other words, the tests had a close relationship to what was being taught in class, and related well to the behavioral objectives.

Achievement Tests

The achievement tests were item analyzed to produce data on the mean, variance, standard deviation, average item difficulty, reliability, error variance, and error of measurement for raw scores and T-scores (Table 4).

The results of the achievement tests were analyzed by co-variance in two ways; by classroom units, and by individuals. Analysis by individuals, while a less sound statistical technique, was justified partly because each student moved at his own pace through the programmed instruction. In addition, each student had the opportunity during audio-tutorial laboratory work to control the pace of instruction. The analysis revealed highly significant differences in achievement between the experimental and control groups in the test over the photosynthesis unit, the unit on lower plants, the post-test, and total scores over all units in the study. This makes it possible to reject null hypotheses 1a, 1b, 1d, and 1e. Results of the co-variance analysis by individuals are in Table 5.

The classroom was the basic unit used in the design. In the analysis of achievement when classrooms were considered, significant differences were found for the units on photosynthesis and total scores over all units in the study. The F value of 5.3973 for the retention test approached significance, but did not reach it. This makes it possible to reject null hypotheses 1a and 1e. Results of the co-variance analysis by classroom units are in Table 6.

The co-variance analysis was made on a computer using a modified

Table 5. Analysis of co-variance of achievement tests, by individuals

Source	df	Sum of squares	Mean squares	F
Pretest				
Total	310	11227.299035		
Regression	4	5349.484451	1337.371113	
Residual	306	5877.814584	19.208544	
Set (2, 1)	3	349.467682	1783.155894	
Difference	1	0.016769	0.016769	0.0009
Photosynthesis				
Total	310	10527.967846		
Regression	4	5240.528723	1310.132181	
Residual	306	5287.818831	17.279213	
Set (2, 2)	3	4969.818831	1656.606277	
Difference	1	270.709892	270.709892	15.6668**
Lower plants				
Total	310	13449.691318		
Regression	4	5933.857523	1483.464381	
Residual	306	7515.833796	24.561548	
Set (2, 3)	3	5794.408014	1931.469338	
Difference	1	139.449508	139.449508	5.6776*
Vascular plants				
Total	310	12492.295820		
Regression	4	6754.425919	1588.606480	
Residual	306	5737.869901	18.751209	
Set (2, 4)	3	6684.067449	2228.022483	
Difference	1	70.358470	70.358470	3.7522

*$P < 0.05$.

**$P < 0.01$.

Table 5. (continued)

Source	df	Sum of squares	Mean squares	F
Post test				
Total	310	9716.713826		
Regression	4	5164.771908	1291.192977	
Residual	306	4551.941918	14.875627	
Set (2, 5)	3	4885.313702	1628.437901	
Difference	1	279.458206	279.458206	18.7863**
Total scores				
Total	310	141645.498392		
Regression	4	91288.558236	22822.139559	
Residual	306	50356.940157	164.565164	
Set (2, 6)	3	88440.506913	29480.168971	
Difference	1	2848.051323	2848.051323	17.3065**

Table 6. Analysis of co-variance of achievement tests, by classrooms

Source	df	Sum of squares	Mean squares	F
Pre test				
Total	11	18.089200		
Regression	4	4.760910	1.190228	
Residual	7	13.328290	1.904041	
Set (2, 1)	3	4.681390	1.560463	
Difference	1	0.079520	0.079520	0.0418
Photosynthesis				
Total	11	27.925492		
Regression	4	18.211031	4.552758	
Residual	7	9.714461	1.387780	
Set (2, 2)	3	9.487161	3.162387	
Difference	1	8.723870	8.723870	6.2862*
Lower plants				
Total	11	25.635300		
Regression	4	12.159508	3.039877	
Residual	7	13.475792	1.925113	
Set (2, 3)	3	5.448079	1.816026	
Difference	1	6.711430	6.711430	3.4863
Vascular plants				
Total	11	20.808900		
Regression	4	7.474775	1.868694	
Residual	7	13.334125	1.904875	
Set (2, 4)	3	4.871107	1.623702	
Difference	1	2.603668	2.603668	1.3668

*$P < 0.5$.

Table 6. (continued)

Source	df	Sum of squares	Mean squares	F
Post test				
Total	11	25.472292		
Regression	4	12.235374	3.058843	
Residual	7	13.236918	1.890988	
Set (2, 5)	3	2.029157	0.676386	
Difference	1	10.206217	10.206217	5.3973
Total scores				
Total	11	264.689892		
Regression	4	152.624936	38.156234	
Residual	7	112.064955	16.009279	
Set (2, 6)	3	45.464416	15.154805	
Difference	1	107.160520	107.160520	6.6937*

regression program. In addition to computing total sums of squares, regression sum of squares was computed for each classroom. This was the sum of squares due to both the co-variates and the the effect of the treatment. Sum of squares due to co-variates only was designated as "set". By subtracting the set from regression sum of squares it was possible to determine the sum of squares due to treatment only. This was designated as "difference." The F value was calculated by dividing the mean square for the difference by the residual mean square.

Attitude Scale

The attitude scale was hand scored because it was impractical to use machine scoring, due to the relatively small number of answer sheets. Some items were loaded positively, and some negatively. A positive item, such as "I am satisfied with the methods used in teaching this class" would receive a high numerical score from someone pleased. On the other hand, a negative item, such as "I can see no advantage of this method of teaching over other methods" would receive a low numerical score from someone pleased with the method. The negative items thus were reversed by subtracting the raw score for each item from 10. Results were added to the total score from the positive items. Table 2 summarizes the positive and negative loads on items for each of the three attitudes measured by the 26-item scale. The answer sheet for each student was hand scored.

Scores for each of the three attitude measures were analyzed by co-variance using the previously stated model. Results indicate a significant difference in attitude toward expectation and method in the analysis by classrooms (Table 8) and extremely highly significant differences, well beyond the .001 level, in these two attitudes when individuals (Table 7) were analyzed. This makes it possible to reject the null hypotheses 2a, and 2c on the basis of analysis by classrooms, and hypotheses 2a and 2c on the basis of analysis by individuals.

Personality Scales

The four scales measuring personality characteristics were administered a short time after the post-test. They were hand scored, with the higher scores reflecting direction of externality, high need for structure or high social desirability, depending on the scale under consideration.

Two kinds of analyses were performed with the data from the personality scales: co-variance and correlation.

Scores from the four personality scales were analyzed by co-variance, using as co-variates the scores on each student for IQ, grade point average, and ITED composite raw score.

The analysis of personality scale results by individuals, using co-variance techniques, was also carried out. Results are reported in Table 9. As the results indicate, there was no significant difference on any of the four scales between experimental and control section. Thus, there was insufficient evidence to reject the null hypotheses 3a, 3b, and 3c.

Table 7. Analysis of co-variance of attitudes, by individuals

Source	df	Sum of squares	Mean squares	F
Attitude toward expectation				
Total	310	26839.138264		
Regression	4	2029.385310	507.346327	
Residual	306	24809.752954	81.077624	
Set (2, 7)	3	111.930400	37.310133	
Difference	1	1917.454910	1917.454910	23.6496**
Attitude toward content				
Total	310	22837.897106		
Regression	4	1081.540065	270.385016	
Residual	306	21756.357041	71.099206	
Set (2, 8)	3	1024.665213	341.555071	
Difference	1	56.874852	56.874852	0.7999
Attitude toward method				
Total	310	145864.424437		
Regression	4	14716.545173	3679.136293	
Residual	306	131147.879264	428.587841	
Set (2, 9)	3	423.792671	141.264224	
Difference	1	14292.752502	14292.752502	33.3485**

$^{**}P< 0.01$.

Table 8. Analysis of co-variance of attitudes, by classrooms

Source	df	Sum of squares	Mean squares	F
Attitude toward expectation				
Total	11	173.8899967		
Regression	4	118.977608	29.744402	
Residual	7	54.912359	7.844623	
Set (2, 7)	3	56.596652	18.865551	
Difference	1	62.380955	62.380955	7.9521*
Attitude toward content				
Total	11	84.353292		
Regressional	4	11.075998	2.769000	
Residual	7	73.277293	10.468185	
Set (2, 8)	3	7.947600	2.649200	
Difference	1	3.128399	3.128399	0.2988
Attitude toward method				
Total	11	1067.026892		
Regression	4	616.453007	154.113252	
Residual	7	450.573884	64.367698	
Set (2, 9)	3	123.361398	41.120466	
Difference	1	493.091610	493.091610	7.6605*

*$P < 0.05$.

Table 9. Analysis of co-variance of personality scales, by individuals

Source	df	Sum of squares	Mean squares	F
I-E focus of control				
Total	310	4056.559486		
Regression	4	75.276939	18.819235	
Residual	306	3981.282547	13.010727	
Set (2, 10)	3	75.143561	25.047854	
Difference	1	0.133378	0.133378	0.0103
Need for structure				
Total	310	4011.710611		
Regression	4	477.708508	119.427127	
Residual	306	3534.002103	11.549026	
Set (2, 11)	3	455.363102	151.787701	
Difference	1	22.345406	22.345406	1.9348
Academic I-E				
Total	310	4506.797428		
Regression	4	105.050802	26.262701	
Residual	306	4401.746625	14.384793	
Set (2, 12)	3	85.786439	28.59580	
Difference	1	19.264364	19.264364	1.3392
Social desirability				
Total	310	6672.212219		
Regression	4	233.479933	58.369983	
Residual	306	6438.732285	21.041509	
Set (2, 13)	3	228.613745	76.204582	
Difference	1	4.866189	4.866189	0.2313

Results of the co-variance analysis by classroom units on the personality scales are reported in Table 10. As these results indicate, the only significant F value was that for the need for structure scale. This makes it possible to reject null hypothesis 3b.

Correlation Matrices

As a means of determining the degree of relationship between any two variables in the study, a 15 x 15 correlation matrix was constructed. This enabled correlation of any given variable with any other. Two tables were constructed; one for the experimental group, and one for the control group. The matrices are given in Tables 11 and 12.

Correlations significantly different from zero have been identified with a single asterisk if they equalled or exceeded the value for the .05 level of 0.16. Those with a double asterisk equalled or exceed the .01 level of 0.21.

Intercorrelations of all achievement tests in the experimental group ranged from 0.53 to 0.77, while in the control group the range was from 0.61 to 0.81. The correlations were highly significantly different from zero in both groups.

Co-variates correlated highly with each other, with a range of 0.55 to 0.78 in the experimental group and 0.53 to 0.74 in the control group.

In both groups, correlation of achievement tests with co-variates was highly significantly different from zero, with no exception.

Much lower correlations were noted between and within the attitude

Table 10. Analysis of co-variance of personality scales, by classrooms

Source	df	Sum of squares	Mean squares	F
I-E focus of control				
Total	11	7.643892		
Regression	4	0.303318	0.075829	
Residual	7	7.340574	1.048653	
Set (2, 10)	3	0.260609	0.086870	
Difference	1	0.042709	0.042709	0.0407
Need for structure				
Total	11	2.373900		
Regression	4	1.381664	0.345416	
Residual	7	0.992236	0.141748	
Set (2, 11)	3	0.380876	0.126959	
Difference	1	1.000788	1.000788	7.0603*
Academic I-E				
Total	11	10.098625		
Regression	4	3.305214	0.826303	
Residual	7	6.793411	0.970487	
Set (2, 12)	3	2.259819	0.753273	
Difference	1	1.045395	1.045395	1.0772
Social desirability				
Total	11	8.925692		
Regression	4	3.114848	0.778712	
Residual	7	5.810843	0.830120	
Set (2, 13)	3	2.759849	0.919950	
Difference	1	0.354999	0.354999	0.4276

*$P < 0.05$.

Table 11. Correlation matrix for all measures; experimental group

		Pre-test	Photo-syn-the-sis	Lower plants	Vascu-lar plants	Post-test	Atti-tude-expecta-tion
1.	Pre-test	1.00					
2.	Photosynthesis	.56**	1.00				
3.	Lower plants	.55**	.58**	1.00			
4.	Vascular plant	.53**	.68**	.67**	1.00		
5.	Post-test	.59**	.75**	.70**	.77**	1.00	
6.	Attitude-expectation	-.03	.10	.17*	.14	.16*	1.00
7.	Attitude-content	.06	.17*	.29**	.28**	.24**	.54**
8.	Attitude-method	-.05	.07	.18*	.18*	.14	.75**
9.	Social I-E	-.05	-.25**	-.16*	-.20*	-.19*	-.25**
10.	Need for structure	.13	.03	.15	.15	.03	.11
11.	Academic I-E	-.16	-.28**	-.24**	-.30**	-.31**	-.25**
12.	Social desirability	-.07	.05	-.01	.02	-.02	.00
13.	Grade point	.61**	.57**	.51**	.66**	.57**	.02
14.	IQ	.43**	.55**	.38**	.51**	.53**	-.10
15.	ITED	.57**	.67**	.56**	.66**	.68**	-.05

*P <0.05.
**P< 0.01.

Attitude-control	Attitude-method	Social I-E	Need for structure	Academic I-E	Social desirability	Grade point	IQ	ITED
1.00								
.50**	1.00							
-.38**	-.28**	1.00						
.11	.17*	-.14	1.00					
-.30**	-.32**	.48**	-.21**	1.00				
.00	.19*	-.20*	.04	-.14	1.00			
.14	.05	-.09	.34**	-.19*	.00	1.00		
.07	.00	-.08	.04	-.20*	-.08	.55**	1.00	
.18*	.03	-.18*	.12	-.25**	-.07	.67**	.78**	1.00

Table 12. Correlation matrix for all measures; control group

		Pre-test	Photo-syn-the-sis	Lower plants	Vascu-lar plants	Post-test	Atti-tude-expecta-tion
1.	Pre-test	1.00					
2.	Photosynthesis	.61**	1.00				
3.	Lower plants	.66**	.65**	1.00			
4.	Vascular plants	.67**	.62**	.68**	1.00		
5.	Post-test	.64**	.64**	.72**	.81**	1.00	
6.	Attitude-expectation	.22**	.19*	.22**	.21**	.28**	1.00
7.	Attitude-content	.16*	.26**	.24**	.32**	.37**	.44**
8.	Attitude-method	-.01	.09	.17*	.16*	.20*	.59**
9.	Social I-E	-.22**	-.12	-.17*	-.15	-.12	-.13
10.	Need for structure	.11	.02	.13	.01	.01	.08
11.	Academic I-E	-.06	-.05	-.08	-.08	-.10	-.05
12.	Social desirability	-.04	-.04	.09	.03	.00	.21*
13.	Grade point	.69**	.58**	.67**	.60**	.61**	.07
14.	IQ	.51**	.46**	.44**	.54**	.51**	.10
15.	ITED	.67**	.69**	.65**	.75**	.73**	.13

*$p < 0.05$

**$p < 0.01$.

Atti-tude-control	Atti-tude-method	Social I-E	Need for struc-ture	Aca demic I-E	Social desir-ability	Grade point	IQ	ITED
1.00								
.49*	1.00							
-.08	-.16*	1.00						
-.07	.09	-.19*	1.00					
-.14	-.27*	.47**	-.09	1.00				
.06	.17*	-.30**	.12	-.09	1.00			
.10	-.10	-.16*	.17*	-.05	-.03	1.00		
.19*	.01	-.05	-.13	-.01	-.23**	.53**	1.00	
.23**	.02	-.05	-.03	-.03	-.18*	.70**	.74**	1.00

measures and the personality scales. For example, the intercorrelations within attitude measures in the experimental group ranged from 0.50 to 0.75, and in the control group from 0.44 to 0.59. However, all of these correlations were highly significantly different from zero.

The above high positive intercorrelations of achievement tests, attitude scores, and co-variates indicate that to some extent each is measuring the same factor, within each group.

On the other hand, intercorrelations with the personality scales produced some negative values. Of particular interest is the negative relationship between the need for structure, social I-E, and social desirability scales. This indicates these three measures were evaluating different traits. Social I-E and academic I-E scales, however, were positively correlated with values approaching 0.50 in both groups. This indicates both scales measure similar factors.

Attitudes and personality factors correlated to a lesser extent with each other, producing a number of values not significantly different from zero. Of interest, however, was the relationship between social desirability and attitude toward expectation, which was 0.21 in the control group, but 0.00 in the experimental group. Academic I-E correlated with attitude toward method -0.32 in the experimental group and -0.27 in the control group, emphasizing the negative relationship between externalizers and attitude toward the method of teaching, regardless of the method.

DISCUSSION AND RECOMMENDATIONS

The purpose of the study was to compare a multimedia system for teaching high school biology with a conventional approach. Results indicate that the multimedia approach to teaching and learning does indeed offer advantages. Among these are gains in achievement, and increased favorable student attitude. Favorable attitude is an important factor in increasing a student's motivation to pursue biology in the future, either as a career or as a leisure time activity. While the gains in achievement were not consistent for every measure, several significant differences did appear, as was pointed out in the findings.

In the personality scales the significant difference between experimental and control groups on the need for structure scale might be explained by the fact that a high need for structure was made to seem important to students in the experimental group. Two types of structure may be identified. One is content structure, and the other is teaching method structure. The content sequence and development was highly structured, with principles and concepts being brought out in a careful sequence. It was this type of structure to which students apparently responded favorably. This could provide a basis for designing instruction for specific types of students Instead of sectioning students by ability, which is the traditional method, it might be more meaningful to create sections by personality type. Those who learn more effectively because they prefer a highly structured learning environment might comprise one section. Those who favor an unstructured approach might make up another group.

Correlations between the personality scales and other measures brought out some relationships between personality scales and the achievement tests. Looking at the correlations between the four scales and all of the achievement tests, a negative r-value was found between all of the academic measures and Survey I, the social internal-external scale. Since this was scored in the direction of externalizers, a negative correlation indicated that students expressing an external view tended to earn lower scores on the achievement tests. In the majority of cases the social I-E scale correlated higher negatively with achievement in the experimental group than in the control group.

Survey III, the academic internal-external scale, also showed greater negative correlations with the achievement tests in the experimental group than in the control group. This would indicate that students with higher achievement tended to be internalists.

These findings are not consistent with Butterfield (1964) who reported a significant positive relationship between course grade in introductory psychology and degree of externality. Butterfield felt that internals were more inner-directed and autonomous. He felt they studied mostly those things they regarded as interesting and important.

However, the findings do agree with Rotter's locus of control concept, which holds that an external-type student may not perceive that behavior and reinforcement are related to each other. The internal-type student is more likely to perceive the positive relationship between grades and his studying of material considered important by the instructor.

Students in the experimental group who were internalizers apparently felt that their study habits and learning activities determined their success on achievement tests. This could be due to instructions for using the programmed instruction and audio-tutorial laboratory work. The instructions encouraged students to control the pace of the learning system, stopping or reversing the audio tape when necessary, or reviewing programmed instruction.

The reduction in F values for successive test scores indicated the difference between the experimental and control groups lessened with time. This could be due to a decrease in the Hawthorne effect, which was probably strongest when the study first started.

Another explanation might be related to the relative difficulty of the three chapters and achievement tests. This explanation might be verified if the chapters were administered in reverse order that the F values would increase rather than decrease.

There was no particular reason for the students in the experimental group to feel special unless they believed they were learning by means of a new method. There was no particular effort on the part of anyone connected with this study to make the experimental group feel different, or set apart from the control group. Students in both experimental and control groups were told that they were a part of an experiment to find out which teaching method was more effective. It was hoped this would make the control group feel as much a part of the study as the experimental group.

A common problem in studies of this type was the identification of differences in teacher personality. While an attempt was made to randomly assign teachers to both experimental and control groups, so that teacher differences would not load either group, bias in favor of the experimental group still may have occurred. For example, the heavy use of media in the experimental group may have been more naturally assimilated into the teaching style of certain of the teachers. Although no data was collected to measure the effectiveness with which each of the three teachers used media, it was observed that certain of the teachers seemed to be more effective when using media. Similarly, the small-group discussion that took place was more effectively handled by certain teachers. Since little media or discussion was employed in the control groups, there was little opportunity for any of the teachers to amplify their style in control sections.

While conventional teaching was defined as largely lecture-demonstration/conventional laboratory work/text, in practice perhaps the control sections were not as conventional as supposed. It was a temptation for the teachers to contaminate the teaching of control sections by using ideas and media from the experimental sections. Conscious effort was necessary on the part of the investigator and the teachers to prevent this from happening. Even so, some of the ideas and teaching techniques used in the experimental sections may have been incorporated into the control sections. At the Ames High School it is possible that conventional teaching may not have been strictly conventional, when compared to teaching in a non-university community. A number of techniques already being used were dropped from the teachers' repertoire during the study. These included use of transparencies, questioning techniques and small group discussion, and use of peer teaching.

The multimedia system provided for a variety of learning styles through a variety of learning activities. The value of such an instructional system lies in its ability to provide a wide range of learning experiences. An important question, which may be answered by further research, is to decide the relative importance of each of the experiences. If it could be determined which of the components of the system contributed in a major way to effective learning it would be possible to build a system that capitalized on these strengths.

No attempt was made to incorporate data on each teachers' past experience, educational background, or measures of teaching effectiveness. Certain teacher differences may have been uncovered by including an analysis of teaching that took place in both experimental and control groups.

A number of students commented on the value of the behavioral objectives. Since these were furnished only to the experimental group, and not the control group, difference in achievement or attitude could have been widened. Once a student knows what is expected of him, and has a list of the important objectives from each chapter, from which he can structure his studying for the tests, he has an advantage over students who do not have a list of objectives. The fact that behavioral objectives were given only to the experimental group could have accounted for much of the success of that group in surpassing the achievement of the control group.

The large investment of time, money, and equipment to create this teaching system may raise the question of the end justifying the means. It would be unrealistic to expect teachers to design their instruction around a multimedia system unless they could expect rather large differences in achievement, in favor of the multimedia system. However, over a period of several years, with the help of a team of teacners (such as those who helped with this study) the investement is feasible. If multimedia units of a few weeks' duration can be designed each year, in several years an entire course can be constructed using this format. Such a system would then begin to free the teacher for more personalized help of individual students. And students might begin to accept more personal responsibility for learning. Of course, it would be necessary for the school to have on hand the equipment and study carrels necessary for the system to operate.

At the present time a certain quantity of software is available commercially for teaching through multimedia. If funds are available it is possible for a school system to purcahse these for use in teaching, freeing teachers from the responsibility of building a system themselves. In the future even larger numbers of systems and their components will likely be produced by industry for use in teaching.

A number of recommendations for further research grow out of the study.

1. Replicate the study, using essentially the same materials, in a number of different schools.
2. Determine the relationship between sex differences and the other measures. Analysis of achievement test results, attitude, and personality data might reveal differences between males and females.
3. Continue the investigation of the relationship between personality factors, attitudes, and achievement. Additional personality factors that might be included are introversion

and extroversion, need for achievement, and test anxiety.

4. Compare the effectiveness of small-group audio-tutorial laboratory work, as described in this study, and individualized audio-tutorial laboratory work.
5. Analyze the data in such a way that teacher/media interactions, if any, can be identified.
6. Determine if there is a difference in attitude or personality measures when the data is stratified on the basis of high achievers, middle achievers, and low achievers.

SUMMARY

The problem was to compare a multimedia system for teaching high school biology with a conventional approach. Students were evaluated with achievement tests, attitude measures, and personality scales.

The experiment was designed in such a way that the 12 sections of students taking high school biology at Ames High School were divided into an experimental and control group of six sections each. The experimental group received instruction through audio-tutorial laboratories, programmed instruction, audio tapes, 35mm slides, 16mm films, and single concept film loops. They employed small group discussion techniques and peer teaching as methods of study. The conventional sections were taught by a teacher who primarily used the lecture-demonstration method. Little media was used in the control group.

A pre-test, three achievement tests, and a post-test were used to measure growth. Attitude measures on expectation, content, and method were given, in addition to personality scales on social locus of control, need for structure, academic locus of control, and social desirability.

Several hypotheses were tested: 1) There is no significant difference in achievement between the experimental and control groups, as measured by a series of achievement tests; 2) There is no significant difference in attitude toward expectation, content, or method, as measured by an attitude scale; 3) There is no significant difference in personality characteristics as measured by social internal-external locus of control scale, need for structures scale, academic internal-

external scale, and social desirability scale.

An analysis of covariance was used to treat the data. Independent variables were IQ scores, grade point average, and ITED composite score. Both individuals and classroom units were analyzed. F values were obtained on the pre-test, achievement tests, post-test, total scores for post-test and achievement tests, and attitude and personality measures.

In the analysis by classroom units, significant F values in favor of the experimental group were obtained on the first achievement test, the total scores for achievement tests and post-test, attitude towaid expectation and method, and the need for structure. In the analysis by individuals all of the above were highly significant escept the need for structure measure, which did not reach the .05 level of significance.

A correlation matrix for all variables was constructed for both the experimental and control groups. Values ranged from .53 to .77 in the experimental group, .61 to .81 in the control group within achievement tests, within co-variates the values were .55 to .78 and .53 to .74 respectively. Correlation of achievement tests with co-variates was high significantly different from zero in all cases, in both groups. Attitudes and personality factors correlated to a lesser extent with each other, producing a number of values not significantly different from zero. Of interest, however, was the relationship between social desirability and attitude toward expectation, which was .21** in the

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$^{**}p < 0.01$.

control group, but .00 in the experimental group.

The major conclusion of this study was that a multimedia system for teaching high school biology can be superior to a traditional method in causing gains in achievement, and in attitude toward expectation and method. The personality factors measured showed little relationship to the type of instruction.

BIBLIOGRAPHY

Becker, Samuel L. 1963. The relationships of interest and attention to retention and attitude change. Unpublished Ph.D. thesis. Iowa City, Iowa, Library, University of Iowa. (Microfilm copy 64-4898. Ann Arbor, Michigan, University Microfilms, Inc.)

Becker, Samuel L. Fall 1964. Interest, tension, and retention. AV Communication Review 12, No. 3: 277-291.

Bloom, Benjamin S., ed. 1956. Taxonomy of educational objectives. Handbook I: Cognitive domain. New York, New York, David McKay Co., Inc.

Briggs, Leslie J. May 1964. The teacher and programmed instruction: roles and role potentials. Audiovisual Instruction 9, No. 5: 273-276.

Briggs, Leslie J. March 1967. A procedure for the design of multi-media instruction. Audiovisual Instruction 12, No. 3: 228.

Briggs, Leslie J., and others. 1967. Instructional media, a procedure for the design of multi-media instruction, a critical review of research, and suggestions for future research. American Institute for Research Monograph 2.

Briggs, Leslie J. 1968. Learner variables and educational media. Review of Educational Research 38, No. 2: 160-176.

Burmester, Mary A. and Lawson, Chester A. 1963. A comparison of the effectiveness of programmed learning with respect to students with different learning abilities. In James W. Brown and James W. Thornton, Jr., eds. New Media in Higher Education. Pp. 18-21. Washington, D.C., Association for Higher Education and the Division of Audiovisual Instruction Service, National Education Association.

Butterfield, E. C. 1964. Locus of control, test anxiety, reactions to frustration, and achievement attitudes. Journal of Personality 32: 355-370.

Campbell, Donald T. and Stanley, Julian C. 1963. Experimental and quasi-experimental designs for research. Chicago, Illinois, Rand McNally and Company.

Campbell, Vincent N. December 1963. Bypassing as a way of adapting self-instruction programs to individual differences. Journal of Educational Psychology 54: 337-345.

Carnes, Phyllis Eileen; Bledsoe, Joseph C.; and Van Deventer, W. C. 1968. Programmed materials in seventh-grade open-ended laboratory experiences. Journal of Research in Science Teaching 5, No. 4: 385-396.

Cronbach, L. J. 1957. The two disciplines of scientific psychology. American Psychologist 12: 671-684.

Crowne, D. P. and Marlowe, D. 1964. The approval method. New York, New York, John Wiley and Sons.

Diamond, Robert M. June 1968. A programmed biology laboratory for the non-science major. Instructional Resources Center, Fredonia, New York, Research Report No. 1.

Dissinger, Jean K. 1968. Locus of control in achievement: measurement and empirical assessment. Unpublished Ph.D. thesis. Lafayette, Indiana, Library, Purdue University.

Dwyer, Francis M., Jr. 1969. An experiment in visual communication. Journal of Research in Science Teaching 6, No. 2: 185-195.

Edling, Jack V. June 1963. A study of the effectiveness of audio-visual teaching materials when prepared according to the principles of motivational research. Unpublished Ph.D. thesis. Monmouth, Oregon, College of Education. (Microfilm copy 64-4835. Ann Arbor, Michigan, University Microfilms, Inc.)

Eigen, Lewis D. March 1963. High school student reactions to programmed instruction. Phi Delta Kappan 44, No. 6: 282-285.

Frey, Sherman H.; Shimabukuro, Shinkichi; and Woodruff, A. Bond. Summer 1967. Attitude change in programmed instruction related to achievement and performance. AV Communication Review 15, No. 2: 199-205.

Gagne, Robert M. 1965. The conditions of learning. New York, New York, Holt, Rinehart and Winston.

Gilpin, John. 1962. Design and evaluation of instructional systems. AV Communication Review 10, No. 2: 75-84.

Glaser, Robert. 1966. Psychological bases for instructional design. AV Communication Review 14, No. 4: 433-449.

Heinich, Robert. 1965. The systems engineering of education II: Applications of systems thinking to instruction. Los Angeles, California, Instructional Technology and Media Project, School of Education, University of Southern California.

Hilgard, E. R. March 16, 1955. The human dimension in teaching. Association of Higher Education College and University Bulletin.

Hoban, Charles F., Jr. and Van Ormer, Edward B. December 1950. Instructional film research, 1918-1950. Technical Report No. SDC 269-7-19. University Park, Pennsylvania, Instructional Film Research Program, Pennsylvania State College.

Kemp, Jerrold E. 1968. Planning and producing audiovisual materials. 2nd ed. San Francisco, California, Chandler Publishing Company.

Knowlton, James Q. 1964. A socio- and psycho-linguistic theory of pictorial communication. Bloomington, Indiana, Indiana University Division of Educational Media and Audio-visual Center.

Likert, R. A. 1932. A technique for the measurement of attitudes. Archives of Psychology No. 140.

Lindvall, C. M. February 1964. Studies of pupil attitude in pupil attention and attitude under conditions of programmed instruction. Pittsburgh, Pa., Department of Psychology, University of Pittsburgh.

Markle, Susan Meyer. 1964. Good frames and bad. New York, New York, John Wiley and Sons.

Meierhenry, Wesley C. November-December 1962. Needed research in the introduction and use of audiovisual materials: a special report. AV Communication Review 10, No. 6: 307-316.

Menne, John W. 1968. Use of computer analysis in evaluating and improving the measurement characteristics of examinations. Report No. 68-12. Student Counseling Service, Iowa State University, Ames, Iowa.

Neidt, Charles O. 1964. Changes in attitudes during learning. Final Report. No. C-1139. Washington, D.C., U.S. Department of Health, Education, and Welfare.

Neidt, Charles O. and Sjogren, D. D. Fall 1968. Changes in student attitudes during a course in relation to instructional media. AV Communication Review 16, No. 3: 268-279.

Niedermeyer, Fred C. Fall 1968. The relevance of frame sequence in programmed instruction: an addition to the dialogue. AV Communication Review 16, No. 3: 301-317.

O'Reilly, Robert P. and Ripple, Richard E. 1967. The contribution of anxiety, creativity, and intelligence to achievement with programmed instruction. Unpublished report. Ithaca, New York, Department of Psychology, Cornell University.

Payne, David A.; Krathwohl, David R.; and Gordon, John. March 1967. The effect of sequence on programmed instruction. American Educational Research Journal 4: 125-132.

Postlethwait, S. N.; Novak, J.; and Murray, H. 1964. An integrated experience approach to learning. Minneapolis, Minnesota, Burgess Publishing Company.

Ripple, Richard E. February 1963. Comparison of the effectiveness of a programed text with three other methods of presentation. Psychological Reports 12: 227-37.

Rotter, J. B. 1966. Generalized expectancies for internal versus external control of reinforcement. Psychological Monographs 80: 1-27.

Saettler, Paul. 1968. Design and selection factors. Review of Educational Research 38, No. 2: 115-128.

Schramm, Wilbur. 1964. The research on programmed instruction: an annotated bibliography. Office of Education, U.S. Department of Health, Education and Welfare, Bulletin 1964, No. 35, OE-34034.

Severin, Werner J. Winter 1967. The effectiveness of relevant pictures in multiple-channel communications. AV Communication Review 15, No. 4: 386-401.

Siegel, Laurence and Siegel, Lila Corkland. Spring 1964. The instructional gestalt: a conceptual framework and design for educational research. AV Communication Review 12, No. 1: 16-45.

Skinner, Ray, Jr. 1968. Inquiry sessions: an assist for teaching science via instructional television in the elementary schools. Journal of Research in Science Teaching 5, No. 4: 346-350.

Smith, M. Daniel. 1969. Response to a multimedia system. Journal of Research in Science Teaching 6, No. 4: 322-332.

Smith, M. Daniel; Schagrin, Morton; and Poorman, L. Eugene. Winter 1967. Multimedia systems: a review and report of a pilot project. AV Communication Review 16: 345-369.

Snedecor, George W. and Cochran, William G. 1969. Statistical methods. 6th edition. Ames, Iowa, The Iowa State University Press.

Snow, Richard E. and Salomon, Gabriel. Winter 1968. Aptitudes and instructional media. AV Communication Review 16, No. 4: 341-357.

Snow, R. E.; Tiffin, J.; and Seibert, W. E. 1965. Individual differences and instructional film effects. Journal of Educational Psychology 56: 315-326.

Stickell, David White. 1963. A critical review of the methodology and results of research comparing televised and face-to-face instruction. Dissertation Abstracts 24: 3237-40: No. 8.

Thompson, James J. 1969. Instructional communication. New York, New York, American Book Company.

Travers, Robert M. W., editor. 1964. Research and theory related to audiovisual information transmission. Salt Lake City, Utah, Bureau of Educational Research, University of Utah.

Trump, Richard F. and Volker, Roger P. ca. 1970. Foundations of life science. New York, New York, Holt, Rinehart and Winston Publishing Company.

Warman, Roy E. 1968. Test scoring and analysis service. Report No. 68-01. Student Counseling Service. Iowa State University, Ames, Iowa.

Yager, Robert E.; Engen, Harold B.; and Snider, Bill C. F. 1969. Effects of the laboratory and demonstration methods upon the outcomes of instruction in secondary biology. Journal of Research in Science Teaching 6, No. 1: 76-86.

ACKNOWLEDGMENTS

Sincere appreciation is expressed to a number of people who helped in carrying out the study. Special thanks is expressed to those in the Ames school system, especially the three teachers who aided in the planning and carrying out of the study; Richard Trump, Cecil Spatcher, and Roger Spratt.

Gratitude is expressed to Dr. Harold Dilts for help and guidance in planning and completing the project, and to members of the committee, including Dr. Ray Bryan, Dr. Trevor Howe, Dr. C. C. Bowen, and Mr. Herold Kooser.

The staff of the Instructional Resources Center, and particularly Mrs. Jane Elsberry, were especially helpful.

Finally, to my wife Carol, and Paul, Christopher, and Timothy, I express a special thank you for encouragement and understanding.

APPENDIX A. BEHAVIORAL OBJECTIVES FOR PROGRAMMED INSTRUCTION

CHAPTER 8. LIGHT AND THE FUELS OF LIFE

Behavioral Objectives

1. List the products from the scope of plant chemistry
2. Describe Priestley's and Ingenhousz's work with gases
3. Draw and label a "typical" leaf
4. Describe functions of parts of a leaf
5. List the major plant pigments
6. Explain what a light spectrum is
7. Define action and absorption spectra
8. Discuss action and absorption spectra in relation to photosynthesis
9. Draw and label a chloroplast
10. Define cyclosis and explain what functions it may perform
11. Discuss the role of chloroplasts in photosynthesis
12. Write the equation for photosynthesis that shows where the oxygen comes from
13. Explain why photosynthesis is an uphill reaction
14. Discuss experimental evidence for light and dark reactions
15. Discuss the mechanism of ATP formation in photosynthesis
16. Discuss experimental evidence using labeled CO_2 for stepwise reactions in photosynthesis
17. Discuss mechanics of the light and dark reactions
18. List reasons why photosynthetic pathways are indirect

These arc the objectives for the programmed instruction only. As we point out on the audio tape, which you will listen to on the day you are given this programmed instruction, these objectives will be used by your instructor to make up the test over this chapter. If you study the programmed instruction carefully, and check off the above objectives one by one, as you find you are able to perform them, you should be well prepared for the chapter test IT'S AS SIMPLE AS THAT!

There are similar objectives for the laboratory work. You will be given the laboratory work in a few days, along with the objectives for it.

IF YOU HAVE ANY QUESTIONS --- ASK YOUR INSTRUCTOR TODAY!

CHAPTER 9. PLANTS FROM THE SEA

Behavioral Objectives

1. Describe Miller's hypothesis, experiment, and conclusions about the origin of life
2. Describe conditions on the early earth
3. Outline the hypothesis Oparin had about the origin of life
4. List the capabilities early cells needed to remain alive
5. Describe functions of hemoglobin and chlorophyll; their similarities and differences.
6. Outline the importance of cell membranes
7. Label and describe structures and functions of organelles in Chlamydomonas
8. Describe algal body forms; filaments, plates, spheres
9. Discuss characteristics of water that makes it suitable to support life
10. Discuss problems plants faced as the earth dried out
11. Label and describe structures and functions of bryophytes
12. Compare bryophytes (structures and functions) to algae

13. Discuss adaptations in brophytes that suited them to a land environment

14. Discuss adaptations other land plants developed for living on land

CHAPTER 10. PLANTS ON LAND

Behavioral Objectives

1. Discuss the significance of Rhynia and its connection to present day plants like Psilotum.
2. Describe the process for studying thin sections of fossilized plant parts
3. Label and describe structures and functions in Psilotum.
4. List specializations for survival in land plants
5. Define teleology, differentiation, and meristem.
6. Describe the primary meristems and what they produce
7. Contrast structures in a stem tip and root tip
8. Label structures and discuss functions in stems
9. Label structures and discuss functions in xylem tissue
10. Define transpiration and discuss its significance.
11. Define cohesion
12. Label structures and discuss functions in phloem tissue
13. Discuss structure and function of vascular and cork cambiums.
14. Define secondary growth
15. List functions of roots
16. Define divergent evolution.

APPENDIX B. SCHEDULE OF TOPICS

Experimental Group

Mon 11/17	Chapter 8. Light and the fuels of life Orientation tape and programmed instruction	
Tue 11/18	Films: Gift of Green; Photosynthesis	Frames 1-20; PI
Wed 11/19	Laboratory: Exercise 8A - Leaves	Read Ex. 8A Frames 21-31; PI
Thr 11/20	Discussion: Questions in Ex. 8A	Prepare answers to lab questions
Fri 11/21	Laboratory: Exercise 8C - Photosynthesis	
Mon 11/24	Discussion: Recap first half of Chapter 8	Brush up on first half of Chapter 8
Tue 11/25	Discussion: Exercise 8C	Prepare answers to lab questions
Wed 11/26	Laboratory: Exercise 8B - chromatography	Read Ex. 8B; finish PI
Mon 12/1	Discussion: Recap last half of Chapter 8	Brush up on last half of Chapter 8
Tue 12/2	Test: Chapter 8, Pick up Chapter 9 Plants from the Sea	
Wed 12/3	Film: Algae; Read PI	
Thr 12/4	Laboratory: Exercise 9A - Algae	
Fri 12/5	Laboratory: Exercise 9B - Bryophytes	
Mon 12/8	Discussion - Chapter 9 and Exercises 9A and 9B	
Tue 12/9	Discussion: Recap chapter and labs Test: Chapter 9	
Wed 12/10	Films: Angiosperms; Gymnosperms; Pick up Chapter 10	
Thr 12/11	Chapter 10: Orientation tape. Read PI	

Fri 12/12	Laboratory: Exercise 10A - Stems	Frames 1-30; PI
Mon 12/15	Discussion: Review first half of chapter	
Tue 12/16	Films: Growth of Plants; Seed Germination	
Wed 12/17	Laboratory: Exercise 10B - Roots	
Thr 12/18	Discussion: Recap Chapter 10	Finish PI
Fri 12/19	Test: Chapter 10	

Control Group

Mon 11/17	Chapter 8. Light and the fuels of life Introduction and in-class reading
Tue 11/18	Discussion. Chlorophyll, energy transfer, pigments
Wed 11/19	Films: Gift of Green; Photosynthesis
Thr 11/20	Discussion: Vascular bundles, TPN·H_2, tagging atoms, chloroplasts
Fri 11/21	Discussion: Products of photosynthesis, light spectrum, conditions for photosynthesis
Mon 11/24	Laboratory: Photosynthesis in Geranium
Tue 11/25	Laboratory, cont: Cyclosis in Elodea, O_2 from Elodea
Wed 11/26	Discussion and Review: Leaf structure, photosynthesis
Mon 12/1	Test: Chapter 8; introduction to Chapter 9. Plants from the Sea
Tue 12/2	Discussion: Algae groups, morphology of algae
Wed 12/3	Film: Algae
Thr 12/4	Discussion and Review: Basis for grouping algae, review chapter

Fri 12/5	Test:	Chapter 9
Mon 12/8	Chapter 10;	Plants on land. Introduction and in-class reading
Tue 12/9	Laboratory:	Microscope slides of stems and roots
Wed 12/10	Films:	Angiosperms, gymnosperms
Thr 12/11	Discussion:	Stems and roots
Fri 12/12	Discussion:	First half of Chapter 10
Mon 12/15	Laboratory:	Work with fresh material (stems and roots)
Tue 12/16	Films:	Growth of Plants, Seed Germination
Wed 12/17	Laboratory:	Root hairs
Thr 12/18	Review:	Last half of Chapter 10
Fri 12/19	Test:	Chapter 10

APPENDIX C. LESSON PLANS FOR EXPERIMENTAL GROUP

AMES HIGH SCHOOL BIOLOGY STUDY

Experimental Group

Lesson Plan for Monday, Nov. 17, 1969

Lesson Title Orientation Tape and Programmed Instruction

Pass out Chapter 8 - Light and the Fuels of Life.

Pass out behavioral objectives for Chapter 8.

Say a word about the audio tapes.

1. There are 10 tapes, all identical.
2. The tape recorders are on some of the tables where students are sitting. After the two students at a table have listened, they should give the recorder to those at a nearby table.
3. It doesn't matter whether a student hears the tape first, and then reads, or vice versa.
4. The tapes run about 5 minutes.
5. An instruction sheet goes with each tape recorder. If students have trouble operating recorder, encourage them to ask teacher for help.
6. Tape content:
   - brief overview of chapter ideas
   - a word about the labs
   - use of behavioral objectives as guidelines for study
   - how to use the programmed instruction

Say a word about the programmed instruction.

1. It is not "mixed up" or scrambled. It reads just like the previous chapters, in sequence.
2. Students will learn most if they really answer each question before going on. Cheating the program by not answering, or by sneak-previewing the correct answer only cheats themselves.

Spend the rest of the period reading and listening to tape.

AMES HIGH SCHOOL BIOLOGY STUDY

Experimental Group

Lesson Plan for Tues., Nov. 18, 1969

Lesson Title Films

Gift of Green - discuss overall message of the film.

- point out important things to watch for.
- Hand out guide sheet, which provides a running account of ideas developed in film
- Pose these questions (see guide sheet) to be answered after film is finished.
- AFTER FILM - have students, in groups of 4, discuss answers to questions - then respond with group concensus

Photosynthesis - Same as above.

AMES HIGH SCHOOL BIOLOGY STUDY

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Experimental Group

Lesson Plan for Wed., November 19, 1969

Lesson Title Lab - 8A - Leaves

Materials: Slides - Leaf types, external views, photo-micrographs of leaf x.s.'s.

Film loop - "Stomatal Opening and Closing"

The instructions for performing the lab work are on tape. Students will view slide set showing both external characteristics of leaves, and leaf x.s. Differences and similarities of these leaves will be pointed out.

After the external views, students label simple, compound, stalked and not-stalked leaves on the drawing.

After a general comment about internal structure, students will label a "typical leaf". Then a series of slides will be used to show differences and similarities in a variety of leaves.

The film loop will be used after a brief word on stomates and their significance.

Discussion questions are asked, and should be the basis for class discussion on the next day.

STOMATAL OPENING AND CLOSING | Film Guide 8-91 3 1/2 minutes

The cutinized epidermis of leaves and young stems is a major factor in the ability of land plants to survive in the atmosphere. However a completely impervious seal over the leaf surface would interfere with many essential processes in the plant and, in almost all cases, the cutinized epidermis is perforated with numerous minute openings called stomata. These permit a ventilation of internal cells of the leaf and facilitate exchanges of oxygen and carbon dioxide with the atmosphere. Each of the green cells of a leaf has a portion of its wall exposed to the internal atmosphere; and exchanges occur between the atmosphere and a film of water held in the exposed wall by imbibition. Some water is unavoidably lost by evaporation to the internal atmosphere, and diffusion of water vapor through the open stomata occurs whenever the relative humidity of the external atmosphere is less than that of the internal atmosphere.

Size of a stoma is controlled by a pair of cells, the guard cells, which surround the opening. It is relatively easy to establish that the greater the turgidity of the guard cells the greater the size of the opening. When the guard

STOMATAL OPENING AND CLOSING | 8-91 (Continued)

cells loose turgidity the opening becomes smaller and is eventually closed. It is difficult to briefly discuss factors involved in changing turgidity of the guard cells, but it is possible to demonstrate with balloons the mechanical principle involved in the opening and closing. Observation shows that a portion of the wall of each guard cell next to the stoma is thicker than the rest of the cell wall, and this condition can be simulated by placing strips of tape on the inner surfaces of two adjoining balloons. When the balloons are inflated, the thin-walled portion bulges outward while the thick-walled portion buckles inward. When the internal pressure in the balloons is released, the walls resume their original positons and the simulated opening disappears.

Reference: Wilson, Carl L. and Walter E. Loomis. 1967. *Botany*. ed. Holt, Rinehart and Winston, New York.

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L.C. Card No. Fi A 68-

AMES HIGH SCHOOL BIOLOGY STUDY

Experimental Group

Lesson Plan for Thurs., Nov. 20, 1969

Lesson Title Discussion of Labs: Leaves and Photosynthesis

Leaves - Give the class about 10 minutes to discuss, in groups of 4, the

30 min. answers to the questions in Exercise 8A.

1. Assign a specific question to each group.
2. Have each group summarize it's answer on a plastic sheet, using felt pen.
3. Ask one member from the group to put the transparency on projector and discuss answer with class.

Photosynthesis - Provide an overview of Exercise 8C.

20 min.

1. Explain that 5 groups will be working simultaneously but that 4 of the groups will be doing two different activities, 20 minutes on each. The 5th group will work the entire period with the Hach Kit.

   a. Group 1 - Spectroscope - 20 min.
      Need for CO_2 - 20 min.

      Group 2 - *Elodea* and bromthymal blue - 20 min.
      Film loops; CO_2 uptake - 20 min.

      Group 3 - Need for CO_2 - 20 min.
      Spectroscope - 20 min.

      Group 4 - Film loops; CO_2 uptake - 20 min.
      Elodea and bromthymal blue - 20 min.

      Group 5 - Hach Kit; CO_2, O_2, pH relationships in *Elodea* growth - 40 min.

2. Say a brief word about each of the 5 exercises.
3. Assign the groups; 5 or 6 students to each.
4. Urge students to read their assignment so they'll know what they are going to do.

AMES HIGH SCHOOL BIOLOGY STUDY

Experimental Group

Lesson Plan for Friday, Nov. 21, 1969

Lesson Title Lab: Photosynthesis

1. See that students are in properly assigned teams.

2. Check with each team to see that it knows what it is going to do.

3. Point out that results will be discussed next Wednesday, November 24.

4. Check with each team as it works, making sure the equipment and apparatus is functioning properly.

5. Remind teams 1, 2, 3, and 4 that they have two exercises to complete. Give them a push if they fall behind. About 20 minutes per exercise should be adequate.

6. Help teams work out some of the answers to questions, if there is time.

PHOTOSYNTHETIC FIXATION OF CARBON DIOXIDE | Film Guide 4-15 | 8 1/3 minutes

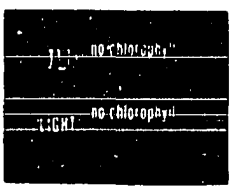

Fig. 1.

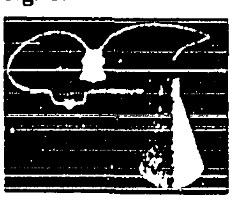

Fig. 2.

Procedure: By using $C^{14}O_2$ in an experiment with variegated (green-white) *Coleus blumei* leaves in a light-dark chamber, the radioactivity of the tagged carbon can be used to measure CO_2 fixation under four different conditions (fig. 1).

Exposure of the leaves to radioactive carbon dioxide is carried out within a closed system consisting of a vessel for generating the carbon-14 dioxide, a light-dark chamber divided by a light-tight baffle which allows free passage of gases, and a pump to circulate the enclosed atmosphere (fig.2). $C^{14}O_2$ is generated by the reaction of a solid carbonate with a non-volatile acid: $BaC^{14}O_3 + 2\,HClO_4 \rightarrow Ba(ClO_4)_2 + H_2O + C^{14}O_2$.

PHOTOSYNTHETIC FIXATION OF CARBON DIOXIDE | 4-15 (Continued)

A 20-minute reaction period assures nearly complete removal of $C^{14}O_2$ from the system. Equivalent samples are taken from the green and white areas of each leaf. The radioactivity of each sample is then measured with a Geiger-Muller counter, using a counting period of 10 minutes.

Data:

$C^{14}O_2$ applied: 4 μc

Background radiation: 259 counts/10 minutes

Condition	Sample	Counts/10 minutes
dark	chlorophyll	410
	no chlorophyll	480
light	chlorophyll	21477
	no chlorophyll	799

Results:

(Corrected for background.)

Reference: Bassham, J. A. *The Path of Carbon in Photosynthesis*, Scientific American, June, 1962.

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AMES HIGH SCHOOL BIOLOGY STUDY

Experimental Group

Lesson Plan for Monday, Nov. 24, 1969

Lesson Title Chapter Review to Date

1. Review points in the chapter you feel need emphasis. Use transparencies listed below:

No.	
23	Leaf variations
24	Leaf variations
25	Leaf structure
26	Leaf structure
27	Leaf photosynthesis

2. Points to consider include:

   a. Scope of products from plant chemistry.

   b. Priestley's and Ingenhouse's work on gases.

   c. Terms: parts of a leaf; external and internal plant
      pigments; chlorophylls, xanthophylls, carotene
      spectra; action and absorption
      chloroplast; grana and stroma
      cyclosis
      ATP; its role in photosynthesis
      light and dark reactions

   d. Discuss photosynthesis as an uphill reaction

3. Discuss any questions students may have.

AMES HIGH SCHOOL BIOLOGY STUDY

Experimental Group

Lesson Plan for Tues., Nov. 25, 1969

Lesson Title Discussion: Recap Labs on Chromatography and Photosynthesis

1. Put the Hach Testing Kit Team to work right away getting results of their set-up from last Friday, November 21.

2. Have other teams observe set-ups and note results. This applies to: Need for CO_2

   Elodea and bromthymol blue

3. Hand out blank plastic sheets and felt pens. Have students summarize answers to questions dealing with the exercises their team worked on.

4. Point out they may wish to make drawings, write chemical equations, or give the answer in a short sentence. They may wish to give some answers verbally, without using the transparency.

5. Pace yourself so there is time to discuss all five exercises.

AMES HIGH SCHOOL BIOLOGY STUDY
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Experimental Group

Lesson Plan for Wed., Nov. 26, 1969

Lesson Title Lab: Chromatography of Plant Pigments

1. Divide class into 5 groups.

2. Have each group view the film loop. They will not use audio tape.

3. Re-run ONE loop, and play the audio tape that accompanies it, for entire class.

4. Discuss questions outlined in Exercise 8B.

PHOTOSYNTHETIC PIGMENTS IN SOME MAJOR PLANT GROUPS | Film Guide 7-17 3 minutes

The development of modern techniques in chromatography is of special interest to botanists. For example, the fact that pigments of the green algae are shown to be more like those of higher plants than those of other groups of algae, lends support to the hypothesis that land plants have evolved from green algae.

In this film paper chromatography is used to compare the pigments of green algae, mosses, ferns, and flowering plants. The plant parts are placed in a mortar and cold acetone is added. The material is ground and the liquid is filtered through paper to remove plant debris. The extract is then placed in a separatory funnel and petroleum ether (Skelly B) is added in an amount equal to the extract. Since acetone is miscible with water, while petroleum ether is not, the addition of water induces a separation with the petroleum ether forming an upper layer. Most of the plant pigments remain dissolved in the petroleum ether which becomes dark green. The acetone-water portion is then discarded.

The paper used for chromatograms (Whatman #2 filter paper) is first washed with petroleum ether to remove traces

PHOTOSYNTHETIC PIGMENTS IN SOME MAJOR PLANT GROUPS | 7-17 continued

of oil, etc. There are various techniques for placing the extract on the filter paper. Heavy application with a camel's hair brush provides a density visible on film. When the solvent has evaporated completely, the paper is dipped briefly in acetone to allow the pigments to diffuse into a definite line. After the acetone has evaporated completely, the filter paper is placed in a jar which contains a developing or "eluting" fluid (100 ml. of Skelly B and 1.3 ml. of *n*-propanol). The bottom edge of the paper is dipped into this and the solvent moves upward by capillarity. (The pigment line is not immersed.) The pigments then diffuse upward at different rates and a separation results. The observed separation, shown in time-lapse, occurred within 20 minutes. Finally, chromatographs of the pigments of green algae, mosses, ferns, and flowering plants are shown side-by-side. The similarities are striking. (The faint band above the chlorophyll in the case of the bean extract is considered a degradation product.)

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AMES HIGH SCHOOL BIOLOGY STUDY

Experimental Group

Lesson Plan for <u>Monday, December 1, 1969</u>

Lesson Title <u>Discussion: Last half of</u> Chapter 8

Discuss these topics:

1. The reaction: $GCO_2 + 12H_2O^* \longrightarrow C_6H_{12}O_6 + 6H_2O + 6O_2^*$

   Point out that the oxygen liberated in photosynthesis comes from the water--and the "labeled" oxygen in the reaction above totals 12 atoms on each side.
2. Blackman's work
3. The energy passing system involving hydrogen, ATP, and TPN.
4. The tagging of carbon and determination of metabolic pathways.
5. Calvin's work
6. Light and dark reactions
7. Reasons for photosynthesis being a long, indirect route to sugar production

Finish discussion of questions from Exercise 8C.

AMES HIGH SCHOOL BIOLOGY STUDY

Experimental Group

Lesson Plan for Tuesday, December 2, 1969

Lesson Title Test over Chapter 8

Administer multiple-choice test using special answer sheets.

Have students pick up, assemble, and staple program for Chapter 9.

AMES HIGH SCHOOL BIOLOGY STUDY

Experimental Group

Lesson Plan for Wednesday, December 3, 1969

Lesson Title Film and Orientation to Chapter 9

Algae - Pass out Guide Sheets to film

Point out (1) What the film shows

(2) Questions for discussion

(3) Key words

Show film

Spend 10-15 minutes discussing the Guide Sheet

Have students listen to orientation tape on Chapter 9 after showing film.

Experimental Group

Lesson Plan for Thursday, Dec. 4, 1969

Lesson Title Lab - 9A - Algae

Materials: Slides - collection of algae, body forms, photomicrographs of algae.

Film Loops - see film guides below.

Audio tape - contains narrative for lab work.

See Exercise 9A for specific instructions and discussion questions

Prepare to discuss questions on Monday, December 8.

A FRESH-WATER ALGAL BLOOM

Film Guide
7-42
2 3/4 minutes

The term, algal bloom, refers to a phenomenon in which one or a few species of algae become so numerous that aquatic habitats become colored by their presence. Although algae in many different groups can enter the bloom condition, it is the blue-green algae which form the most conspicious and obnoxious blooms. Blue-greens exist in a wide variety of habitats and can be found in all seasons of the year, but certain species flourish best in waters which are mildly alkaline, which warm to about 25°C. or more in summer, and which contain abundant quantities of nitrates, phosphates, etc. Since these conditions exist in many of the shallow prairie lakes of the midwest, the occurrence of blue-green algal blooms in mid-summer is a common phenomenon there.

Three common blue-green algae are illustrated in this film. *Aphanizomenon flos-aquae* is of widespread occurrence and is easily recognized by its habit of forming raft-like colonies in which hundreds of filaments lie side by side, gliding past each other slowly so the "rafts" constantly change shape. Perhaps the most common blue-green in algal blooms is *Microcystis aeruginosa (Anacystis cyanea)*. In this species, thousands of small spherical cells are suspended in a gelatinous

A FRESH-WATER ALGAL BLOOM

7-42
(Continued)

matrix. The genus *Anabaena* contains many species, some of which are straight and solitary, others (like the one in this film) of which are twisted and tangled resembling *Nostoc*.

Many blue-green algal cells contain numerous small gas vacuoles (pseudovacuoles) which apparently cause them to float upwards slowly. On reaching the surface film, colonies may then be pushed shoreward by gentle breezes. (Strong wind action causing waves is not as effective as a gentle breeze.) Noticeable differences between concentrations of algae on opposite sides of a lake may result. On downwind shores the conspicious floating masses are often washed up on rocks and beaches, while concentrations near the opposite (upwind) shore are much less obvious.

Most blue-green algae have an outer gelatinous coating (which makes them stick to rocks, etc.). When stranded in exposed positions, they begin to decompose, giving rise to offensive odors. During this process the chlorophyll pigments disintegrate rapidly. The two phycobilin pigments, one red and one blue, persist for a longer time and are thus responsible for the colored coatings on exposed surfaces.

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LIBERATION OF ZOOSPORES IN THE ALGA, *Basicladia.*

Film Guide
4-66
3 1/2 minutes

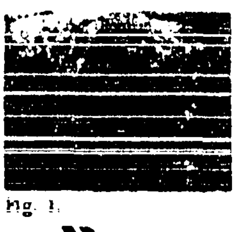

Fig. 1.

Fig. 2.

A common method of asexual reproduction in the green algae is the formation of zoospores. This often occurs as light intensity increases in the early morning or after sudden environmental changes.

On the backs of turtles or on the shells of snails, we sometimes find the fresh water alga, *Basicladia*. The so called "moss" on a "moss-backed" turtle is usually a tangled mat of *Basicladia* filaments (fig. 1)

Illumination from the microscope lamp frequently stimulates zoospore formation. Individual cells in the filament are observed to gradually darken as maturation of the zoospores progresses. An exit pore forms (fig. 2), and most of the spores

LIBERATION OF ZOOSPORES IN THE ALGA, *Basicladia.*

4-66
(Continued)

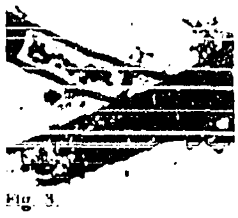

Fig. 3.

Fig. 4.

escape through it during the first few seconds after the pore membrane bursts. Several minutes, however, may elapse before the sporangium is completely empty (figs. 3 and 4).

Those zoospores that encounter a suitable substrate attach themselves and develop into new filaments.

Reference: Smith, G. M., *Freshwater Algae of the United States*, McGraw-Hill Book Co., 1950.

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AMES HIGH SCHOOL BIOLOGY STUDY
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Experimental Group

Lesson Plan for Friday, December 5, 1969

Lesson Title Lab - 9B - Bryophytes

Materials: Slides - external views of mosses, photomicrographs of selected structures.

Film Loop - see film guide below.

Audio tape - contains information on Exercise 9B.

See Exercise 9B lab sheets for more specific instructions and discussion questions.

Prepare to discuss the questions in Exercise 9B next Monday, December 8.

GAMETE TRANSFER IN BRYOPHYTES—
The Splash Cup in a Moss.

Film Guide
4-73
3 1/3 minutes

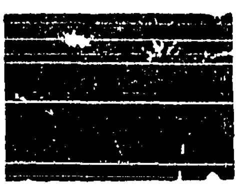

Fig. 1.

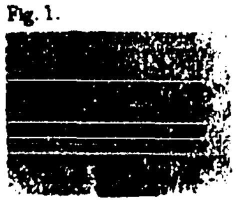

Fig. 2.

This film can be used either as an example of a structural modification facilitating gamete transfer or as an appropriate segment of the life cycle of a moss.

In some mosses the male and female (fig. 1) gametangia are borne on separate plants. The antheridia in mosses such as *Polytrichum* and *Atrichum* are nestled among a cluster of leaves at the tip of the stem of the male gametophyte. In the presence of moisture from dew or rain, masses of sperm cells are discharged from mature antheridia (fig. 2).

The individual male gametes swim freely in the splash cup which is formed by the overlapping leaves at the apex of the male gametophyte. As moisture ac-

GAMETE TRANSFER IN BRYOPHYTES— **4-73**
~~The Splash Cup in a Moss.~~ ~~(Continued)~~

Fig. 3.

cumulates, water films develop over the leaves of the female gametophytes. The impact of falling water upon the splash cup of the male gametophyte scatters sperm-bearing droplets, some of which may hit the apices of nearby female gametophytes.

The archegonia are borne at the tips of these female plants. Sperms must still swim to the immobile egg within the archegonium (fig. 3). The neck cells of the mature archegonium enclose a canal which provides a passageway for the sperms. From the fertilized egg a sporophyte develops.

Reference: Bold, Harold C. 1957. Morphology of Plants, Harper & Bros., New York.

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Lesson Plan for Monday, December 8, 1969

Lesson Title Discussion of Chapter 9

1. Discuss points in the chapter you feel need emphasis. Use transparencies listed below:

No.	
2	Algae - green
3	Algae - blue green
14	Moss

2. Points to consider include:

   a. Miller's experiment

   b. What we believe the early earth was like

   c. The atmosphere around the early earth

   d. Adaptations early cells needed for survival

   e. *Chlamydomonas* structures and functions

   f. Three body forms of algae: filaments, plates, and spheres

   g. Physical and chemical properties of water that enable living things to survive in an aquatic environment.

   h. Mountain building and the changing earth

   i. Problems plants on land face

   j. Bryophyte structures and functions

3. Discuss questions in Exercises 9A and 9B.

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Experimental Group

Lesson Plan for Tuesday, Dec. 9, 1969

Lesson Title Test - Chapter 9 - Plants from the Sea

Administer test over Chapter 9.

Pass out guide sheets to films used tomorrow.

Experimental Group

Lesson Plan for Wednesday, December 10, 1969

Lesson Title Films: Angiosperms and Gymnosperms

Angiosperms - Pass out guide sheets to film

Point out (1) What the film shows

(2) Questions for discussion

(3) Key words

Show film

Spend 10-15 minutes discussing Guide Sheet

Gymnosperms - Pass out guide sheets to film

Point out (1) What the film shows

(2) Questions for discussion

(3) Key words

Show film

Spend 10-15 minutes discussing Guide Sheet

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Experimental Group

Lesson Plan for Thursday, December 11, 1969

Lesson Title Chapter 10 - Plants on Land - Orientation to PI

Have students pick up, assemble, and staple PI for Chapter 10

Have students spend the period listening to orientation tape and reading PI.

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Experimental Group

Lesson Plan for Friday, December 12, 1969

Lesson Title Lab - Exercise 10A - Stems

Materials: Slides - external and internal views of herbaceous and woody stems
Film Loops - See film guides below
Audio tape - Contains narrative for lab work

Prepare to discuss answers to questions in the lab sheets on Monday, December 15.

TRANSPIRATION RATES | Film Guide 7-24 | 2 1/4 minutes

Transpiration is the loss of water in the form of vapor from the aerial parts of plants. A major plant adaptation for reduction of transpiration is the cutinized epidermis. This is perforated by numerous minute openings (stomata) which permit essential exchanges of carbon dioxide and oxygen with the atmosphere, and coincidently allow escape of water vapor from air spaces within the leaf.

There are many types of apparatus which may be used to measure transpiration. Basically, however, they measure either the amount of water lost by the plant or the amount of water taken up to replace that which is lost.

This film demonstrates the occurrence of transpiration but does not measure exact rates. (Students should be aware that precise measurement of transpiration rates is a complicated procedure.) In the first demonstration a plant is cut under water to prevent air bubbles from plugging the xylem. The cut stem is connected to a water system (to which a dye has been added for viewing purposes) by a plastic tube. Changes in the water level as observed through a calibrated pipette indicate the rate of water uptake by the plant.

TRANSPIRATION RATES | 7-24 continued

In the other demonstration an entire plant is used to measure the rate of water loss. The pot and the soil are covered with plastic to prevent evaporation from their surfaces. The plant is placed on a scale and time-lapse observation of the needle indicates gradual weight loss over a period of several hours.

Certain environmental influences on transpiration are illustrated. (The subject should be studied in a standard botany textbook before any interpretation is attempted.) A stable rate of transpiration is assumed at the start of the demonstration. A gentle breeze continuously removes water vapor molecules from the vicinity of the stomata, thus maintaining the steepness of the diffusion gradient for water vapor between the internal and external atmosphere. When a plastic bag is placed over the plant, transpiration continues until the atmosphere inside approaches saturation. At such time the rate of diffusion of water vapor through the stomata in each direction will be equal and thus the transpiration rate falls to zero.

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EARLY DEVELOPMENT OF THE SHOOT IN *Quercus* | Film Guide 5-32 | 3 1/3 minutes

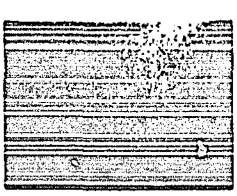
Fig. 1

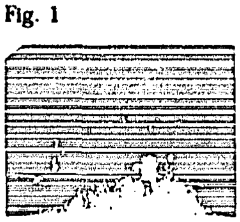
Fig. 2

Leaves are initiated at the apex of shoots in characteristic patterns. Patterns of leaf distribution on mature stems are based on patterns of leaf initiation but may be variously modified during growth.

By dissecting an acorn and removing one of the two cotyledons from the embryo (fig. 1) it is possible to observe (and record with time-lapse photography) the initiation of new leaves by the apical meristem (fig. 2). During their early development, the young leaves arch over and enclose the meristem (fig. 3) thus providing a degree of protection against adverse environmental factors such as desiccation. Later, they are gradually

EARLY DEVELOPMENT OF THE SHOOT IN *Quercus* | 5-32 (Continued)

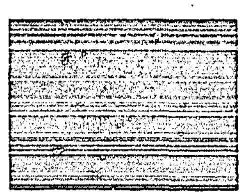
Fig. 3

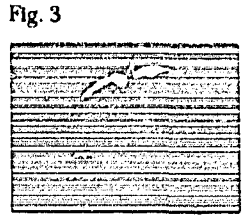
Fig. 4.

separated from one another by internodal elongation (fig. 4).

The spontaneous growth movements (nutations) which occur during stem development are especially apparent when photographed in time-lapse.

References: Esau, Katherine. 1960. *Anatomy of Seed Plants*. John Wiley & Sons, Inc., New York. Mogensen, Hans Lloyd. 1966. *A Contribution to the Developmental Anatomy of the Acorn*. Iowa State J. of Sci. (In press.)

Produced under a grant from the National Science Foundation by Iowa State University, Ames.

AMES HIGH SCHOOL BIOLOGY STUDY

Experimental Group

Lesson Plan for Monday, December 15, 1969

Lesson Title Discussion - First half of Chapter 10 and Exercise 10A

Discuss these topics:

1. The significance of Rhynia and Psilotum
2. Adaptations of land plants for survival
3. Teleology
4. The stem tip
5. The root tip
6. Stem structure
7. Transport in xylem
8. Phloem function

Use transparencies listed below:

No. 20 Angiosperms - Monocot, dicot

21 Angiosperms - Stem structure

22 Stem structure

28 Roots - Structure and function

29 Roots - Structure and function

30 Roots - Structure and function

Discuss questions on Exercise 10A - Stems

AMES HIGH SCHOOL BIOLOGY STUDY

Experimental Group

Lesson Plan for Tuesday, December 16, 1969

Lesson Title Films; Growth of Plants and Seed Germination

Growth of Plants - Pass out guide sheets to film

Point out (1) What the film shows

(2) Questions for discussion

(3) Key words

Show film

Spend a few minutes discussing guide sheet

Seed Germination - Pass out guide sheets to film

Point out (1) What the film shows

(2) Questions for discussion

(3) Key words

Show film

Spend a few minutes discussing guide sheet

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Experimental Group

Lesson Plan for Wednesday, December 17, 1969

Lesson Title Lab - Exercise 10B - Roots

Materials: Slides - external and internal views of roots

Film loop - see film guide below

Audio tape - contains narrative for lab work

EARLY DEVELOPMENT OF THE ROOT SYSTEM

Film Guide 6-31
2½ minutes

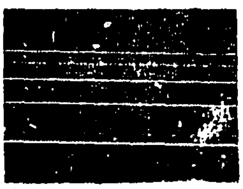

Fig. 1

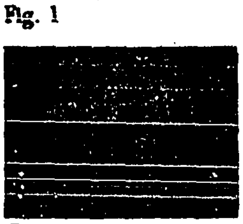

Fig. 2

Soon after a seed (in this case *Pisum sativum*) imbibes water, the radicle emerges and grows downward. The growth of roots involves both new cell formation and cell enlargement. In the apical meristem, where most of the new cells are formed, synthesis of protoplasm and absorption of water constantly tend to increase the average cell size, while cell divisions have the opposite effect.
The rate of cell division gradually slows down in the zone behind the root tip, but cell enlargement continues. Thus the cells in this zone become much bigger, particularly in the longitudinal axis.
This growth is primarily responsible for pushing the root tip through the soil. During this process the delicate cells

EARLY DEVELOPMENT OF THE ROOT SYSTEM 6-31 (continued)

of the apical meristem are protected from mechanical injury by a thimble-shaped covering of cells called the root cap.
Root cells elongate rapidly to maximum size and, thereafter, continue to differentiate until the major tissue systems become mature. One of the obvious changes which occur in the zone of differentiation is the development of root hairs as outgrowths of epidermal cells (fig. 1). (The developing root hairs shown are emerging from the epidermis of slender roots of red-top grass, *Agrostis alba*.)
In the region where primary tissues have essentially matured, lateral roots develop from internal tissue and grow outward through the cortex. Time-lapse cinemicrography shows emergence and growth of such a lateral root (fig. 2).
Separation of evenly spaced dots on a root indicates limitation of the zone of cell elongation.
Reference: Fuller, Harry J., and Oswald Tippo. 1949. College botany. Holt & Co., New York.

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Experimental Group

Lesson Plan for Thursday, December 18, 1969

Lesson Title Discussion - Chapter 10

Discuss points in the chapter you feel need emphasis.

1. Secondary growth - vascular and cork cambium

2. Root characteristics - external and internal

3. Divergent evolution

Discuss answers to questions in Exercise 10B.

AMES HIGH SCHOOL BIOLOGY STUDY

Experimental Group

Lesson Plan for Friday, December 19, 1969

Lesson Title Test - Chapter 10 and Attitude Scale

Administer test over Chapter 10

Administer attitude scale

APPENDIX D. EXAMPLES OF PROGRAMMED INSTRUCTION

CHAPTER 8. LIGHT AND THE FUELS OF LIFE

Frame 1

In the darkness of night the 40 million cells of a young elm leaf carry on a busy chemical industry, constructing the molecules of life. They convert one sugar into another. They link sugars to make starch and cellulose. They add nitrogen to the rearranged atoms of sugars, making amino acids, and link amino acids to make proteins. They construct pyrimidines, purines, and many other molecules that are essential to the tree's chemistry of living. All of this activity requires energy. It comes from the oxidation of carbohydrates, through the reactions of respiration.

IQ What kinds of activities are carried on by the "busy chemical industry" in the cells of a young elm leaf--or any other leaf--at night?

2

1A.

1. Convert one sugar to another.
2. Make amino acids and proteins.
3. Construct pyrimidines, purines, and other essential molecules.

At dawn another activity is added. Microscopic pores on the lower surface of the leaf open, speeding the exchange of gasses between the cells and the atmosphere. As the sunlight becomes brighter, chlorophyll and other pigments absorb energy that splits molecules of water apart. The oxygen diffuses out of the leaf through the open pores; and by means of chemical energy that came from light, the hydrogen atoms are linked to molecules of carbon dioxide.

Frame 2

<u>The scope of plant chemistry</u>. Chlorophyll the green substance of the leaf, has been called the link between the sun and life on the planet earth. It provides for the needs of virtually all other life, in addition to the needs of the plants in whose cells it works.

2Q What activities are added when leaves are exposed to light?

CHAPTER 9. PLANTS FROM THE SEA

In one of the University of Chicago laboratories in 1952, 22 year old Stanley Miller was testing a hypothesis concerning the origin of life. Scientists had suggested that early in the history of the lifeless earth, inorganic substances combined to produce simple organic compounds. At

Frame 1 the suggestion of his advisor in biochemistry, Dr. Harold Urey, Miller had designed and built apparatus to test this hypothesis. Now the long and often tedious laboratory work was beginning to pay off. After a week of high voltage discharge across two electrodes in the large glass sphere, the colorless liquid that condensed from the atmosphere inside began to turn dark red. The mixture of methane, ammonia, hydrogen, and water vapor that Miller had put in the sphere a week before was almost gone. According to the hypothesis, new organic compounds should form from these gasses, in the presence of intense bursts of electricity.

IQ. What hypothesis was Miller testing?

2

1A. Inorganic substances could combine to produce organic compounds.

Evan though the reactions in the flask were nearing completion, it would still require another 24 hours before results could be interpreted. The colored, watery mixture of chemicals had to be spread in a line on filter paper and separated by the process of paper chromatography. Perhaps no unusual compounds had been formed with the artificial lighting in the maze of twisted glass tubing. On the other hand, if his reasoning was correct, Miller should find small quantities of simple amino acids.

When the chromatographs were finished, Miller analyzed the compounds that had been produced in his apparatus. He found that his experiment supported an important hypothesis that had been advanced years earlier by a Russian scientist. It concerned the origin of life.

2Q What technique did Miller use to analyze the composition of the solution that resulted from experiment?

CHAPTER 10. PLANTS ON LAND

Frame 1 In the 1920's near Rhynie, Scotland a group of scientists discovered an unusual plant fossil. It was a small plant, less than two feet tall, with no leaves, roots, or flowers. In fact, it was little more than a stem with a few branches. The scientists named it Rhynia, after the town where it was found.

IQ Describe the plant called Rhynia.

2

1A Rhynia was a small plant, about 2' tall, with no roots, leaves, or flowers. It was apparently just a branched stem.

Paleobotanists (scientists who study plant fossils) wanted to find out if Rhynia had any living relatives. Tests indicated the fossils were over 300 million years old. Yet they were among the first plants that had the right combination of characteristics for life on land. Since external features can be misleading, the paleobotanists made a study of internal structures. By polishing the end of the fossilized stem and coating the surface with plastic, the cells in the stem formed an impression in the plastic. This was peeled from the fossil and studied.

2Q How were paleobotanists able to study the internal structure of fossilized stems?

APPENDIX E. MATERIALS USED IN THE STUDY

Programmed Instruction

Photosynthesis (Chapter 8. Light and the fuels of life) - 37 frames
Lower plants (Chapter 9. Plants from the sea) - 44 frames
Vascular plants (Chapter 10. Plants on land) - 46 frames

Laboratory Guide Sheets

Exercise 8A - Structure and Function in Leaves
Exercise 8B - Photosynthetic Pigments in Major Plant Groups
Exercise 8C - A Closer Look at Photosynthesis
Exercise 9A - Alage
Exercise 9B - Bryophytes
Exercise 10A - Stems
Exercise 10B - Roots

Audio Tapes

Chapter 8 - Orientation (10 copies) 7 minutes
Chapter 10 - Orientation (10 copies) 8 minutes
Exercise 8A - Leaves (5 copies) 19 minutes
Exercise 8B - Chromatography (1 copy) 8 minutes
Exercise 9A - Algae (5 copies) 17 minutes
Exercise 9B - Bryophytes (5 copies) 10 minutes
Exercise 10A - Stems (5 copies) 19 minutes
Exercise 10B - Roots (5 copies) 13 minutes

35mm Slides

Exercise 8A - Leaves; 13 slides in a set, 5 sets

1. Leaf types - simple leaves of angiosperms with petioles, and gymnosperms
2. Leaf types - compound leaves of angiosperms
3. Palmately compound leaf
4. Oak leaf showing eroded mesophyll and veins
5. Model of petiolate angiosperm leaf
6. Model of angiosperm leaf cross section (same as #10)
7. Photomicrograph of grass leaf cross section showing bulliform cells

8. Photomicrograph of grass leaf cross section showing midrib
9. Photomicrograph of apple leaf cross section showing midrib
10. Model of angiosperm leaf cross section (same as #6)
11. Needles and branch of larch
12. Photomicrograph of pine needle cross section
13. Photomicrograph of portion of pine needle cross section showing resin ducts

Exercise 9A - Algae; 11 slides in a set, 5 sets

1. Collection of Spirogyra showing habitat
2. Cladophora growing on rocks
3. Cladophora growing on dock post under water
4. Vaucheria showing branching habit

Slides 5, 6, 7 from plates 1-6 of Palmer, C. Mervin. Algae in Water Supplies, U.S. Department of Health, Education and Welfare, U.S. Government Printing Office, Public Health Service Publication No. 657, 1959.

5. Plates 1 and 2. Taste and odor algae
   Filter clogging algae
6. Plates 3 and 4. Pollution algae
   Clean water algae
7. Plates 5 and 6. Plankton and other surface water algae
   Algae growing on reservoir walls
8. Photomicrograph of Spirogyra showing conjugation tubes
9. Photomicrograph of Trachelomonas showing eye spot
10. Photomicrograph of Daphina showing a algae in digestive tract
11. Decaying blue-green algae showing phycacyanins

Exercise 9B - Bryophytes; 11 slides in a set, 5 sets

1. Mosses growing in forest
2. Mosses growing under eaves in a greenhouse
3. Mature mosses growing on a rock
4. Close-up of moss capsules after spores have been released
5. Capsules of Funaria
6. Capsules of Sphagnum
7. Photomicrograph of moss capsule, longitudinal section
8. Model of antheridium
9. Mnium antheridia, longitudinal section
10. Model of archegonium
11. Polytrichum archegonia, longitudinal section

Exercise 10A - Stems; 11 slides in a set, 5 sets

1. Kentucky Coffee Tree stem showing leaf scars, bundle scars, leaf petioles
2. Models of lilac stem apices; flower bud and leaf bud
3. Model of dicot stem, cross section
4. Photomicrograph of clover stem, cross section
5. Photomicrograph of vascular bundle of clover, cross section
6. Model of monocot stem, cross section
7. Photomicrograph of Dracena stem (monocot), cross section

8. Photomicrograph of vascular bundle of corn, cross section
9. Model of woody stem, cross section
10.
11. Photomicrograph of 2-year old basswood stem, cross section

Exercise 10B - Roots; 8 slides in a set, 5 sets
1. Adventitions roots of cypress trees
2. Adventitions roots of a vine attached to pine tree trunk
3. Model of dicot root, cross section
4. Photomicrograph of quackgrass root, cross section
5. Photomicrograph of Ranunculus root, cross section
6. Photomicrograph of soybean root, cross section, showing secondary root emerging from central cylinder
7. Photomicrograph of Larix root, cross section
8. Photomicrograph of Larix root showing annual rings in wood, cross section

Film Loops

All from Iowa State University Plant Science Studies series

Exercise 8A -	Stomatal Opening and Closing	No. 8-91, 3½ min.	5 copies
Exercise 8B -	Photosynthetic Pigments in Some Major Plant Groups	No. 7-17, 3 min.	5 copies
Exercise 8C -	Photosynthetic Fixation of Carbon Dioxide	No. 4-15, 8½ min.	5 copies
Exercise 9a -	A Fresh Water Algal Bloom--Liberation of Zoospores in the Alga Basicldia	No. 7-42, 2 3/4 min. No. 4-66, 3½ min.	5 copies 5 copies
Exercise 9B -	Gamete Transfer in the Bryophytes; Splash Cup in Moss	No. 4-73, 3 1/3 min.	5 copies
Exercise 10A -	Transpiration Rates	No. 7-24, 2¼ min.	5 copies
	Early Development of the Sheet in Quercus	No. 5-32, 3 1/3 min.	5 copies
	Pathways of Water in Herbaceous Plants	No. 5-23, 3 1/3 min.	5 copies
Exercise 10B -	Early Development of the Root System	No. 6-31, 2 1/3 min.	5 copies

Transparencies

Commercial (Library of Science)

1. Algae - Green
2. Algae - Blue-Green
3. Mosses
4. Angiosperms - Monocot, dicot differences
5. Angiosperms - stems
6. Stem
7. Leaf variations
8. Leaf variations
9. Leaf structure
10. Leaf structure
11. Photosynthesis
12. Roots
13. Roots
14. Roots

Special transparencies made for this study

1. Leaf cross section - page 8A-4 of Exercise 8A
2. Chart of spectrum readings - page 8C-2 of Exercise 8C
3. Chart of bromthymol blue experiment - page 8C-4 of Exercise 8C
4. Chart of Hach Chemical test - page 8C-5 of Exercise 8C
5. Moss life cycle - page 9B-2 of Exercise 9B
6. External characteristics of stems - page 10A-2 of Exercise 10A
7. Cross section of dicot vascular bundle - page 10A-4 of Exercise 10A
8. Cross section of monocot stem - page 10A-6 of Exercise 10A
9. Cross section of monocot vascular bundle - page 10A-7 of Exercise 10A
10. Longitudinal section of root - page 10B-4 of Exercise 10B
11. Dicot root cross section - page 10B-6 of Exercise 10B
12. Monocot root cross section - page 10B-7 of Exercise 10B

APPENDIX F. LABORATORY EXERCISES

Exercise 8A Structure and Function in Leaves

Background This is an exercise dealing with external characteristics of leaves, internal structures, and the way stomates open and close. Your instructions for working through the exercise are on audio tape. You will be using a tape recorder, slide projector, and film loop projector.

You will be asked to label some drawings. The terms are on the drawings; you merely need to indicate which areas of the drawings they refer to.

Feel free at any time to ask your instructor for help, either in operating the equipment, or in labeling the drawings.

Demonstration microscopes are set up on the side shelf with microscope slides of some of the materials you will be studying. If you wish you may look at these in addition to viewing the 35mm slides in the projector. The specific questions, however, are about the slides in the projector.

Before you proceed---

STOP!

1. Do you know how to operate the equipment? If not, ask.

2. Do you have all of the pages of this exercise ready?

Now, look over the drawings. You should have three

Drawing 1. Three-dimensional diagram of a leaf.

Drawing 2. Leaf cross-section, and surface view showing stomates

Slides of leaves Follow instructions on the tape in working with the slides. Then write your answers below

Drawing 1 Follow instructions on the tape in working with this drawing Then label the drawing using these terms.

cutin	palisade cells
upper epidermis	spongy cells
lower epidermis	chloroplasts
vascular bundle	stomate
xylem	guard cells
phloem	air space
	epidermal cell

<u>In addition</u> - count the number of chloroplasts in a palisade cell, record number here ________

- count the number of spongy cells in a palisade cell, record number here ________

On the basis of this information, which layer of cells has more chloroplasts? ____________________

Which layer carries on more photosynthesis? ____________________

Drawing 2 You have just finished labeling structures on Drawing 1. Now, using Drawing 2, you will label <u>functions</u>. Use the list below to aid in labeling

waxy secretion that reduces evaporation from upper epidermis
specialized cells that open and close to let water vapor out of the leaf
conducting tissue
cells that bring water up from other parts of the plant
cells that conduct food materials down from the leaf to other parts of the plant
cells in which most of the photosynthesis occurs
tiny green bodies in cells in which photosynthesis actually takes place

When you have finished with Drawing 2 and Drawing 3 you should be able to:

1. Name the parts of a leaf
2. List the functions of each part

After working with the drawings, follow the instructions on the tape for viewing the film loop on stomates

Then look over the following discussion questions and work out the answers in your laboratory group

Questions for Discussion

1. What survival value, if any, is suggested by the fact that some leaves have a stalk, and some are connected directly to the plant stem?

2. How would you examine an onion bulb, and what would you look for, to determine if it is made up of leaves?

3. List some functions of leaves besides photosynthesis.

4. Which leaf cells contain green pigments and which don't. Suggest some reasons for this.

5. How do the relative number of chloroplasts in the spongy and palisade cells compare?

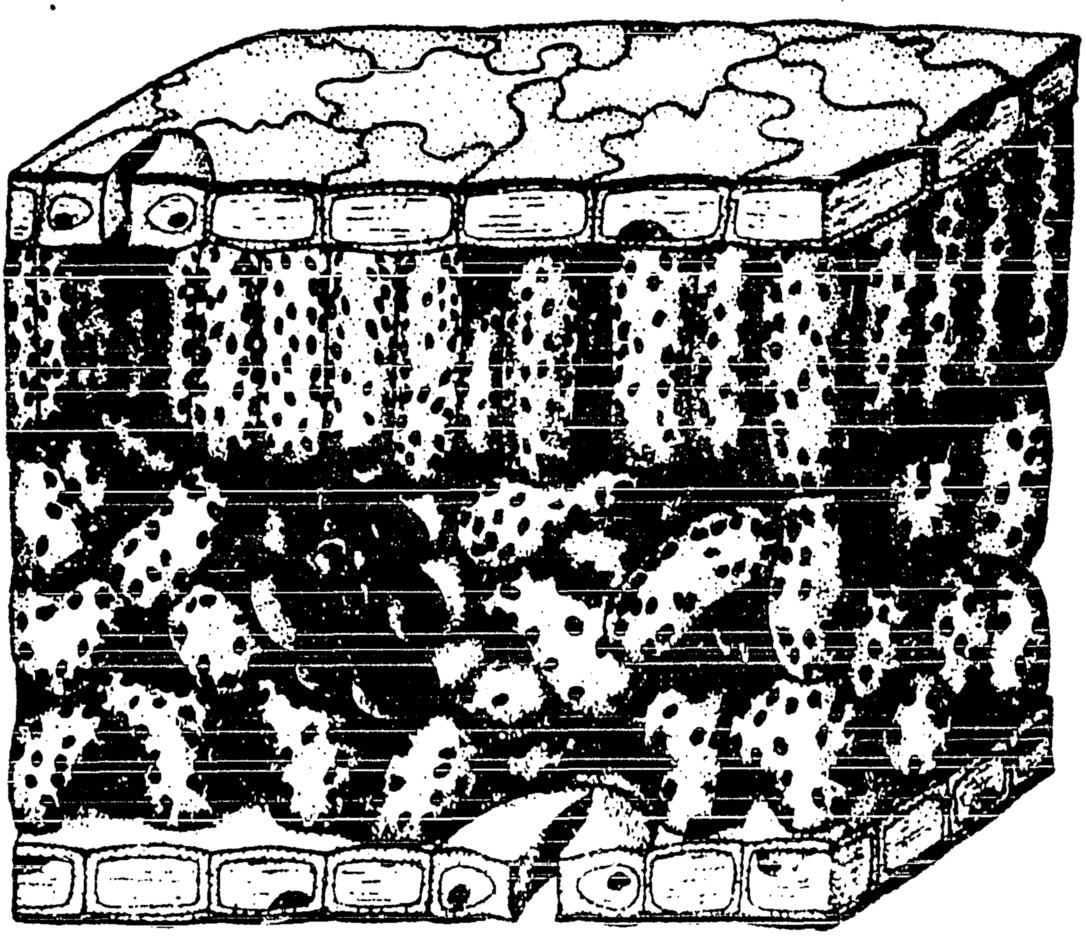
6. What role do turgor pressure and thick inner walls of guard cells play in stomate action?

7. In a living plant, what environmental conditions would cause stomates to open or close?

8. What importance do you attach to adaptations like:
   a. cutin layer on epidermis
   b. leaves with a stalk
   c. leaves without a stalk
   d. stomates
   e. needle-like leaves of evergreen
   f. flat blade-like leaves like grass or maple trees
   g. different numbers of stomates in palisade and spongy cells
   h. different kinds of conducting cells (xylem and phloem) in a vascular bundle in a leaf

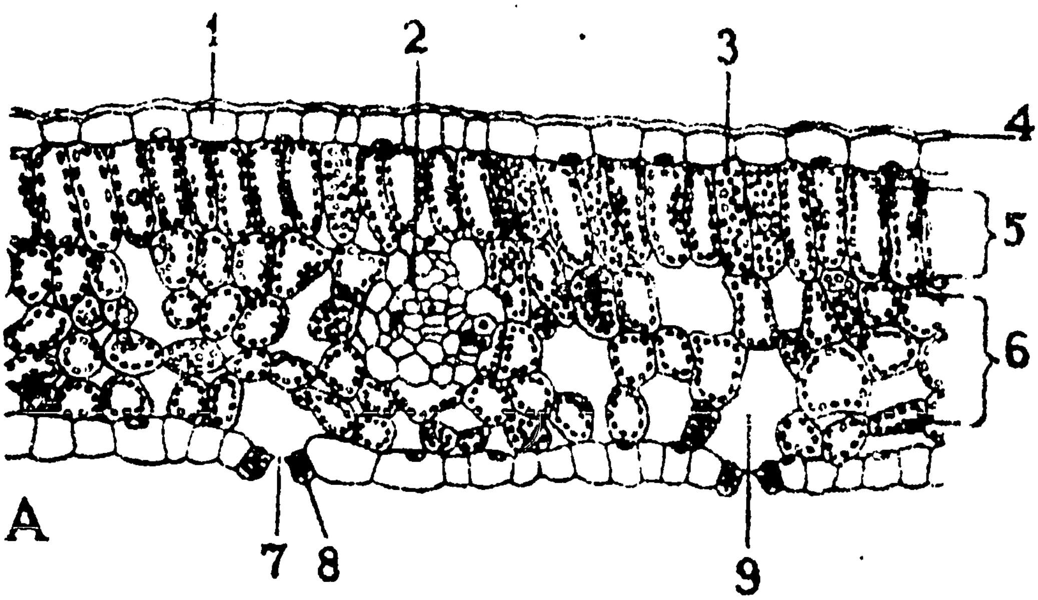
8A - 4

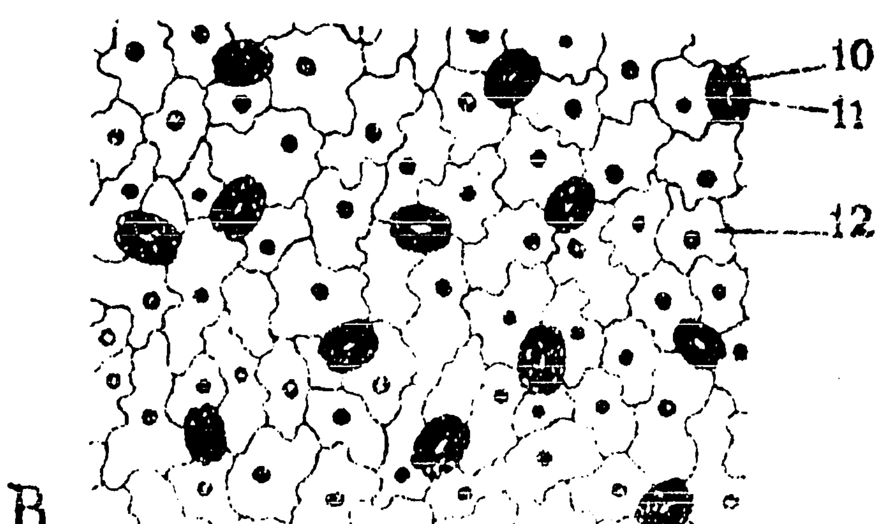
Drawing 1. Three-dimensional diagram of a leaf



8A - 5

Drawing 2. Leaf cross-section and surface view showing stomates





Exercise 8B Photosynthetic Pigments in Major Plant Groups

This film loop shows the extraction and chromatography of plant pigments of algae, mosses, ferns, and a flowering plant.

The audio tape will explain what chromatography is, and will provide the sound track for the film

As before, follow the taped instructions carefully as you work through this laboratory material

When you have finished with the tape and film loop, discuss the questions below with your laboratory partners and then write your answers.

1. What major photosynthetic pigments do the plant groups in the film have in common?
2. Green algae are thought to be more closely related to the higher plants than to other algae What evidence did the film point out for this?
3. Describe the steps in the process for preparing a chromatograph.

Exercise 8C. A Closer Look at Photosynthesis

Background. In this exercise you will test a few basic ideas about photosynthesis. Much of the important work requires complicated apparatus and long periods of time. But there are ways to find out what raw materials are needed and what products are given off in the process. In this exercise you will investigate:

1. Light absorption by plant pigments, using a spectroscope.
2. The need for CO_2 in photosynthesis.
3. The use of CO_2 by an aquatic plant.
4. The relationship of oxygen, CO_2, and pH in photosynthesis.
5. Uptake of radioactive CO_2, measured by a Gieger Counter.

In order to complete the laboratory work in one period the class will be divided into teams. Each team will do two exercises (except team 5, but <u>each student is responsible for the procedure in every exercise.</u> When you finish your work look at some of the exercises the other teams are setting up. In several days, after the results are determined, they will be presented to the class by each team.

Several chemicals are needed in the exercises. Directions for making the solutions are given in each exercise. Potassium hydroxide absorbs CO_2, and bromthymol blue is a pH indicator (blue in base, yellow in acid).

1. Light Absorption by Plant Pigments

In this exercise you will use a spectroscope, a device that breaks light into colors. It contains a special plate the light is viewed through. The plate, ruled with 15,000 lines per inch, is called a diffraction grating. The grating acts as a prism, splitting white light into red, orange, yellow, green, blue, indigo, and violet.

By finding which colors in white light are absorbed by an extract of plant pigments we can estimate which colors of the spectrum provide energy for photosynthesis.

1. Grind a few leaves in a mortar with a small amount of sand and about 25 ml. acetone. Pour the extract into a test tube and hold the tube in front of the slot at the rear of the spectroscope.
2. Put the light source about 8" away from the tube of chlorophyll so that the light shines through the tube, into the slit.
3. Look through the eyepiece and observe the intensity of the bands of light. Record intensities in the chart below, using the terms BRIGHT, DIM, or ABSENT.
4. Repeat the steps above, using a test tube full of pure acetone.
5. Repeat, omitting the test tube and acetone.

	red	orange	yellow	green	blue	indigo	violet
Light only							
Light & test tube of acetone							
Light, test tube, & pigment extract							

a. Describe the controls in this exercise.

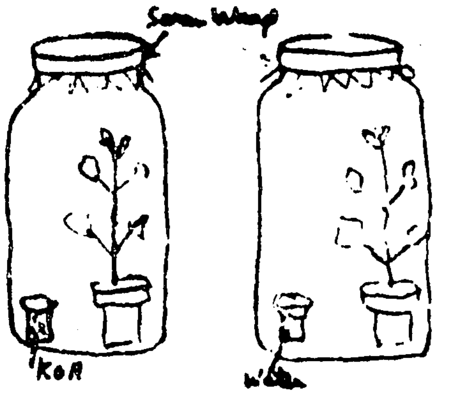
b. Do you think sunlight has a different spectrum than artificial light? How could you find out?

c. According to your results, which colors are most absorbed by the pigment extract?

d. Which colors of light do you believe are most necessary

2. Need for CO_2 in Photosynthesis

Make 2 set-ups according to the diagram. Use two Coleus plants of nearly equal size. In one jar put a small beaker of pellets of potassium hydroxide, and in the other put a beaker of water. Put a piece of Saran Wrap over the top of the jar and then put the lid on tight. Write your name on the jar with a felt pen. Observe the experiment over the next few days.



a. What is the purpose of the KOH?

b. Describe the control used in this experiment.

c. What factors, other than lack of CO_2, could cause death of the plant?

d. Do plant cells use oxygen? Do they use it in photosynthesis?

3. Use of CO_2 by an Aquatic Plant

Plants that grow on land get CO_2 for photosynthesis from the air. Aquatic plants get CO_2 from the water, where most of it is present as carbonic acid, H_2CO_3. The carbonic acid breaks down according to the equation: $H_2CO_3 \longrightarrow CO_2 + H_2O$

If water contains a large amount of CO_2, enough H_2CO_3 will form to lower the pH well below 7. When CO_2 is removed, during photosynthesis, pH rises.

Bromthymol blue is a dye that changes color as pH changes. It is yellow in acid and blue in base. It can be added to the water in which Elodea grows without harming the Elodea.

1. Fill 3 large test tubes 3/4 full with water from a tank in which Elodea has been growing.

2. Add about 30 drops of bromthymol blue to each tube.
3. Using a straw, GENTLY bubble your breath into 2 of the tubes until the solution turns pale yellow.
4. Put a sprig of Elodea in one of the yellow solutions.
5. Put a loose fitting cap of aluminum foil on each tube.
6. Record results in 3 or 4 days, using the chart below.

	Tube 1	Tube 2	Tube 3
Start	Blue--no Elodea	Yellow--no Elodea	Yellow + Elodea
Finish			

a. What color is bromthymol blue in an acid? What color is it in a base?

b. As Elodea grows in water, will the water become more acidic or more basic? Why?

c. Why is the yellow solution with no Elodea used in this exercise?

d. Why is the blue solution with no Elodea used in this exercise?

e. At the end of the exercise which solution will have the highest oxygen content?

4. Relationship of Oxygen, CO_2, and pH in Photosynthesis

In this exercise you will use the Hach Water Testing Kit. With it you can make simple chemical tests to determine pH, CO_2, and oxygen content of water.

As a land plant photosynthesizes it uses CO_2 from the air and produces oxygen. When aquatic plants photosynthesize they use CO_2 that is dissolved in water. They also give off oxygen, which dissolves in the water. You can measure the concentration of these two gases before and after photosynthesis. The change in their concentration in the water is an indication of the amount of photosynthesis.

Tap water may already contain a high concentration of either of the two gases. To obtain suitable water for beginning the experiment, use water that has been standing in a glass container for a couple of days. You will need about 1 liter of water for this exercise.

1. Test a liter of boiled water for oxygen, CO_2, and pH, following directions included with the Hach Kit. Record results in the chart below.
2. Fill two 400-ml. beakers with water and add several sprigs of Elodea to one.
3. Set both beakers in light for a few days. Do NOT allow them to heat above room temperature.
4. Re-test the water in each beaker in a few days. Record results in the chart.

	Oxygen in parts per million	CO_2 in ppm	pH
Initial test on boiled water			
Final test on water without Elodea			
Final test on water with Elodea			

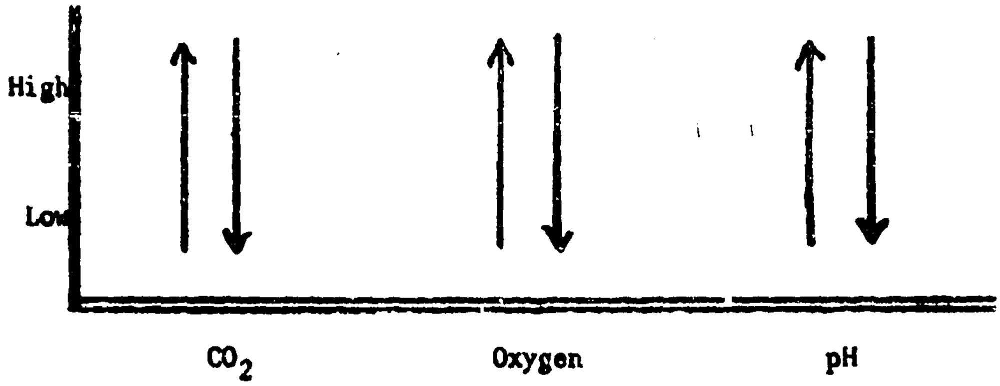
a. What does "parts per million" mean?

b. Air contains about 20% oxygen. How much would this be in ppm?

c. What kind of acid does CO_2 form when it dissolves in water?

d. Does oxygen form an acid or base when it dissolves in water?

e. Using results from your work above, encircle the arrow in each space in the chart below that summarizes your experiment.



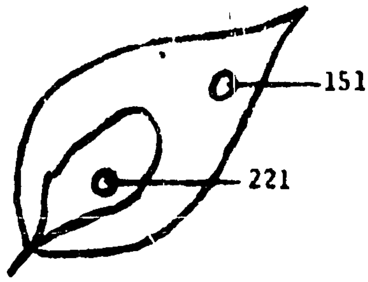
5. <u>Uptake of CO_2, Measured by Radioactivity: Film Loops.</u>

An experiment involving rather complex apparatus for measuring the uptake of radioactive carbon dioxide is explained in two film loops, running about 4 minutes each. The second loop is a continuation of the first one.

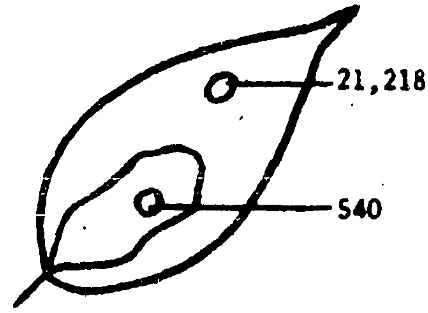
Explanation of the procedure is on audio tape. You should start the tape at the same time you start the film loop. If you want to reverse the tape to replay the explanation, feel free to do so at any time. Of course, if you do this, you must stop the film, since it cannot be reversed.

The data, or results of the experiment, given at the end of the second loop, are summarized below. On the basis of this, and the procedure you see, discuss answers to the questions below.

Data



DARK



LIGHT

Questions

1. What was this experiment designed to show?
2. How do you account for any radioactivity at all in the leaf that was in the dark?
3. In the leaf in the dark, why does the white portion show more radioactivity than the green portion?
4. What other processes, in addition to photosynthesis, does the data indicate may be going on in the leaves in this experiment?

In this laboratory work you will be doing these things:

1. **Study slides of a variety of algae.**

2. **Label drawings of algae that grow as filaments, plates, and spheres.**

3. **Study film loops of an alga that reproduces by forming zoospores, and algae that reproduce in large numbers during the summer, creating an "algal bloom" in a lake.**

Turn on the audio tape now - and follow the instructions on it.

Refer to the attached drawings and the questions below, as indicated on the tape.

Questions for Discussion

1. **Many people refer to algae as "moss" or seaweed". Why are these terms unsuitable?**

2. **Make a model from the clay provided in one of the body forms of algae discussed in the text. Choose from a sphere, filament, single cell, or plate of cells. Pass the model to the next group in your class, working to your LEFT. They will describe the adaptations of that particular body form.**

3. **Although algae have a wide variety of shapes, sizes, and colors, they are also very much alike. In the chart below list all of the characteristics algae have in common, as well as individual differences they have.**

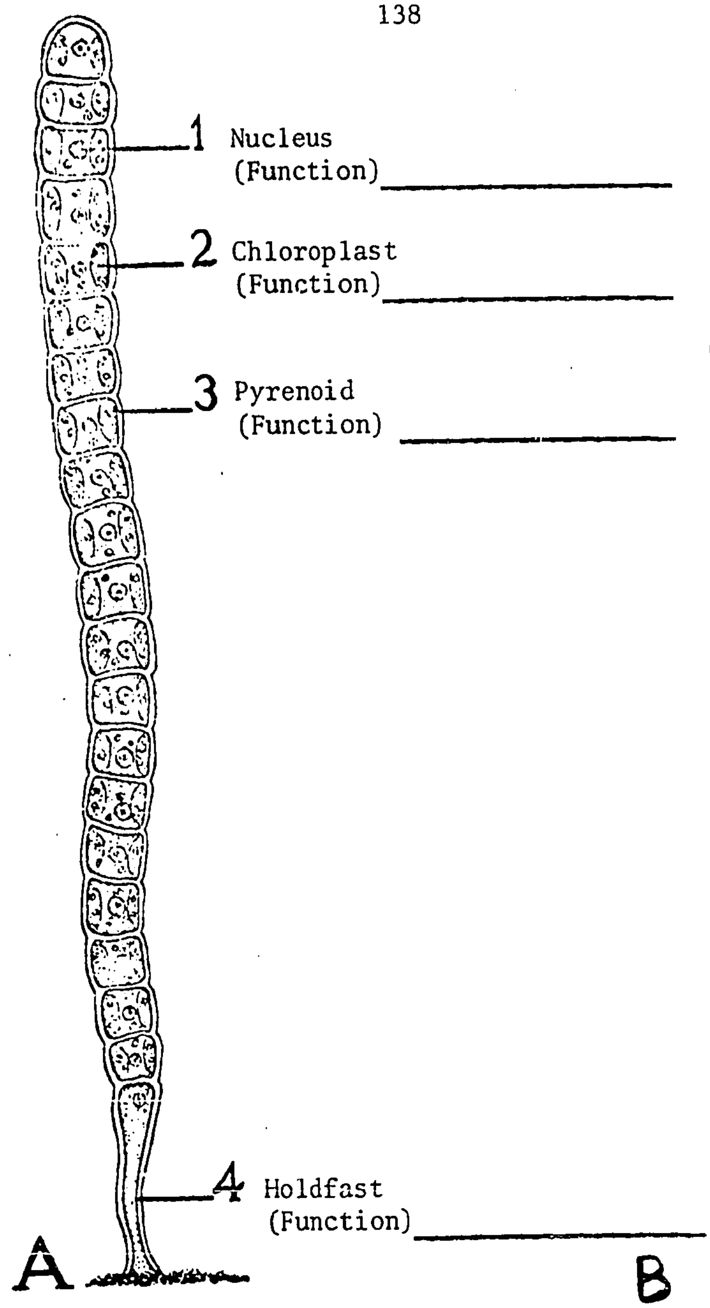
Similarities	Differences

4. List the types of growth patterns or body forms found in certain algae.

5. Arrange these organisms in the sequence you believe represents transfer of energy captured from sunlight. Of course, some of the organisms will serve as food for others. Tadpoles, fish, Chlamydomonas, man, water fleas.

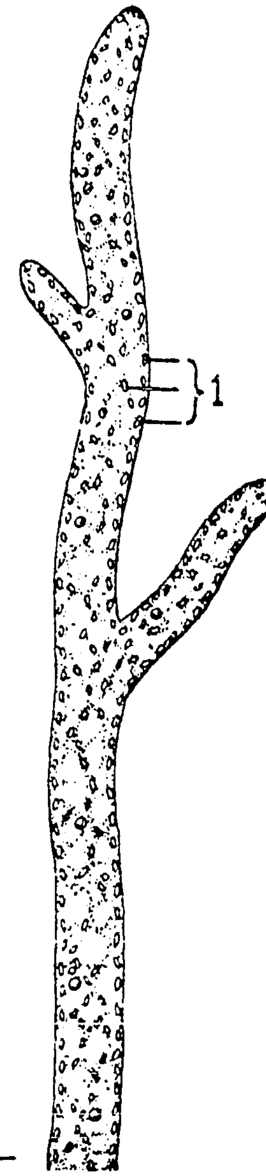
6. What advantage does formation of zoospores in Basicladia provide in increasing efficiency of reproduction?

7. How do algae reproduce if they don't form zoospores?



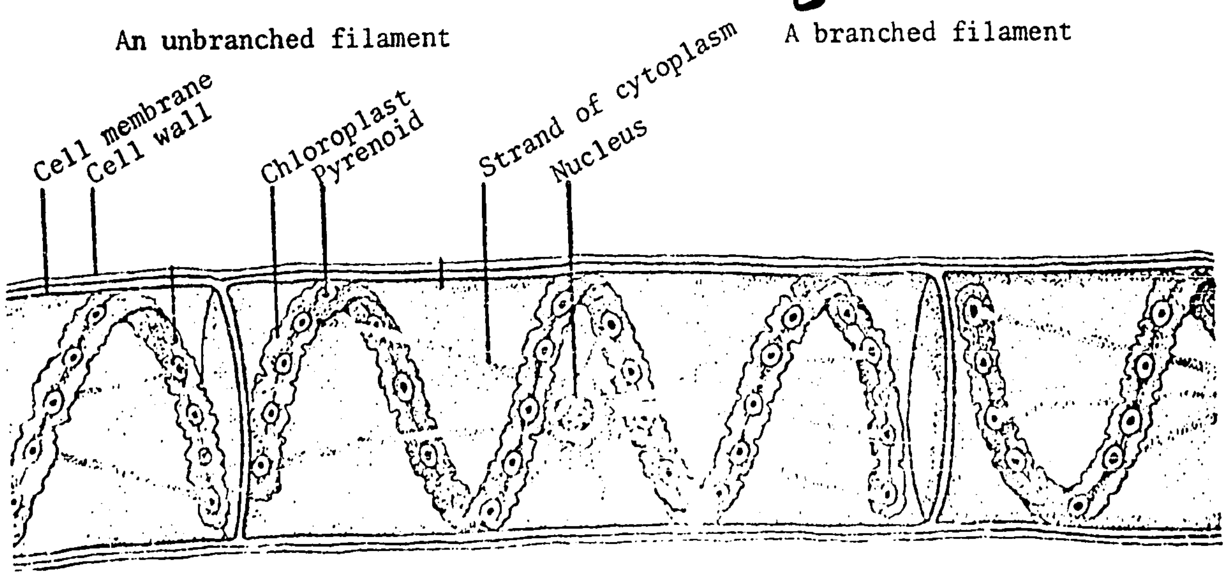
A

An unbranched filament



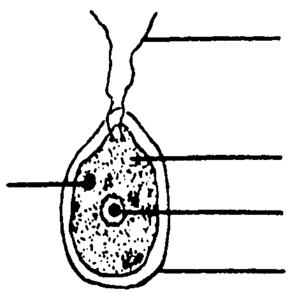
B

A branched filament

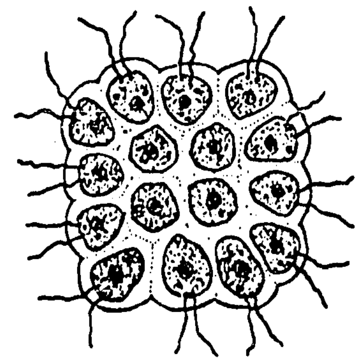


C Spyrogyra - an unbranched filament

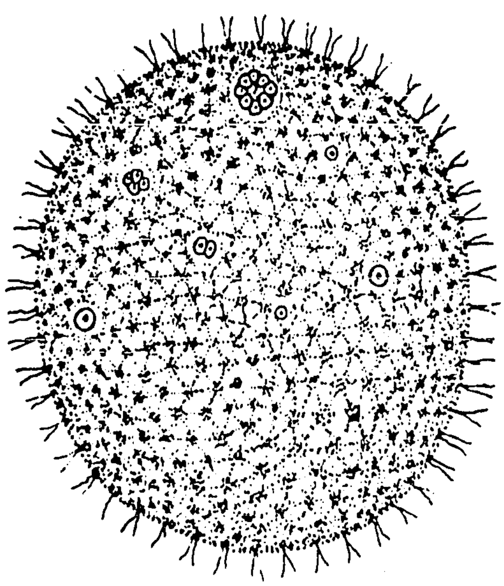
List structure and function of
each part shown in Chlamydomonas.



D. Chlamydomonas



E. A plate-like colony



F. Volvox: A spherical colony

This exercise deals with those small land plants called bryophytes. You will be studying some slides and a film loop in this exercise. The instructions for the laboratory work are on audio tape.

Turn on the tape now and follow the instructions on it.

Refer to the attached drawings and the questions below, as indicated on the tape.

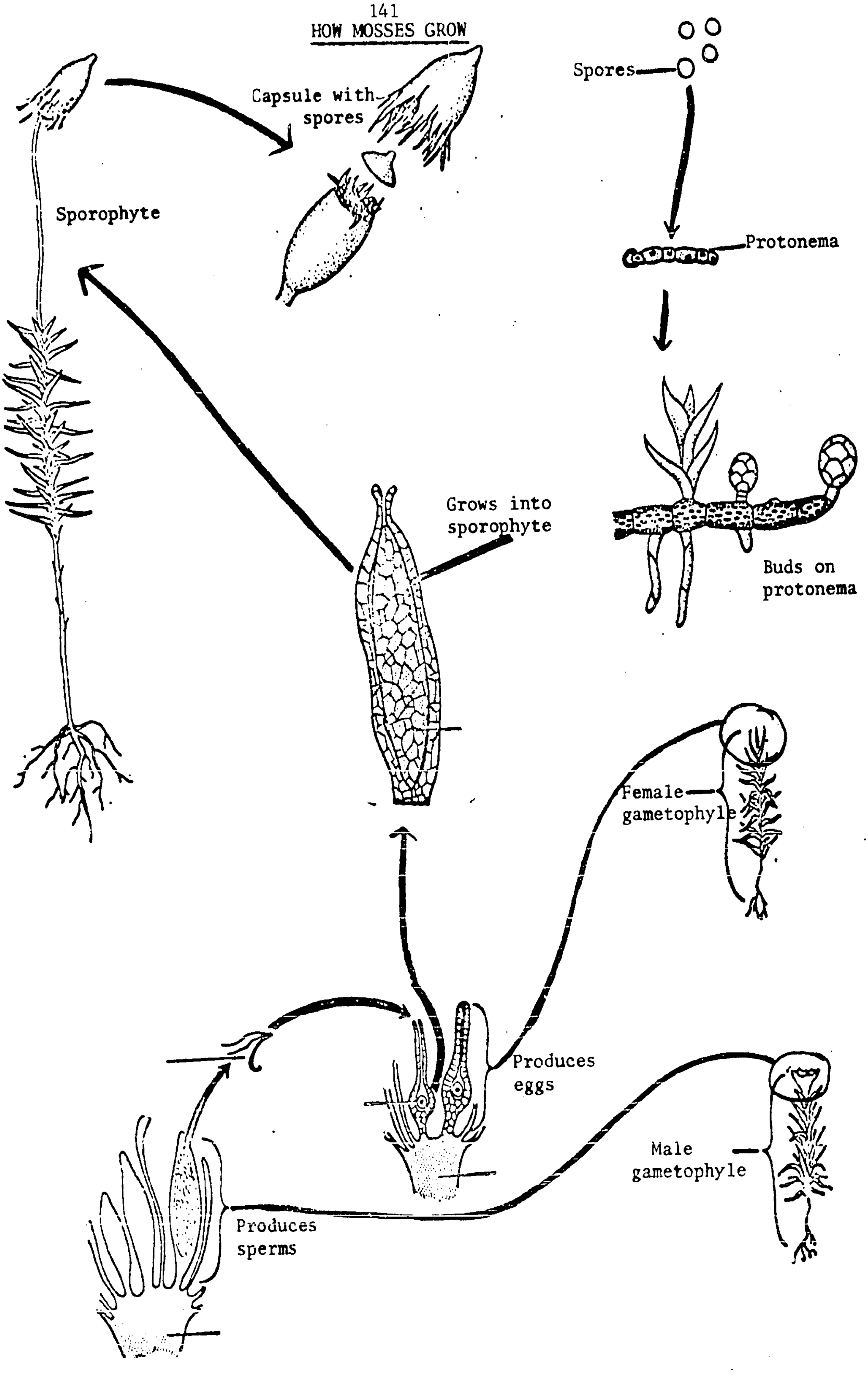
Questions for Discussion

1. What functions in the bryophytes require water?
2. What two mechanisms of reproduction are found in bryophytes?
3. List advantages of reproduction by spores.
4. Bryophytes have sometimes been called amphibious plants. List some evidence to support this.
5. Mosses need water for reproduction. What kinds of animals have a similar requirement?
6. Mosses are usually found in clumps rather than widely scattered as individual plants. But the clumps themselves may be widely scattered. Considering the means of reproduction in the mosses (spores and gametes) which might account for:

   Mosses growing in small clumps ____________________

   The clumps being widely scattered ____________________

HOW MOSSES GROW



Exercise 10A. Stems

Background. In this exercise you will look at slides of stem cross-sections, models of stem tips and stem sections, and films of stem growth and the transpiration process.

Several drawings are included in this exercise, in the form of worksheets. You can complete those worksheets later. They will be discussed next week.

After viewing the slides and film loops, work on the discussion questions. There will be opportunity later for you to bring up these questions in class for discussion.

Turn on the tape now for further instructions

Questions for Discussion

1. List some differences between herbaceous and woody stems.
2. What structures does a woody stem have that a herbaceous stem doesn't have.
3. How does the amount of xylem compare to the amount of phloem in a herbaceous vascular bundle?
4. How does the amount of phloem compare to the amount of xylem in a woody stem?
5. What changes must a herbaceous stem undergo to become woody?

External Characteristics of Stems

Label and state function of:

terminal bud

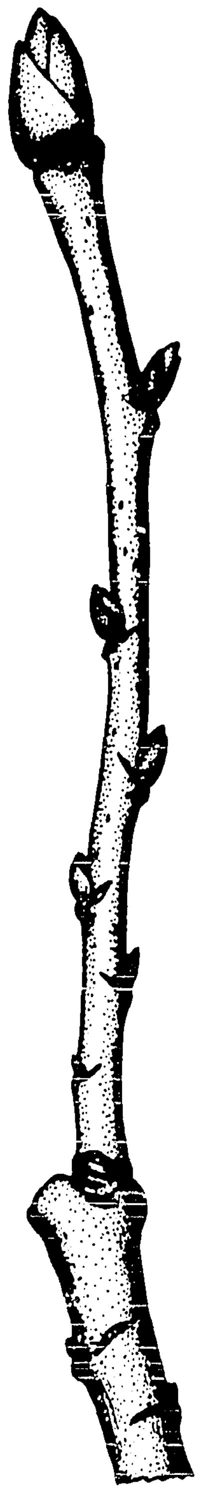
bud scales

lenticels

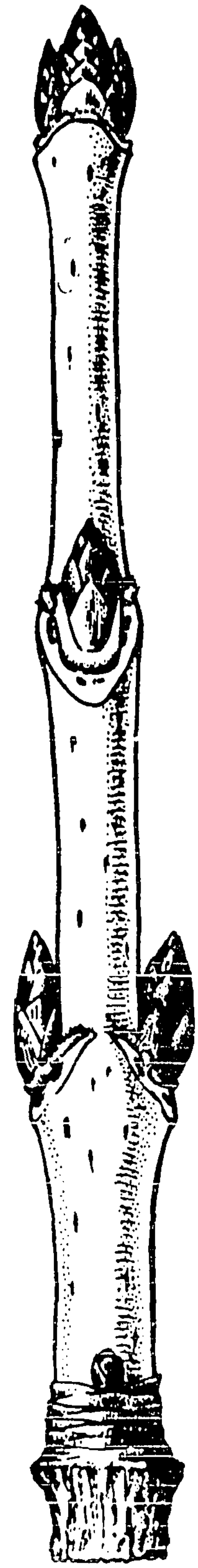
leaf scar

bundle scars

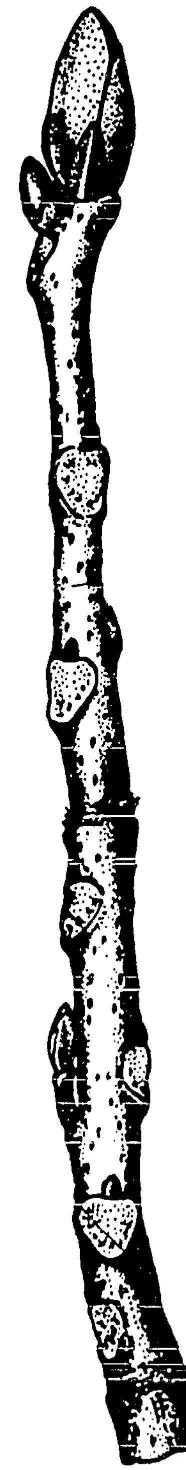
terminal bud scale scars



Alternate Buds



Opposite Buds

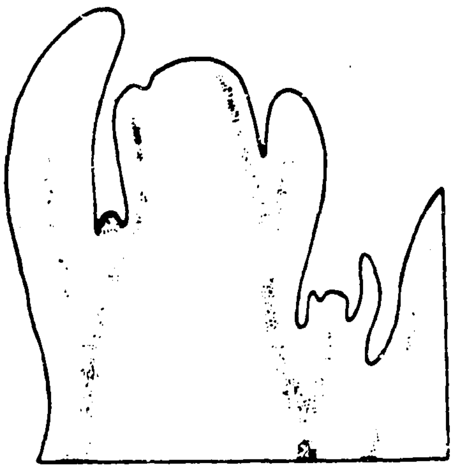


Stem Tips

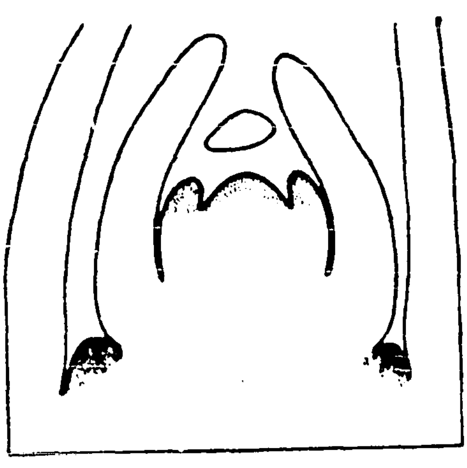
These are microscopic views of stem tips.

The red areas are meristematic tissue.

What type of tissue do the strands of meristematic tissue develop into?

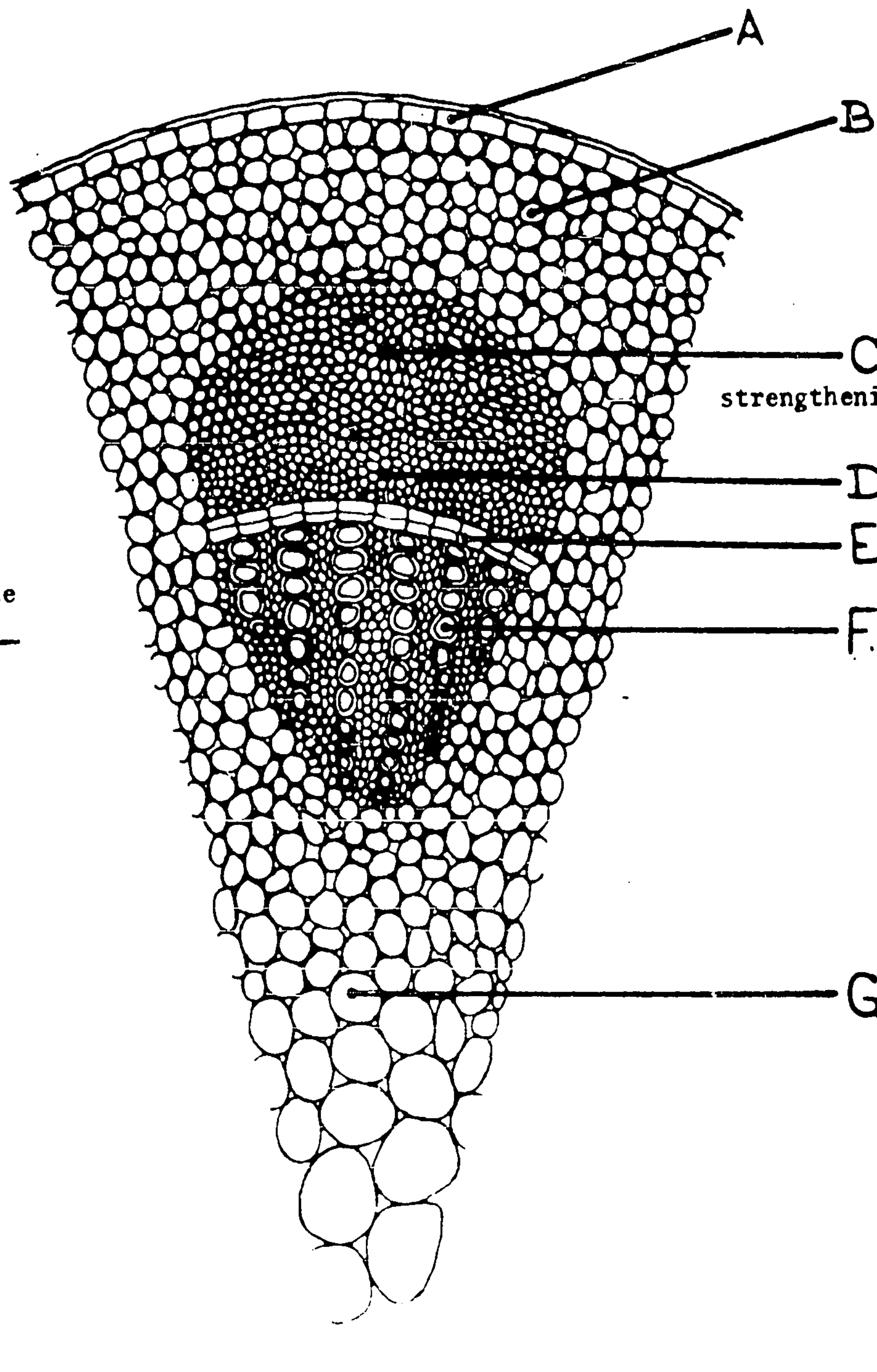


Alternate buds



Opposite buds

Cross section of a herbaceous stem showing a vascular bundle



Label and state function of:

pith

cortex

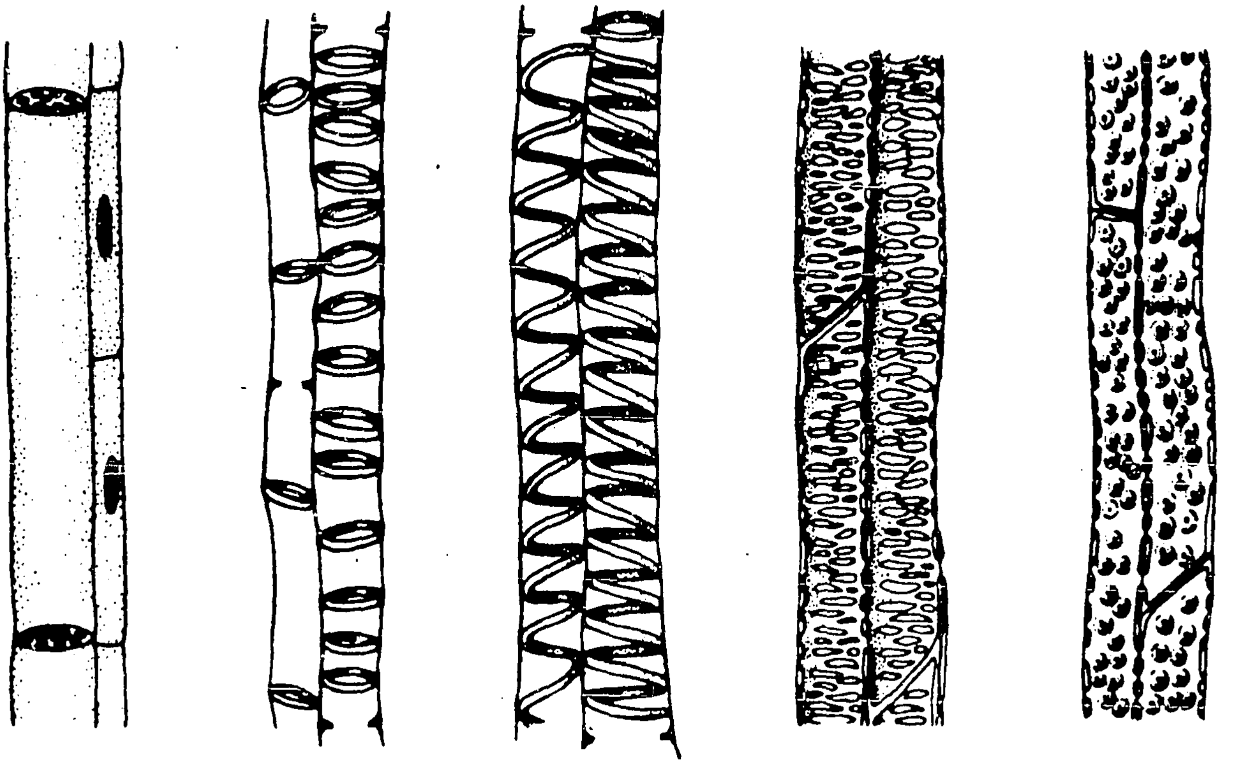
xylem

epidermis

phloem

procambium

Vascular Tissue - Longitudinal Sections



phloem xylem vessels xylem tracheids

Label and list characteristics of:

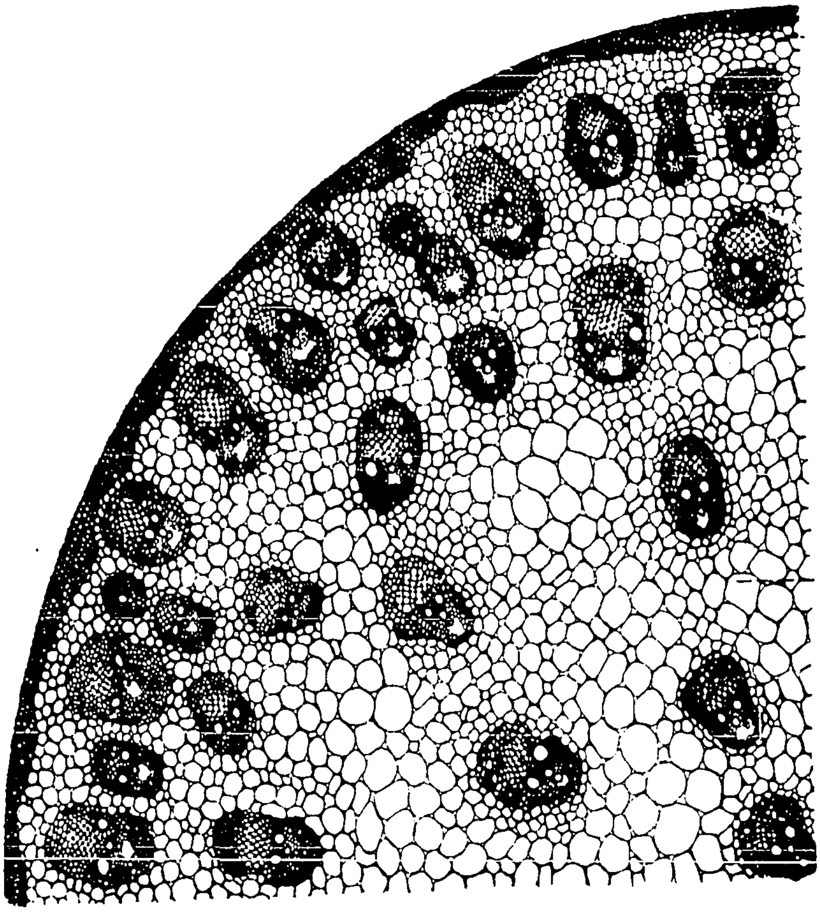
sieve tubes

companion cells

thickenings in walls of vessels

pits in walls of tracheids

Cross Section of a Monocot Stem



Herbaceous stems are soft (woody stems are tough, and produce secondary growth)

Herbaceous stems are found in both monocotyledon and dicotyledon plants

This is a herbaceous monocot stem drawing

Label and state function of:

vascular bundle

epidermis

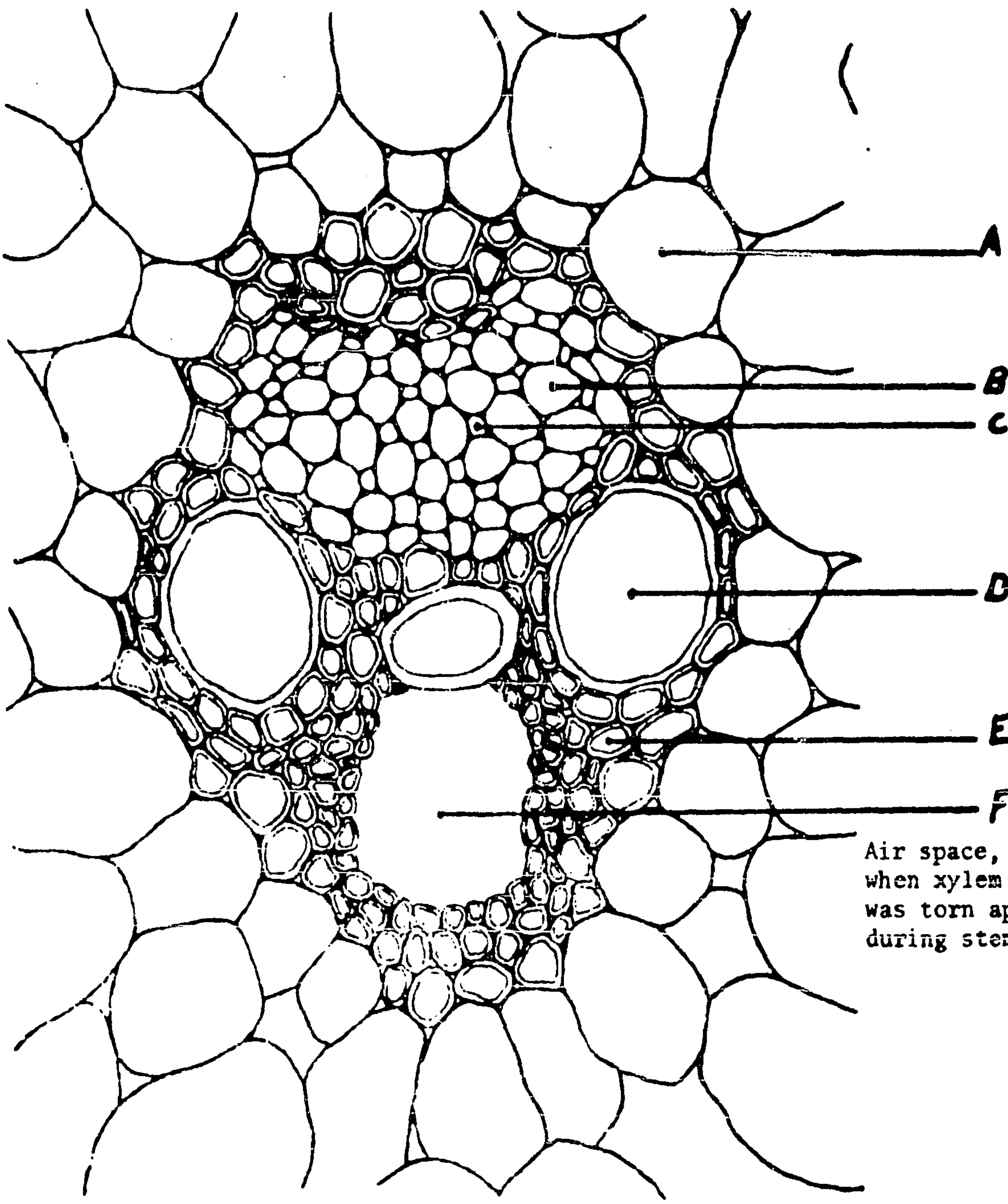
cortex cells

xylem

phloem

Monocot Vascular Bundle

This is an enlarged view of a vascular bundle from the previous drawing.

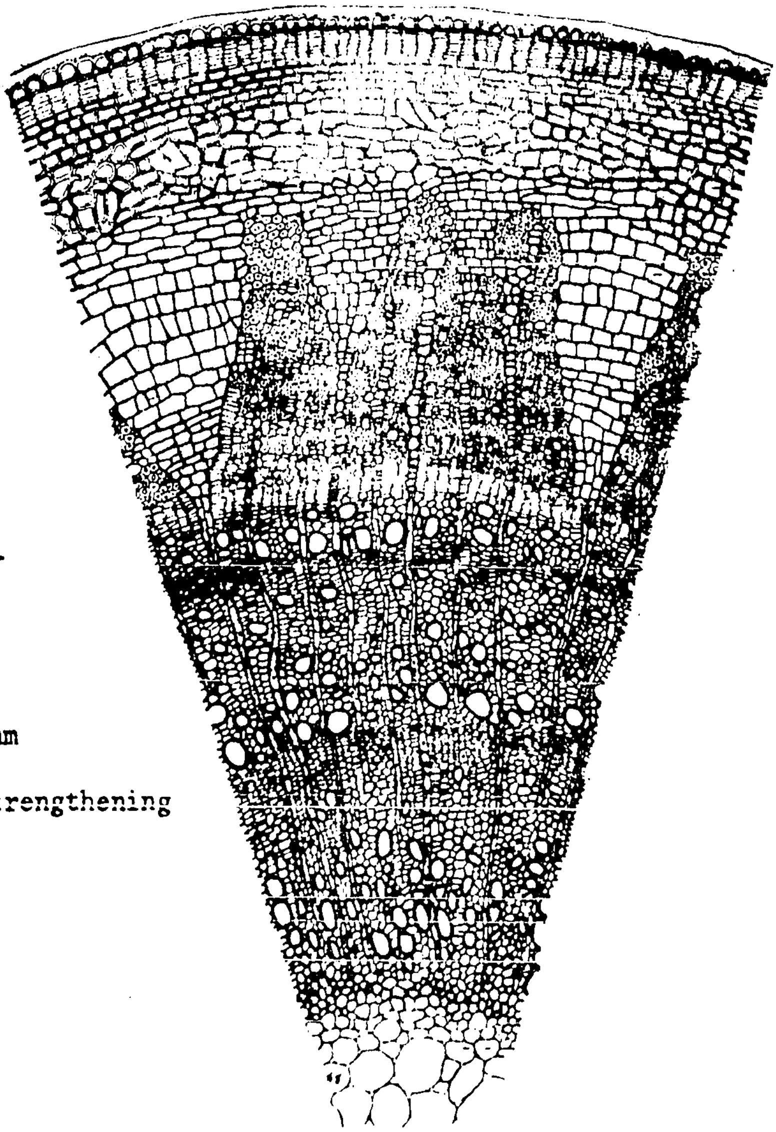


Air space, left when xylem vesse was torn apart during stem grow

Label and state function of:

cortex cells
sieve tube
xylem vessel
companion cell
phloem

Woody Stem Cross Section



Label and state function of:

epidermis

cork cambium

vascular cambium

thick-walled strengthening cells

pith

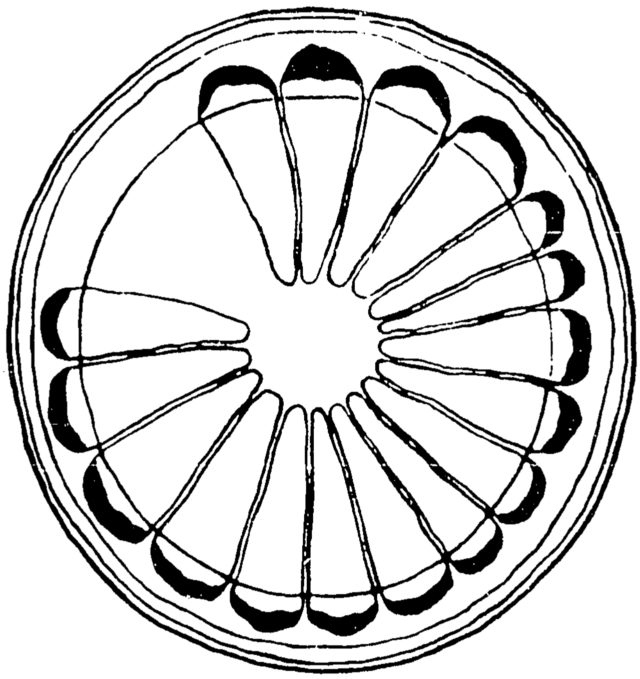
cortex

xylem

phloem

cambium

annual ring



Cross section of a 1-year-old stem.

Label

epidermis

annual ring

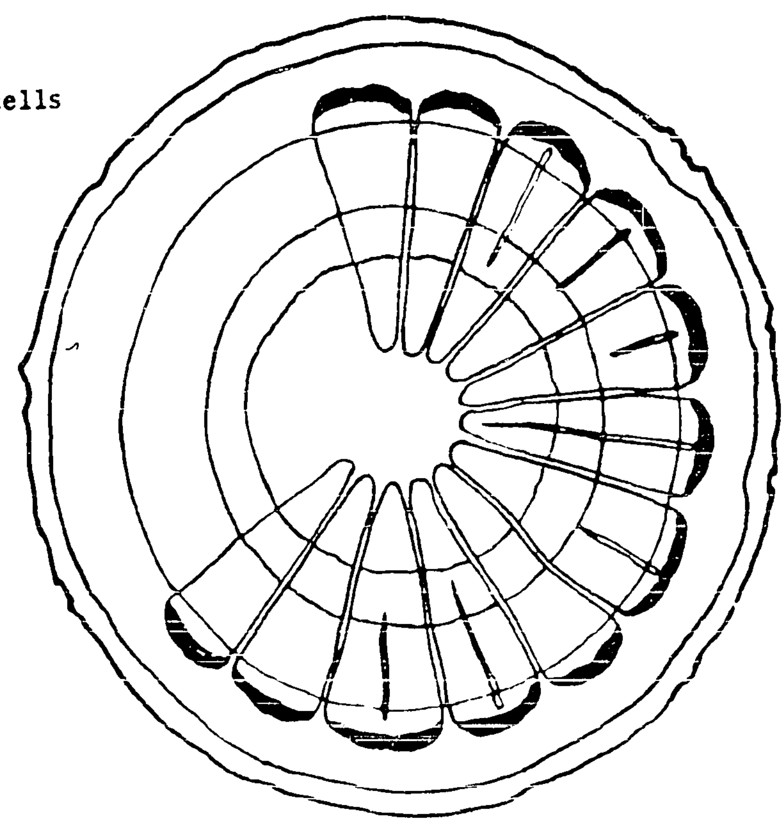
pith

cortex

phloem

strengthening cells

xylem



Cross section of a 3-year-old stem.

EXERCISE 10B. ROOTS

Roots and stems are alike in many ways. They both contain vascular tissue; both are round in cross section; and both may have secondary growth. Roots differ from stems in some functions. They anchor the plant in the soil and absorb water and minerals. They do not produce leaves. And on many species they serve as storage organs to a greater extent than stems do.

This exercise is designed to help you understand important functions of roots, through a study of structure. To help correlate the study to the previous exercise, a chart at the end of the exercise will provide a place to summarize important features of both stems and roots.

You will be viewing some projected slides in the beginning of this exercise. In addition, there is a film loop on root growth. There are several drawings in this exercise, which you should complete <u>before the class discussion tomorrow.</u> Also, work on the discussion questions if there is time today.

Turn on the audio tape for further instructions

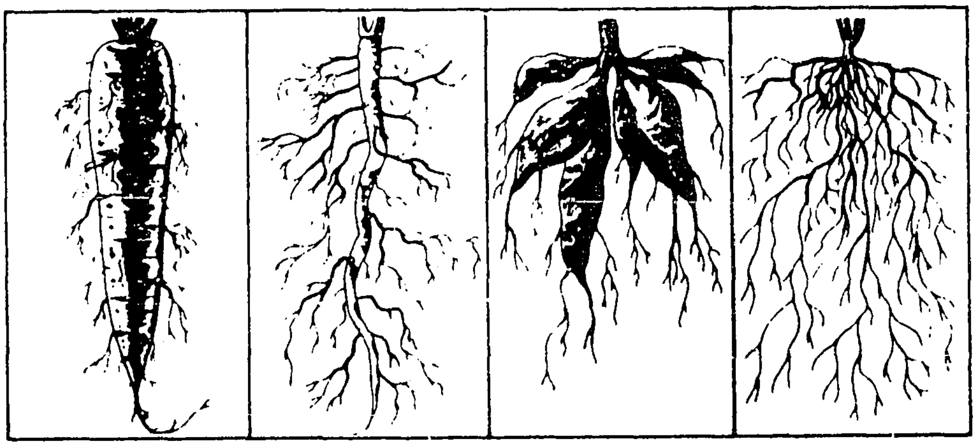
Questions for Discussion

1. What root functions contribute to the welfare of the entire plant?
2. Name several plants whose roots are used as food by man.
3. Complete the chart:

Structure	Function
	absorbs water
cortex	
	conducts water up to stem
root cap	

4. Classification of Root Systems

The primary root of many plants remains the principal root of the root system, resulting in a tap root system. In some plants, it enlarges and becomes a fleshy tap root. In many cases, however, the primary root is short-lived and is replaced by many secondary roots. This produces a diffuse root system. Roots of this system may be either thick and fleshy, or slender and fibrous.



Carrot Dandelion Dahlia Grass

In the chart below classify the four root systems as: fleshy tap, fleshy diffuse or diffuse in row A. Then rate each, using GOOD, FAIR, or POOR in rows B, C, D, E.

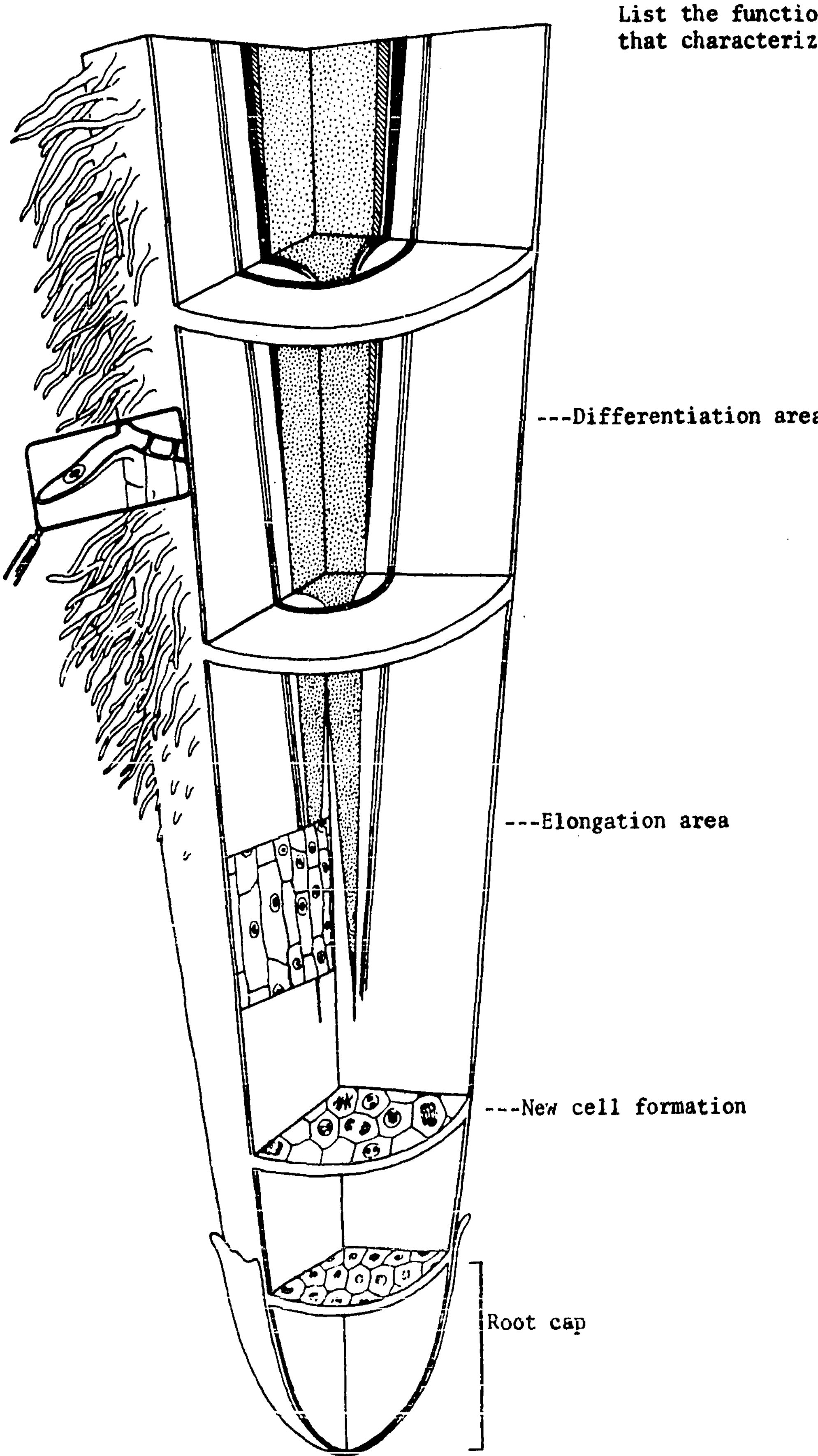
		CARROT	DANDELION	DAHLIA	GRASS
A.	Type of root system				
B.	Anchorage				
C.	Absorption of minerals and surface water				
D.	Absorption during drought				
E.	Storage				

5. The chart below will enable you to make an orderly comparison of stems and roots. You will need to consult other students, your instructor, and references in books in the classroom or library.

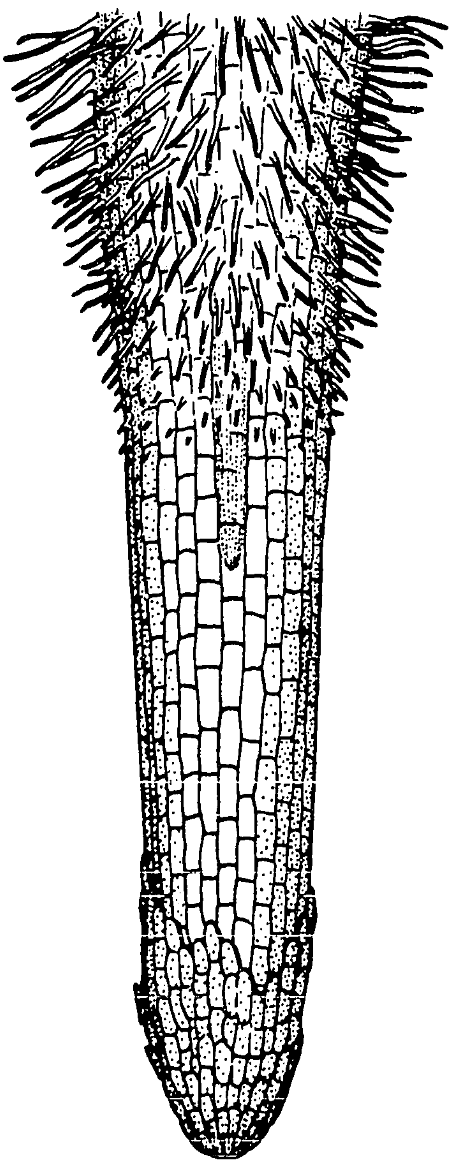
CHART FOR COMPARING ROOTS AND STEMS		
	STEMS	ROOTS
Arrangement of vascular tissue (Make a sketch of both monocot and dicot)		
Origin of branches or secondary roots		
Quantity of water and food storing cells in proportion to vascular tissue. (Express as a ratio).		
Important functions		
Exchanges gases, through pores, with the outside environment.		
Does secondary growth occur? If so, describe briefly.		

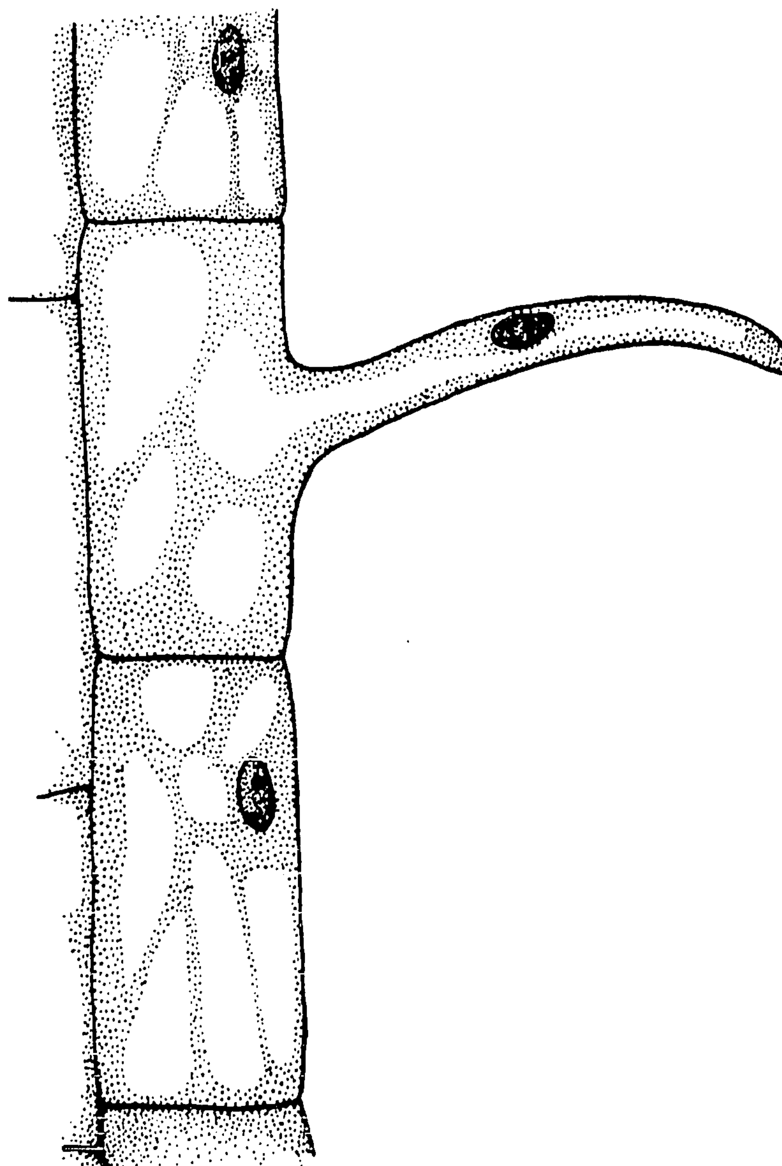
Major Growth Areas of a Root

List the function or activity that characterizes each area.



Root Hairs

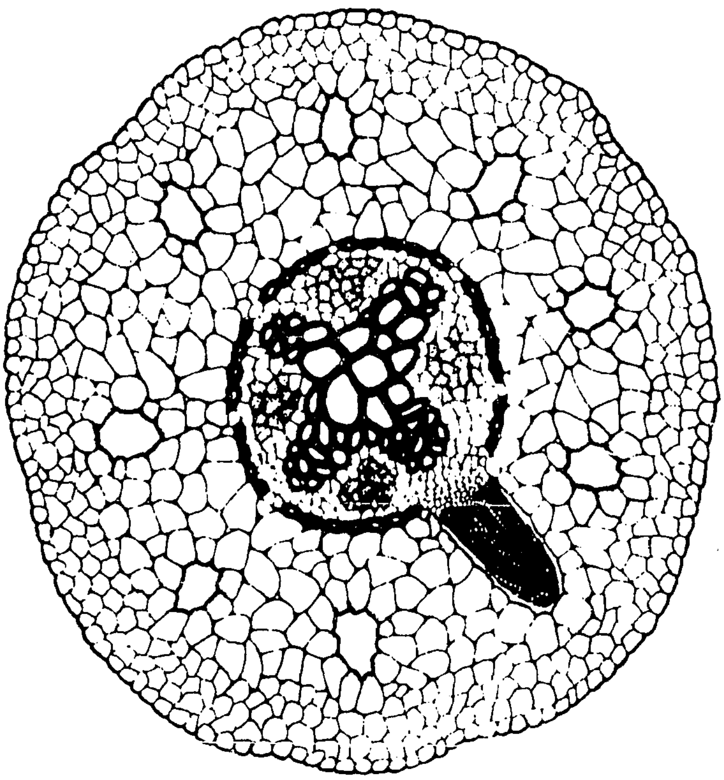




What is the function of root hairs?

How is their formation different from secondary roots?

Dicot Root - Cross Section



endodermis; layer of cells separating cortex from vascular tissue

Label and state function of:

epidermis

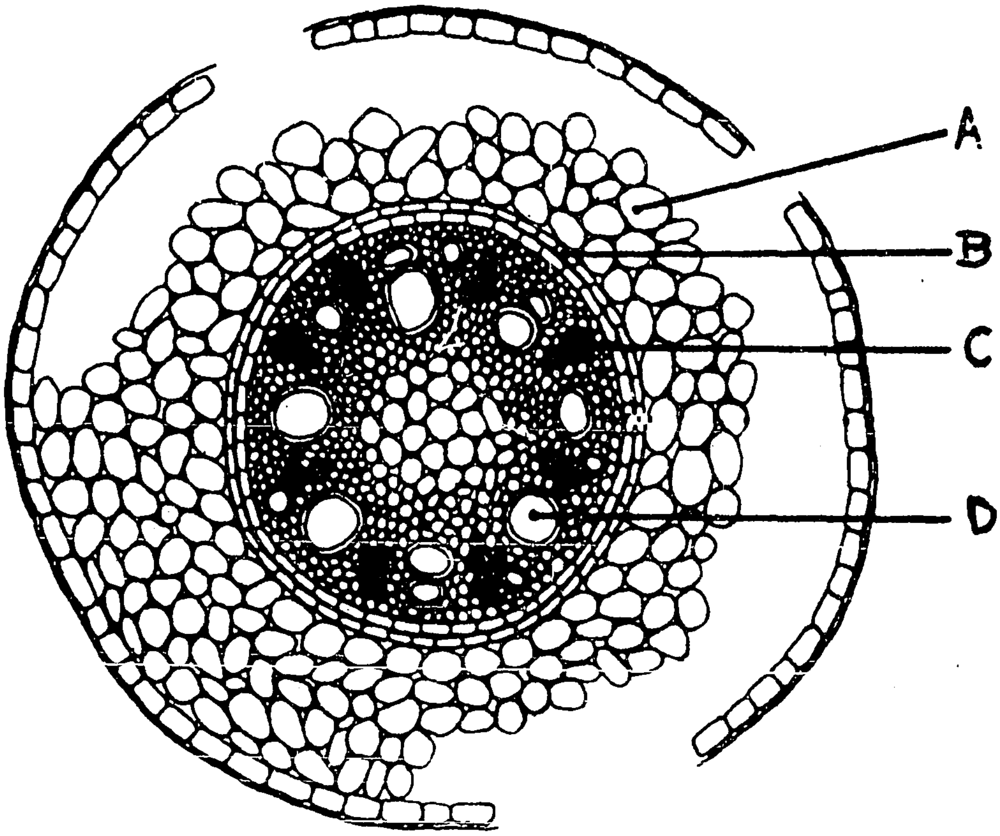
cortex

xylem

phloem

secondary root

Monocot Root - Cross Section



Label structures A, B, C, D and list functions. Refer to your notes, the previous page of laboratory work, or a textbook illustration.

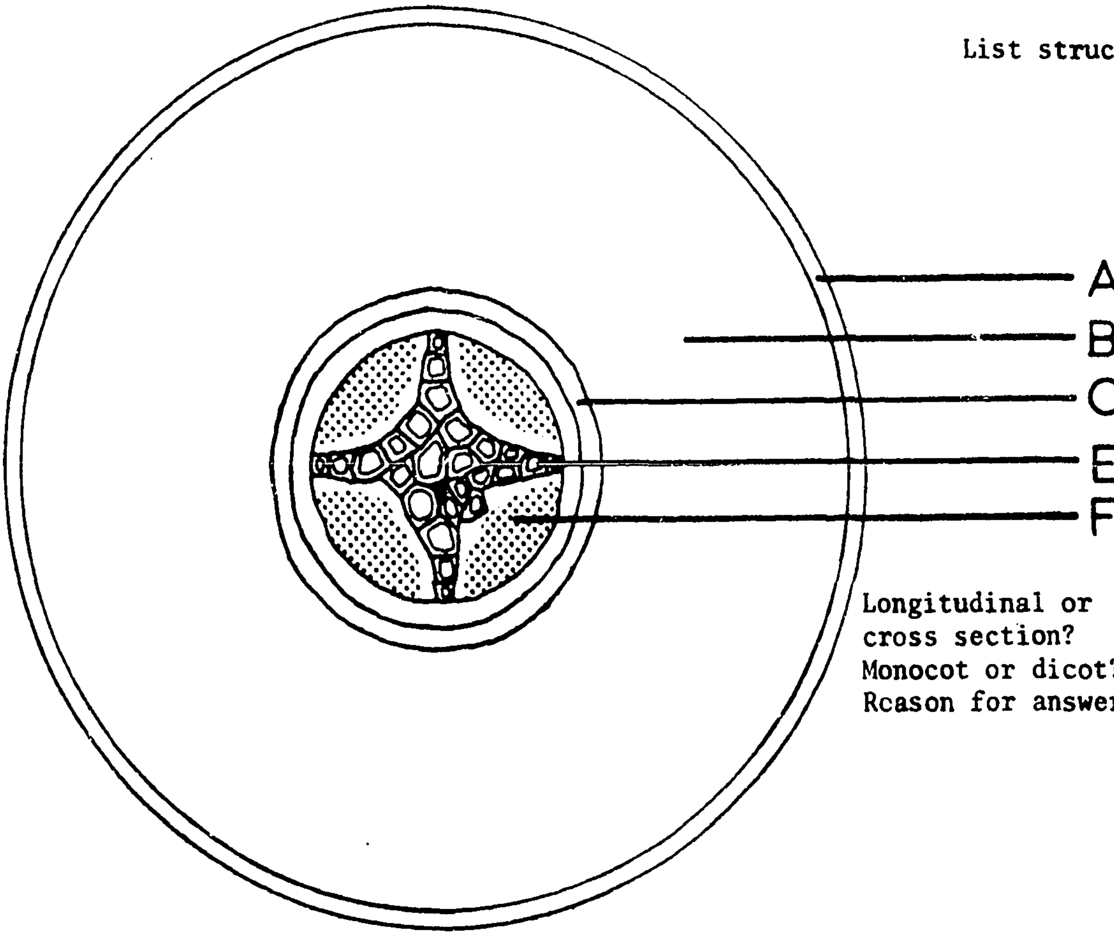
A.

B.

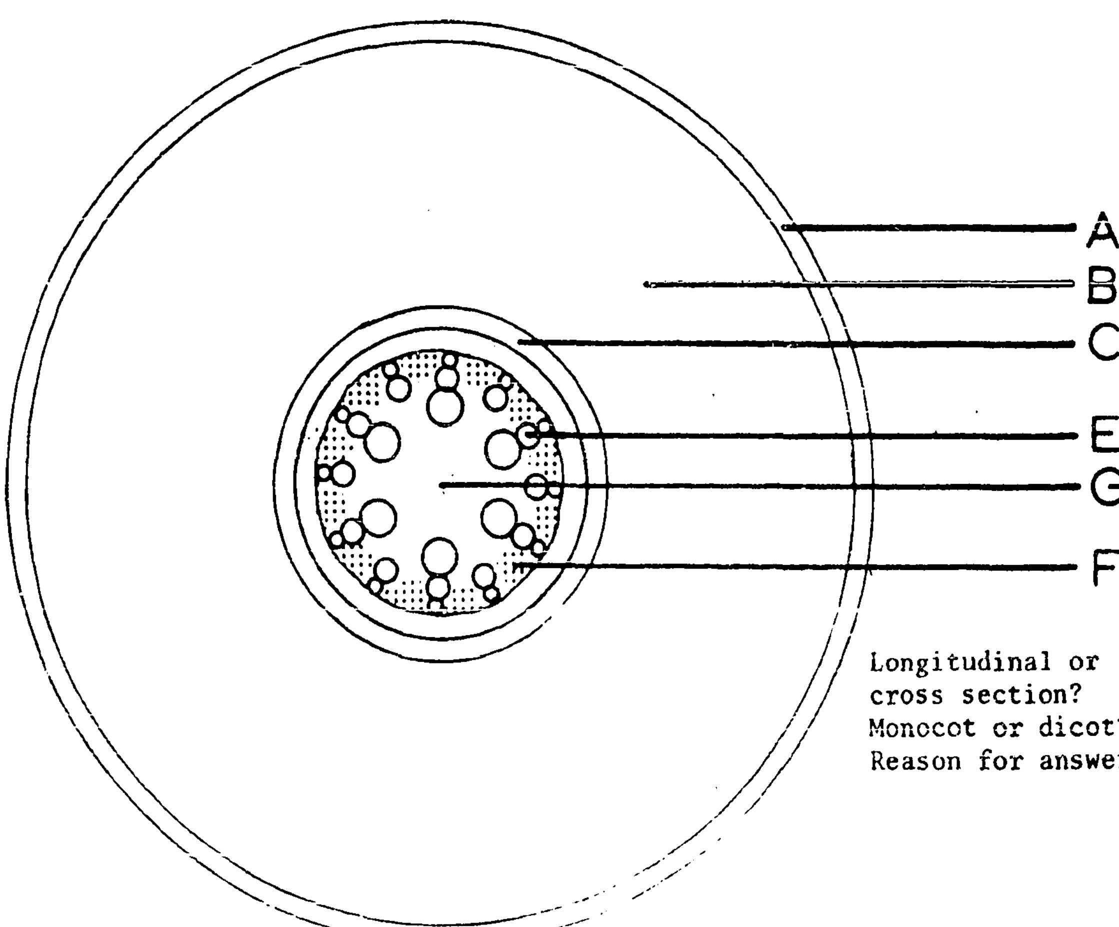
C.

D.

List structure and function.



Longitudinal or cross section?
Monocot or dicot?
Reason for answers?



Longitudinal or cross section?
Monocot or dicot?
Reason for answer?

APPENDIX G. ACHIEVEMENT TESTS

Chapter 8 Test - Photosynthesis

1. The chlorophyll molecule is similar to that of:
a. hemoglobin, b. sucrose, c. methane, d. amino acids, e. protein

2. If a green plant is successively divided into smaller components what is the smallest part that is able to carry out photosynthesis when provided with energy and raw materials?
a. the whole plant, b. a leaf, c. a cell, d. a chlorplast, e. a granum

3. If you subjected a plant to equal amounts of light energy of different wavelengths, which would you find least efficient in powering photosynthesis?
a. red, b. orange, c. yellow, d. green, e. blue

4. It has been estimated that 80 to 90 percent of the photsynthesis occurs in the oceans. Compared with the productivity of the land areas. However, man makes little use of the food produced in the oceans. Suppose that because of pollution, the plant life of the oceans were suddenly eliminated. Which of these suggested effects would be of greatest immediate concern to man?
a. decrease in CO_2 in the atmosphere, b. increased rainfall, c. decrease in O_2 in the atmosphere, d. increased salt content of the oceans, e. decreased rainfall

5. When F. F. Blackman measured the rate of photosynthesis, he found that as he increased the intensity of the light, the rate of photosynthesis increased. This was true to to a particular intensity. Beyond this intensity there was no increase in phobosynthesis. Blackman's explanation was:
a. photosynthesis involves more than one kind of reaction, b. light is not really the source of energy for photosynthesis, c. plants are not able to use all wavelengths of light, d. too much light speeds up respiration but not photosynthesis, e. after a certain amount of sugar is produced, the plant stops making more.

6. Guard cells are different from other epidermal cells in this way:
a. they produce food, b. they contain cytoplasm, c. they lack a nucleus, d. they contain a nucleus, e. they have no cell membrane

7. A process that is essentially the opposite of photosynthesis is:
a. excretion, b. respiration, c. secretion, d. diffusion, e. transpiration

8. Which do you think is the best explanation of why there are generally more stomates on the lower surface of the leaf than on the upper

surface?
a. carbon dioxide is heavier than air, b. carbon dioxide is lighter than air, c. the intensity of light is less on the lower surface than on the upper, d. there are not enough guard cells on the upper surface, e. plants are generally in danger of losing too much oxygen

9. During the night leaf cells synthesize:
a. amino acids from sugars and nitrogen, b. oxygen from water and carbon dioxide, c. starch from cellulose, d. glucose from water and carbon dioxide e. none of these

10. If a leaf were allowed to photosynthesize in an atmosphere of radioactive carbon dioxide, and the vascular tissue in the leaf stem were checked later for radioactivity which part of the vascular tissue would probably be most radioactive?
a. palisade cells, b. spongy cells, c. xylem d. phloem
e. guard cells

11. Which statement best accounts for the right answer to the previous question? a. radioactive carbon is heavier than other carbon, b. water moves out of the leaf through the stomates, c. in the production of glucose, water is a product as well as a reactant, d. many parts of the plant depend on the leaves for their food, e. water diffuses from a region of high concentration to a region of low concentration

12. A student wanted to find whether a begonia plant is able to manufacture sugar when lighted by an ordinary light bulb. Knowing that sugar is converted into starch, she decided to base her conclusion on whether or not starch was present in the leaves. She used iodine solution as a means of testing for starch

To obtain the necessary data, she placed a large potted begonia plant in a lightproof closet and directed a small spotlight on the plant. At two-hour intervals, for the next twelve hours, she removed a leaf from the plant (A light shield protected the plant from light when she opened the door.) All six of the leaves contained starch. The student therefore reported that begonia plants are able to carry on photosynthesis when lighted only by an ordinary spotlight.

The following suggestions were made for improving the experiment with the begonia plant. Which one do you think is best? a. she should have repeated the experiment with other kinds of plants, b. she should have compared the growth of the plant in artificial light with one of the same kind in sunlight, c. she should have kept the plant in the dark until it contained no more starch, then turned on the spotlight, d. she should have measured the amount of water she added to the plant, e. she should have compared the results of her experiment with those reported in books on plant physiology.

13. The following report was written by Jean-Baptiste Van Helmont and published in 1748.

"That all vegetable matter immediately and materially arises from the element of water alone I learned from this experiment. I took an earthenware pot, placed in it 200 lb. of earth dried in an oven, soaked this with water, and planted in it a willow shoot weighing 5 lb. After five years had passed, the tree grown therefrom weighted 169 lb. and about 3 oz. But the earthenware pot was constantly wet only with rain or (when necessary) distilled water; and it was ample in size and imbedded in the ground; and, to prevent dust from mixing with the earth, the rim of the pot was kept covered with an iron plate coated with tin and pierced with many holes. I did not compute the weight of the decidous leaves of the four autumns. Finally, I again dried the earth of the pot, and found it to be the same 200 lb. minus about 2 oz. Therefore, 164 lb. of wood, bark, and root had arisen from the water alone."

Which statement best describes the main defeat in Van Helmont's experiment? a. he failed to consider one of the major ingredients essential to phtotsynthesis, b. He used rainwater and distilled water, whereas plants that are growing naturally obtain water containing a variety of minerals, c. His conclusions would have been different if he had continued the experiment for a longer time, d. His conclusions would have been different if he had used a number of plant species, e. His weighing of the soil was apparently inaccurate

14. If an aquatic plant such as Elodea photosynthesizes actively in a container of water--: a. the pH of the water should decrease, b. the oxygen concentration in the water should decrease, c. the amount of carbonic acid in the water should increase, d. the pH of the water should rise, e. the calcium carbonate content of the water should increase

These questions refer to the RED LETTERS:

15. Controls passage of gasses in and out of a leaf.

16. Conducts photosynthesis.

17. Does not photosynthesize.

18. Which of these parts is not shown in the sketch? a. periole, b. plastid, c. guard cell, d. spongy cell, e. palisade cell

These questions refer to the GREEN LETTERS:

19. Conducts water to leaf cells

20. Reduces evaporation

21. Stores substances to be used in photosynthesis.

22. When an aquatic plant such as Elodea photosynthesizes actively in a container of water: a. the additional oxygen makes the water more acidic, b. the additional oxygen makes the water less acidic, c. the oxygen taken out of the water during photosynthesis makes the water less acidic, d. the oxygen taken out of the water during photosynthesis makes the water more acidic, e. none of these

23. When Priestley studied the effect of green plants in "restoring bad air," he obtained some conflicting evidence. This was probably because of: a. errors in measurement, b. Variations in light c. soil differences, d. diseased plants, e. plants of different species

24. Which feature is not a characteristic of most leaves? a. a larger surface area in relation to bulk, b. a layer of epidermal cells on both upper and lower surface, c. presence of chlorophyll in the epidermal cells, d. guard cells containing chlorophyll, e. a layer of mesophyll containing more than one layer of cells

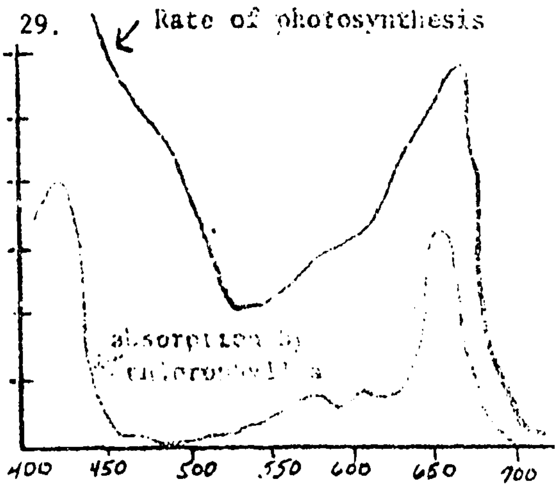
25. The streaming movement of the fluid portion of palisade cells is an aid to photosynthesis because: a. it aids in the breakdown of CO_2, b. it aids in the absorption of N_2, c. it controls the opening and closing of stomates, d. it regulates the production of essential enzymes, e. it increases the efficiency of light absorption

26. If you were attempting to demonstrate the sources of the various elements that a plant uses in the synthesis of carbogydrate, you would probably try to remove from the plant's environment the suspected sources of those atoms. One way to control the environment would be to place the plant in an air-tight container with an appropriate chemical. For one phase of your demonstration the most appropriate chemical would be: a. a substance that removes carbon dioxide from the air, b. a substance that removes carbon dioxide and water vapor from the air, c. a substance that adds carbon dioxide to the air, d. a substance that adds carbon dioxide and water vapor to the air, e. a substance that dissolves chlorophyll

27. Before testing a leaf for the presence of starch, you should remove: a. glucose, b. chlorophyll, c. water, d. carbon dioxide, e. both c and d

28. Examination of leaf extracts by means of paper chromatgraphy provides evidence that: a. more than one pigment may be useful in photosynthesis, b. chlorophyll is the energy-trapping pigment of leaves, c. some of the reactions of photosynthesis do not require light, d. oxygen is removed from the water molecule in photosynthesis, e. oxygen is removed from carbon dioxide in photosynthesis

29.



The similarity of the two graph lines in this illustration suggest: a. that water is degraded in an early reaction of photosynthesis, b. that chlorophyll makes light energy available for photosynthesis, c. that light is essential for only one phase of the reactions of photosynthesis, d. that there are two major phases in photosynthesis, e. that artificial light is not effective in photosynthesis

30. One reason why carbon dioxide and water combine to form sugar only in certain living cells, where conditions are highly organized is that the water molecule is stable. Another reason is: a. molecules tend to react so that they lose energy, b. CO_2 and H_2O generally combine only when under high pressure, c. CO_2 and H_2O generally combine only at a high temperature, d. CO_2 is less stable than CO, e. the reactions must take place in the presence of nitrogen

31. Which is the best basis of evidence that photosynthesis consists of more than one type of reaction? a. experiments with heavy oxygen, b. determining the relationship between light intensity and photosynthesis, c. use of lights of particular alternating periods of light and darkness are changed

32. In his discovery of the sequence in which the reactions of photosynthesis occurred Melvin Clavin's main "tool" was: a. heavy hydrogen, b. heavy water c. a phosphorescent dye d. an isotope of phosphorus, e. carbon 14

For each of the following 4 questions select one process from the list at the right that best fits the condition that is stated:

33. Releases oxygen
34. Releases CO_2
35. Releases O_2 and CO_2
36. Uses CO_2

a. transpiration
b. photosynthesis
c. diffusion
d. differentiation
e. respiration

37. One way the plant harvests the energy of sunlight is by synthesizing carbohydrate, which may then be used in making many other organic substances. Another way the plant harvests the energy of sunlight is: a. by converting CO_2 and H_2O into lipids, b. by converting CO_2 and H_2O into proteins, c. by removing oxygen from CO_2, d. by breaking down protein into amino acids, e. by combining oxygen with hydrogen making ATP using the energy from the combination of O_2 and H_2

38. One source of energy for converting ADP to ATP is the oxidation of sugar. Another is: a. the oxidation of hydrogen, b. the breaking apart of CO_2, c. the breaking apart of H_2O, d. the synthesis of NH_3, e. both b and c

39. Sugars contain three kinds of atoms--C, H, and O. In one of the early reactions in the synthesis of sugar, CO_2 obtains hydrogen by the addition of: a. another sugar, by. hydrogen ions, c. hydrogen atoms, d. hydrogen molecules, e. hydroxide ions

40. In 1954 Daniel Arnon succeeded in observing photosynthesis outside living cells. He accomplished this by: a. isolating chloroplasts from their cells, b. dissolving chlorophyll in a salt solution, c. dissolving chlorophyll in acetone, d. synthesizing chlorophyll outside the leaf, e. removing the muclei from the cells

Chapter 9 Test - Plants From The Sea

1. One function of moss spores is to provide a stage in the life cycle that is able to survive dry conditions. Another function is: a. to provide a stage in which oxygen can be absorbed efficiently, b. to provide a stage in which carbon dioxide can be absorbed efficiently, c. to enable the species to spread from one locality to another, d. to permit more efficient contact of photosynthetic pigments with light, e. to prevent loss of stored food.

2. In paper chromotography, substances in a solution are separated by: a. the rate at which they filter through a paper funnel, b. matching the color of the dissolved ions with standard color prints, c. the manner in which the dissolved substances react with paper that is impregnated with special chemicals, d. the distance to which the dissolved substances move on an absorbent paper, e. the rate at which the substances are attracted to electrically charged terminals.

3. For a long time many scientists had assumed that life originated in the sea. This has recently been modified by the theory that some of the first complex organic substances were synthesized: a. in fresh water, b. on hot wet rocks, c. in the soil, d. in the damp atmosphere above the sea, e. in damp caves.

4. According to Oparin's theory, the first organisms were: a. heterotrophs, b. autotrophs that use CO_2, c. autotrophs that used silicon instead of carbon, d. autotrophs that used sulfur dioxide instead of carbon dioxide, e. viruses.

5. According to the Oparin theory, how was the early atmosphere changed by the first autotrophs?
   a. It's oxygen content increased,
   b. It's carbon dioxide content decreased,
   c. It's methane content increased,
   d. It's hydrogen content increased,
   e. It's carbon monoxide content increased.

6. The function of an alga's pyrenoids is to assist in: a. shielding the choroplast from excessive light, b. concentrating light on the chloroplast, c. acting as a primitive eye, d. propelling the cell through the water, e. converting sugar to starch.

7. The term motile means: a. not anchored in one location, b. capable of living either as a heterotroph or an autotroph, c. capable of living in either fresh or salt water, d. capable of living for a time out of water, e. capable of moving under its own power.

8. Volvox is remarkable in: a. being a single cell of such great size, b. being a highly specialized cell of such small size, c. being a group of cells that coordinate their activity despite the lack of much specialization, d. being either autotrophic or heterotrophic, e. being able to survive either in or out of water.

The following three questions refer to Stanley Miller's experiment (at the University of Chicago), in which he passed electrical charges through a mixture of gases in a glass sphere.

9. Miller's purpose was to find if this procedure would: a. break carbon dioxide molecules apart, b. synthesize sugars, c. break water molecules apart, d. synthesize amino acids, e. remove methane

10. The gases in the sphere were methane, hydrogen, water vapor, and: a. carbon dioxide, b. ammonia, c. ether, d. sulfur dioxide, e. oxygen

11. The results of Miller's experiment suggested that: a. primitive plants made food without carbon dioxide, b. primitive plants made food without water, c. protein-like molecules may have been produced before there was real life on the earth, d. methane may have been used as a raw material by primitive organisms, e. the first organisms made their own food by photosynthesis.

12. The filamentous alga, Cladophora, has an advantage over most solitary forms: a. in being anchored in a suitable habitat, b. in being able to choose the water level in which light conditions are best, c. in having chlorophyll that is better situated to receive light, e. in having storage facilities for food, e. in being resistant to drying.

13. Moss "leaves" differ from true leaves: a. in lacking stomates, b. in lacking guard cells, c. in having no spongy tissue, d. in both a and b, e. in a, b, and c.

14. A gamete is: a. a device for storing starch, b. an organ that functions as a root, c. a sex cell, d. a cell that anchors an alga to the substrate, e. a light-sensitive portion of a cell.

15. The production of the first amino acids was probably powered by the sun's radiant energy and: a. heat from volcanism, b. lightning, c. breakdown of metalic oxides, d. synthesis of metalic oxides, e. oxidation of inorganic substances by viruses.

16. A reproductive structure in the mosses that can withstand drying is a: a. gamete, b. sporophyte, c. gametophyte, d. protonema, e. spore.

17. Water is an ideal medium for supporting life because: a. it permits movement of organisms more freely than air, b. it makes reproduction easier, c. it is a good solvent, d. it freezes and thaws quickly, e. none of these.

18. Organisms like Chlamydomonas change the atmosphere by: a. removing oxygen and adding CO_2 , b. removing essential nutrients, such as dissolved salts, c. increasing the oxygen content, d. serving as food for other organisms, e. removing nitrogen.

19. Moss leaves are similar to leaves of vascular plants because: a. they have xylem and phloem, b. they photosynthesize, c. they have vascular bundles, d. palisade and spongy cells are sometimes present, e. all of these.

20. In Miller's experiment the determination of new substances was accomplished by: a. testing the effect of the solution on living organisms, b. tasting the solution, c. using a spectroscope, d. chromatography, e. using an electrical discharge.

21. The substances Miller found in the solution were: a. proteins, b. ammonia, water, and oxygen, c. hydrochloric and sulfuric acids, d. components of DNA, e. amino acids.

22. Free oxygen was not present in the atmosphere around the early earth because: a. it was being used by the plants and animals, B. it was tied up as metallic oxides, c. in the process of evolution it was one of the last elements to come into existance, d. it was combined with carbon and hydrogen, e. there was a great deal of respiration but little photosynthesis.

23. The opposite of oxidation is: a. hydration, b. dehydration, c. reduction, d. phosphorylation, e. precipitation.

24. One advantage for cells that live in a colony, such as a filament, plate, or sphere, is that: a. photosynthesis can be more efficient, b. cell specialization can occur, c. more enzymes can be manufactured by the cells, d. each cell can grow larger, e. each cell may be smaller, because certain organelles may be absent.

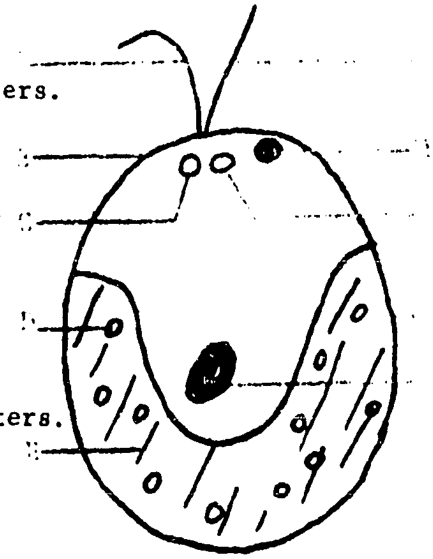
25. Which do you think is the best generalization about this chapter? a. the first organisms on the earth were probably much like modern algae, b. after the early appearance of heterotrophs, algae evolved adaptations that eventually enables plants to live on land, c. before living cells were possible, the chlorophyll molecule must have evolved, d. the first chemical reaction concerned with the origin of life was probably the combination of carbon dioxide and water, producing a simple sugar, e. the first plants of the sea probably arrived there when algae cells were carried there by rivers.

26. Which one of the following is the formula for ammonia? a. CH_4, b. CH_3Cl, c. H_2O_2, d. NH_3, e. CH_3OH.

27. Which of these animals is similar to a moss in its dependence on water? a. mouse, b. salmon, c. eel, d. leopard frog, e. lizard

28. During the gradual development of life in the sea, a compound was formed that could trap and transfer energy from the sun. Later, a molecule with a similar structure but a different function evolved. In which organism would you expect to find this second substance? a. frogs, b. *Chlamydomonas*, c. pine, d. geranium, e. *Paramecium*

The following functions refer to the red capital letters.



29. Aids in movement

30. Rids cell of excess H_2O

31. Photosynthesizes

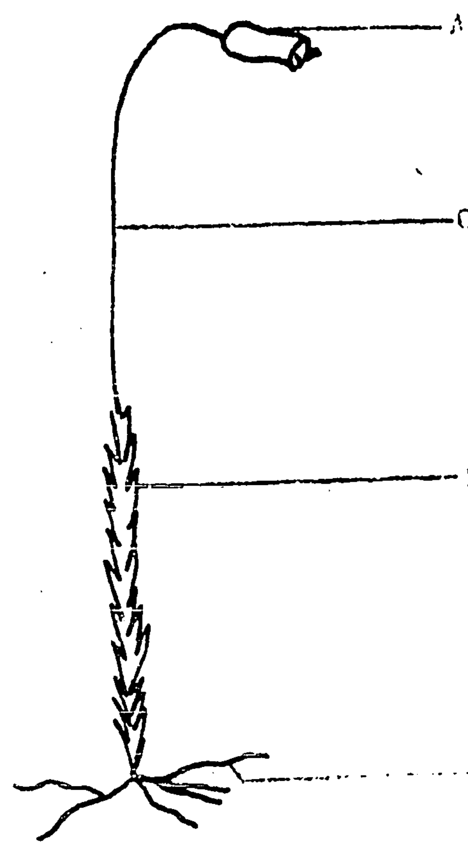
32. Makes starch from sugar

The following functions refer to the small green letters.

33. Acts as a selectively-permeable membrane. Determines which substances that are dissolved in the water will be available for synthesis by the cell

34. Controls reproductive process

35. Aids in detecting changes in light



The following refer to the red letters

36. Forms spores

37. The first structures to develop from a spore

38. Develops when an egg and sperm form a zygote

39. Closely resembles certain green algae

40. Forms gametes during one stage in its development

Chapter 10 Test- Plants on Land

1. The function of guard cells depends on a design that permits them to: a. engulf foreign particles, b. allow carbon dioxide to get in but not out, c. close when they absorb water, d. reduce transpiration, e. secrete cutin

2. The danger of fire in an indoor Christmas tree such as pine or fir is greatly reduced if the water content of the leaves remains high. It is helpful therefore to keep the base of the stem in water. The part that functions most directly in this process is: a. outer bark, b. inner bark, c. woody portion, d. phloem, e. lenticels

3. The growth of a corn stem in diameter is limited mainly by: a. the low photosynthetic rate of the plant, b. its lack of lenticels, c. its lack of a permanent ring of cambium, d. its limited number of cotyledons, e. its high rate of transpiration

4. If you accept the idea that life once arose spontaneously in the sea, you may ask if life is still being created in this way. This is highly unlikely because: a. the sea is now too cool, b. the sea is now too warm, c. the sea is now too salty, d. there isn't enough carbon dioxide today, e. there isn't enough methane today

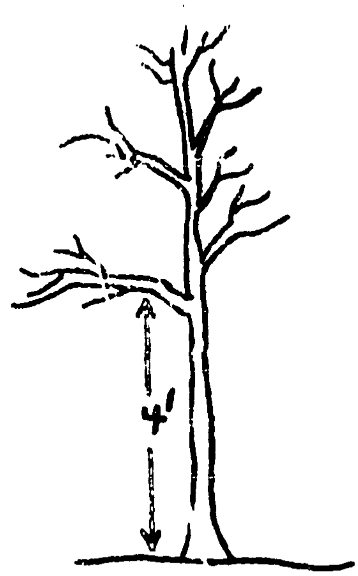
5. Which statement best indicates a difference between roots and stems? a. stems grow in length only near the tip; roots grow all along their length, b. stems have growth rings; roots do not, c. roots respond to gravity; stems do not, d. roots and stems respond differently to gravity, e. stems contain cambium; roots do not

6. A decrease in diameter of a tree stem during daytime has been cited as evidence that: a. osmosis is not an adequate explanation of the rise of water in plant stems, b. the heartwood is dead, c. the lenticels are not functioning properly, d. the rate of transpiration exceeds the intake of water, e. food is being consumed faster than it is being produced

7. Which statement do you think is the best clue to the function of the companion cells? a. they are near cells that contain no nuclei, b. they contain no chloroplasts, c. they contain chloroplasts, d. they contain no nuclei, e. they function after they are no longer alive

8. Which is the best reason for believing that transport in phloem tissue is different from transport in xylem? a. it (transport in phloem) occurs when the tree is dormant, b. it occurs at night, c. it occurs only in living tissue, d. it occurs at a rate similar to diffusion, e. it occurs only when the plant is making food

9. The height of the limb above the ground (see sketch) will: a. remain the same, b. increase more slowly than the tree grows in height, c. increase at the same rate as the tree grows in height, d. increase at a rate depending on the activity of the primary meristem, e. increase at a rate depending on the activity of the secondary meristem



10. Which one of the following would you expect to find in all three of the major parts of a vascular plant--roots, stems, and leaves? a. lenticels, b. xylem cells, c. palisade cells, d. stomates, e. apical meristem

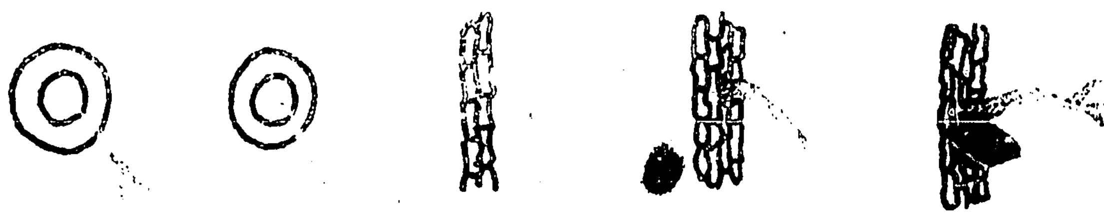
11. What structure is shown in the sketch at the right? a. a longitudinal section of a monocot stem (such as corn). b. a cross section of a monocot stem, c. a cross section of a tree, e. the maturation region of a root

12. In the sketch at the right, the difference between the cells at A and B is best explained by: a. A is xylem while B is phloem, b. A is phloem while B is xylem, c. variable amounts of pigment were available when the two cell groups were produced, d. the cells at A and B were produced during different seasons of the year, e. the cells at A are photosynthetic; those at B are not

13. Investigating the rise of water in plant stems, a biologist opened the stem of a living plant and punctured a xylem vessel with an extremely fine needle. He oberved no leaking of liquid

from the hole. This result suggests: a. that xylem carries materials down the stem rather than up, b. that water is pulled upward in the stem rather than being pushed upward, c. that the xylem vessel punctured was no longer alive, d. that there was a shortage of water in the soil, e. that the plant was not photosynthesizing food

14. Which one of the sketches below best represents root hairs? (The root hairs are shown in red)



a b c d e

15. If you were grafting a twig of an apple tree onto another variety of apple tree, which kind of tissue of the two stems must be properly aligned with each other? a. cambium, b. cortex, c. xylem, d. phloem, e. epidermis

16. Which one of the tissues listed in question 15 is mainly involved with transport of fluids upward through the stem?

17. Which one of the tissues listed in question 15 contains cells that reproduce themselves rapidly?

18. The function of meristem tissue is: a. storing reserve food supplies, b. storing raw materials for food production, c. photosynthesizing new substances for the plant, d. protecting the plant from excessive water loss, e. none of those

19. When a corn field is flooded and the lower parts of the plants remain under water for a week, they generally die. The cause of death is: a. failure of the stems to translocate food, b. inability of the roots to respire, c. failure of minerals to reach the leaves, d. submersion of the plant organs containing most of the mitochondria, e. diffusion of phosphates and nitrates out of the plant

20. Growth rings are visible on the cross section of a tree stem mainly because: a. growth conditions vary throughout the year in a regular pattern, b. only phloem is produced in winter, c. phloem cells are produced only during periods of high food production, d. there is a layer of cambium between one season's growth and the next, e. meristem cells have thinner walls than vascular cells

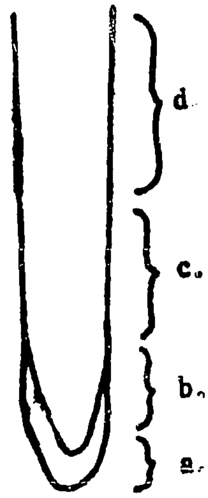
21. Which is the best statement of the relationship of structure to function as it applies to the idea that water is pulled upward in plant stems rather than pushed upward? a. their walls lack cellulose, b. they lack walls altogether, c. specialized water-conducting cells are not found in the roots, d. the water-conducting cells have ringed or spiral bands that appear to prevent collapse, e. these cells have no nuclei at the time they are serving for transport

22. Trees are sometimes killed by girdling cutting a groove completely around the base of the trunk, cutting through the cambium. In such a tree death would eventually occur because: a. cambium cells are unable to divide, b. the leaves would be unable to produce food, c. the roots would starve, d. the stored food would leak from the tree, e. transpiration would stop

23. A plant root sometimes contains a higher concentration of a mineral than is present in the soil. Yet additional molecules of the mineral continue to enter the root. This phenomenon is called: a. turgor, b. diffusion, c. osmosis, d. active transport, e. transpiration

24. The phenomenon described in the previous question is possible because: a. all molecules are in constant motion, b. the concentration of the mineral is higher inside the root than outside, c. the cells of the root are respiring, d. the roots have cellulose walls, e. stomates close during periods of water shortage

25. What is the relationship between the supply of minerals in the root and the plant's water supply? (see question 23) a. since water and minerals enter the root by different processes, there is no relationship between the two, b. since water diffuses from a region of higher concentration to a region of lower concentration, the presence of the minerals in the root helps the plant get the water it needs, c. since water diffuses from a region of low concentration, the presence of the minerals limits the amount of water that the plant can absorb, d. the minerals provide energy, increasing the root's ability to absorb water, e. the absorption of minerals uses energy, limiting the amount of water that can be absorbed



THE NEXT THREE QUESTIONS CONCERN THE SKETCH OF A YOUNG ROOT, SHOWN AT THE LEFT.

26. In which region would you expect to find the greatest number of dividing cells?

27. In which region would you expect to find the greatest number of root hairs?

28. Which one is called the region of elongation?

THE NEXT THREE QUESTIONS CONCERN THIS EXPERIMENT. Ten short rows of pea seeds were planted. When the seedlings started to come up, alternate rows were covered by light-proof boxes. Five days later the boxes were removed and the seedlings were measured. Those that were covered were taller. Equal numbers of the plants in the two groups were cut off at ground level, dried and weighed. Those that were exposed to light were heavier.

29. Which of these ideas is closely related to the greater weight of the seedlings that had been exposed to light? a. plants in the light have not had to use all of the food stored in the seed, b. they lost less carbon dioxide through the stomates, c. they lost less oxygen through the stomates, d. they lost less phosphate through the roots, e. they broke more molecules of water apart

30. The substance most closely involved in an explanation of the faster growth of the seedlings that were covered by the boxes is: a. hemoglobin, b. auxin, c. cutin, d. carbon dioxide, e. phosphorus

31. Which statement is the best explanation of how the substance that you selected in the previous question is related to the faster growth of the covered seedlings? a. it accumulates more rapidly in a darkened stem than in a lighted stem, b. it diffuses out of the leaves faster in the light than in the dark, c. it is absorbed from the soil faster in the light than in the dark, d. it is absorbed from the soil faster in the dark than in the light, e. it is produced only in a lighted plant

32. Certain seeds do not germinate until they have been subjected to low temperatures. This is best interpreted as: a. evidence that pollination occurs after the seed is mature, b. an adaptation that prevents germination until weather conditions are really favorable, c. an example of a way in which the species has not fully adapted to the area in which it is growing, d. evidence

that there is a shortage of stored food in the seed, e. evidence that the soil in which the seeds are planted is low in calcium

33. A type of land plant whose adaptations for life on land are not as complete as for most flowering plants is:
a. fern, b. pine, c. spirogyra, d. alfalfa, e. moss

34. A growth movement in which a plant is responding to a factor of its environment (such as light) is called:
a. a stimulus, b. a retraction, c. a synthesis, d. a translocation, e. a tropism

FOR THE REMAINING QUESTIONS, SELECT YOUR ANSWERS FROM THE LIST AT THE RIGHT. Use each answer as many times as you wish, but do not mark this paper.

35. Flowering plants

36. Male gametophyte represented by pollen

37. Vascular

38. Seeds not enclosed in a fruit

39. Autotrophs

40. Mainly evergreen

a. Gymnosperms
b. Angiosperms
c. Bryophytes
d. All of the above
e. Both a and b

APPENDIX H. ATTITUDE SCALE

SURVEY OF STUDENT OPINION

AMES HIGH SCHOOL BIOLOGY

This has been prepared so that you can indicate how you feel about your biology class. You can respond to each item on a 0 through 9 scale. The scale is related to your feeling about each item.

Strongly disagree		Disagree, but not so strongly		Neutral feelings			Agree, but not strongly		Strongly agree
0	1	2	3	4	5	6	7	8	9
---	---	---	---	---	---	---	---	---	---

The numbers 0 through 9 represent a range of feeling, from strongly disagree to strongly agree. Blacken the space under the number that most accurately represents your attitude.

The only correct answer is the one that actually represents how you feel about this class.

1. I am satisfied with the methods used in teaching this class.
2. My attitude toward this class is less favorable than it was.
3. There is not enough contact between teacher and students in this class.
4. I like the method used in teaching this class.
5. Too much emphasis has been placed on topics that are unimportant.
6. I can see no advantage of this method of teaching over other methods.
7. This class exceeds my highest expectation.
8. Some students benefit more than others from the method of teaching this class.
9. I have neutral feelings toward the subject matter of this class.
10. The presentation of this class is paced too fast.
11. I am pleased with the teaching method used for this class.
12. I am disappointed with this class.
13. I find it easy to study this subject because I am really enthusiastic about it.
14. I am forced by the method in this class to spend too much time on material I already know.
15. Teachers of all classes should employ the method used to teach this class.
16. Students do not participate enough in this class.
17. The method used to teach this class delays our progress through the material.
18. I remember the material in this class because of the method used to present it.
19. I did not think I would learn as much in this class as I have.
20. The teaching method used in this class doesn't give me enough freedom.
21. My attitude about the way this class is taught is one of enthusiasm.
22. The method of instruction used in this class could be improved greatly.
23. The topics presented in this class are well organized.
24. This class has not fulfilled the hopes I had for it.
25. I have not had a chance to review when I wanted to in this class.
26. The subject matter of this class is interesting.

APPENDIX I. PERSONALITY TESTS

STUDENT OPINION SURVEY - I

This is a questionnaire to find out what you think about events in our society. In each pair of statements, select the one you believe to be more true than the other. Blacken the answer (either a or b) on the answer sheet. There should be only one answer for each numbered pair of statements. There are 29 pairs in this survey. Put your name, biology class period, instructor's name, date, and SURVEY I on the answer sheet.

1. a. Children get into trouble because their parents punish them too much.
   b. The trouble with most children nowadays is that their parents are too easy with them.

2. a. Many of the unhappy things in people's lives are partly due to bad luck.
   b. People's misfortunes result from the mistakes they make.

3. a. One of the major reasons why we have wars is because people don't take enough interest in politics.
   b. There will always be wars, no matter how hard people try to prevent them.

4. a. In the long run people get the respect they deserve in this world.
   b. Unfortunately, an individual's worth often passes unrecognized no matter how hard he tries.

5. a. The idea that teachers are unfair to students is nonsense.
   b. Most students don't realize the extent to which their grades are influenced by accidental happenings.

6. a. Without the right breaks one cannot be an effective leader.
   b. Capable people who fail to become leaders have not taken advantage of their opportunities.

7. a. No matter how hard you try, some people just don't like you.
   b. People who can't get others to like them don't understand how to get along with others.

8. a. Heredity plays the major role in determining one's personality.
   b. It is one's experiences in life which determine what he is like.

9. a. I have often found that what is going to happen will happen.
   b. Trusting to late has never turned out as well for me as making a decision to take a definite course of action.

10. a. In the case of the well prepared student there is rarely if ever such a thing as an unfair test.
    b. Many times test questions tend to be so unrelated to my courses, that studying is useless.

11. a. Becoming a success is a matter of hard work, luck has little to do with it.
    b. Getting a good job depends mainly on being in the right place at the right time.

12. a. The average citizen can have an influence in government decisions.
    b. This world is run by the few people in power, and there is not much the little guy can do about it.

13. a. When I make plans, I am almost certain that I can make them work.
    b. It is not always wise to plan too far ahead because many things turn out to be a matter of good or bad fortune anyhow.

14. a. There are certain people who are just no good.
    b. There is some good in everybody.

15. a. In my case getting what I want has little or nothing to do with luck.
    b. Many times we might just as well decide what to do by flipping a coin.

16. a. Who gets to be the boss often depends on who was lucky enough to be in the right place first.
    b. Getting people to do the right thing depends upon ability, luck has little or nothing to do with it.

17. a. As far as world affairs are concerned, most of us are the victims of forces we can neither understand, nor control.
    b. By taking an active part in political and social affairs the people can control world events.

18. a. Most people don't realize the extent to which their lives are controlled by accidental happenings.
    b. There really is no such thing as "luck".

19. a. One should always be willing to admit his mistakes.
    b. It is usually best to cover up one's mistakes.

20. a. It is hard to know whether or not a person really likes you.
    b. How many friends you have depends upon how nice a person you are.

21. a. In the long run the bad things that happen to us are balanced by the good ones.
    b. Most misfortunes are the result of lack of ability, ignorance, laziness, or all three.

22. a. With enough effort we can wipe out political corruption.
    b. It is difficult for people to have much control over the things politicians do in office.

23. a. Sometimes I can't understand how teachers arrive at the grades they give.
    b. There is a direct connection between how hard I study and the grades I get.

24. a. A good leader expects people to decide for themselves what they should do.
    b. A good leader makes it clear to everybody what their jobs are.

25. a. Many times I feel that I have little influence over the things that happen to me.
    b. It is impossible for me to believe that chance or luck plays an important role in my life.

26. a. People are lonely because they don't try to be friendly.
    b. There's not much use in trying too hard to please people, if they like you, they like you.

27. a. There is too much emphasis on athletics in high school.
    b. Team sports are an excellent way to build character.

28. a. What happens to me is my own doing.
    b. Sometimes I feel that I don't have enough control over the direction my life is taking.

29. a. Most of the time I can't understand why politicians behave the way they do.
    b. In the long run the people are responsible for bad government on a national as well as on a local level.

STUDENT OPINION SURVEY - II

This is a questionnaire to find out what you think about school work and classes you attend. In each pair of statements, select the one you believe to be more true than the other. Blacken the answer (either a or b) on the answer sheet. There should be only one answer for each numbered pair of statements. There are 35 pairs in this survey.

Put your name, biology class period, instructor's name, date, and SURVEY II on the answer sheet.

1. a. It bothers me if a teacher does not return a test to me within a day or two.
   b. It does not bother me if a teacher keeps a test for more than one week before returning it.

2. a. I do not explain my reasons for missing class to my teacher even when my reasons may be very good ones.
   b. I make it a point to explain my reasons for absence to the teacher.

3. a. I believe tape recordings of class sessions should be made available to students who wish to make up classes they miss.
   b. There is little need for taped class sessions, since students can get the material on their own if they want to.

4. a. If I know in advance that short quizzes are part of the course, it doesn't bother me to take them.
   b. It bothers me to take quizzes, even if I understand that they are part of the course.

5. a. I believe that a planned sequence of courses more adequately prepares students for graduation than a lot of electives do.
   b. I believe that more learning occurs through independent reading, study, and elective courses.

6. a. It makes little difference to me on later tests whether or not I am aware of specific errors on the first one.
   b. I can do better on future tests if I am given a chance to identify my errors on the first one.

7. a. I do better if I am given daily or weekly assignments rather than a reading list for a month or more.
   b. I do better if I am given a reading list for a month or more instead of weekly assignments.

8. a. It does not bother me to take required courses.
   b. It bothers me to take a course just because it's required for graduation.

9. a. I usually get a better grade on an assignment if the topic is clearly defined by the teacher.
   b. I usually get a better grade on an assignment if I am allowed a great deal of freedom in defining the topic.

10. a. I am apt to telephone a teacher if I have an important question to ask.
    b. I do not telephone a teacher even if I have an important question about homework.

11. a. Courses of study relating to a student's interest or future career should be clearly outlined.
    b. Students should be given greater opportunity to elect classes.

12. a. Exams should be taken at the same time by all students.
    b. Students should be allowed to take exams whenever they are prepared for them.

13. a. If I'm thinking of dropping a course, I am likely to seek the advice of the teacher, counselor, or principal.
    b. If I'm thinking of dropping a course, I am not likely to ask teachers or other faculty members for advice.

14. a. I do not feel it necessary to go over tests the teacher hands back.
    b. Going over tests the teacher hands back benefit me a great deal.

15. a. If I am not doing as well in a course as I would like, I get advice or help from the teacher or from other students.
    b. If I am not doing as well in a course as I would like, I change my study habits.

16. a. If I have a question with respect to a class or an assignment, my first reaction is to ask the teacher about it.
    b. If I have a question with respect to a class or an assignment, my first reaction is to try to work it out by myself.

17. a. I believe that the teacher should correct all sets of study questions, problems, or other homework.
    b. The teacher should explain only those problems or study questions about which students raise questions.

18. a. I do better in a course if my grade is based on 2 or 3 tests covering several chapters.
    b. I do better in a course if my grade is based on weekly quizzes covering certain portions of chapters.

19. a. Before participating in class discussion, I am usually well-prepared to answer questions on the topics.
    b. Before I participate in discussion-type classes, I typically prepare little and try to pick up important points from other members of the group.

20. a. I attend classes if I think the material is worthwhile; otherwise I may find an excuse to be absent.
    b. I attend classes if I think the material will be covered on the test; otherwise I don't feel class is too important.

21. a. I believe that teachers should be required to follow specific outlines prepared by their departments.
    b. I believe that teachers should include in a course whatever content they wish.

22. a. Students should direct their own outside reading in areas where they are deficient.
    b. It is the responsibility of the teacher to assign outside reading for students.

23. a. I believe that every teacher should place "old" tests on file so that students can review them.
    b. I believe that a teacher has no responsibility for placing an old test on file for any student including myself.

24. a. Students should be allowed to enter any university department they desire regardless of entrance qualifications.
    b. Students should be required to take entrance examinations in order to determine their qualifications for entering any college department.

a. Students should work out their own semester schedules and plans for study.
b. Counselors should make available a master plan of study for each student.

26. a. I believe that students should have complete freedom in selecting courses.
b. I believe that students should follow a specific plan of study that prepares them for a specific line of work.

27. a. I believe that my grades would suffer if I was allowed to schedule my own examinations throughout courses.
b. I believe that my grades would be higher if I was allowed to schedule my own examinations throughout courses.

28. a. My grades should be lowered for missing class sessions.
b. My grades should be calculated without regard to the number of times I am absent.

29. a. Mid-semester report slips are meaningless because the student already knows his grade.
b. Students who receive mid-semester report slips are encouraged to work harder.

30. a. I have been in situations where I thought cheating on assignments was justified.
b. I do not believe cheating is ever justified.

31. a. Outside projects should be clearly defined by the instructor.
b. Students should be allowed to choose outside projects on any topic they so desire.

32. a. Before tests, teachers should review important points.
b. Before tests, teachers should provide review sessions to answer student's questions.

33. a. I believe that students should have freedom in organizing the content of a term paper.
b. I believe that teachers should provide the student with a specific outline whenever term papers are assigned.

34. a. I believe students should be responsible for relating readings and assignments to topics covered in class.
b. Handouts outlining and summarizing topics in class should be distributed to students.

35. a. Teachers should discuss topics related to (but other than) those assigned in readings.
b. In class discussion, teachers should point out the important points of assigned materials.

STUDENT OPINION SURVEY - III

This is a questionnaire to find out what you think about tests, grading procedures, and your attitude toward classes you take. In each pair of statements, select the one you believe to be more true than the other. Blacken the answer (either a or b) on the answer sheet. There should be only one answer for each numbered pair of statements. There are 23 pairs in this survey.

Put your name, biology class period, instructor's name, date, and SURVEY III on the answer sheet.

1. a. I perform better on tests if I study alone.
   b. I perform better on tests if I've had the chance to study with other students.

2. a. Many of the items I miss on tests are tricky items.
   b. Many of the items that I miss on a test are difficult items.

3. a. My performance on exams is seldom affected by disturbances or noise in the room.
   b. My performance on exams is frequently affected by noises in the room.

4. a. If I were as lucky in getting grades as some students, I could get through school with very little trouble.
   b. I believe that I am about as lucky in getting grades as the next student.

5. a. If I am well-prepared for a test, I can recognize the correct answer without guessing.
   b. Even though I am well-prepared for an examination, I may as well toss a coin to answer true-false questions.

6. a. I feel that teachers are unduly influenced by how often some students speak up in the classroom.
   b. I feel that teachers are influenced by what students say rather than by how often they speak up in class.

7. a. It does not bother me if I have too many tests scheduled on any given day.
   b. If I have too many tests scheduled on any given day, I ask some of the teachers if I can take their tests later.

8. a. I find that it is just about as easy to get a grade on one course as it is in another.
   b. I typically find it easier to get a grade in some subjects than in others.

9. a. How much I learn in a course depends on how good the teacher is.
   b. How much I learn in a course depends on how much I study.

10. a. My grades depend largely on how stiff the competition is.
    b. My grades depend mostly on how hard I work.

11. a. It would be easier for students to get good grades if they were allowed to select a specific teacher when enrolling in a required course.
    b. Grades earned by students under one teacher are about like those earned under another.

12. a. Success in school requires luck more than brains.
    b. Success in school requires brains more than luck.

13. a. If I receive a low score on a test, it gives me satisfaction to know that most other students did poorly too.
    b. If I receive a low score on a test, I remain dissatisfied even after hearing that most other students did poorly too.

14. a. The teacher's method of presentation has little effect upon my grade in a course.
    b. I cannot do well in a course where the teacher speaks too far "over my head".

15. a. I believe that the grades I earn in school depend more upon the teacher's opinion than upon my achievement.
    b. I believe that the grades I earn in school depend more upon my achievement than upon the teacher.

16 a. I get about the same grades regardless of the type of test given.
   b. I do better on certain kinds of tests (for example, essay or multiple-choice) than I do on others.

17. a. I do about the same in courses regardless of the teacher.
    b. I do better in courses if I have a good teacher.

18. a. I do not get about the same grades in lecture and discussion-type courses; I usually get better grades in one than in the other.
    b. I get about the same grades in lecture and discussion-type courses.

19. a. After scoring low on a test, I know I need to change my study pattern.
    b. After scoring low on a test, I tell the teacher the reason for my poor performance.

20. a. When I am extremely dissatisfied with a course, I drop it.
    b. If I am extremely dissatisfied with a course, I complete the course anyway.

21. a. After taking a test, I have a pretty good idea of what my grade will be.
    b. Before a test is returned to me, I find it difficult to guess what my grade will be.

22. a. I believe that there is a <u>high</u> relationship between how much I study and the grades I receive.
    b. I believe that there is a <u>low</u> relationship between how much I study and the grades I receive in courses.

23. a. Students who have access to old tests receive the highest grades.
    b. Students who study the text and their notes for tests receive the highest grades.

24. a. Sometimes I can do about as well on a test with very little as with a great deal of preparation.
    b. I can seldom do well on a test with little preparation.

25. a. I can usually figure out how much effort I need to put into a course to get the grade I want.
    b. No matter how much effort I put into certain courses, it is difficult to get the grade I want.

26. a. I doubt that my final grade would vary much if I attended several sections of a course and then selected the one that I finally wanted to be in.
    b. I could probably get better grades if I could attend all sections of a course and then select the one that I finally wanted to be in.

27. a. In view of test procedures used by teachers, I believe that school policies should be lenient toward students with low grades.
    b. In view of testing procedures used by teachers, I believe that school policies should readily expel or flunk students with low grades.

28. a. When I get an unexpectedly poor grade, I doubt that "bad luck" had anything to do with it.
    b. When I get an unexpectedly poor grade, I consider it "bad luck".

29. a. It does not bother me if students copy on assignments or tests.
    b. It bothers me if students copy from each other in preparing assignments.

30. a. If I don't know an answer to a test item, it does not bother me to guess the answer.
    b. If I don't know an answer to a test item, it bothers me to guess the answer because I feel I should know it.

31. a. I do well on tests unless I consider them to be "unfair".
    b. I do well on tests unless I am inadequately prepared.

32. a. I sometimes blame myself when I miss an item on a test.
    b. I sometimes blame the exam writer when I miss an item on a test.

33. a. When I get a lower grade than I expected, I usually blame myself.
    b. When I get a lower grade than I expected, I seldom can pinpoint the reason for it.

This is a questionnaire to find out how you interact with others, and how you conduct yourself in various social situations. It is a true-false test. On the answer sheet blacken: "A" for true, "B" for false.
Each of the 33 items should be marked either true or false
Put your name, biology period, instructor's name, date, and SURVEY IV on the answer sheet.

1. Before voting in school elections I thoroughly investigate the qualifications of all the candidates.
2. I never hesitate to go out of my way to help someone in trouble.
3. It is sometimes hard for me to go on with my work if I am not encouraged.
4. I have never intensely disliked anyone.
5. On occasion I have had doubts about my ability to succeed in life.
6. I sometimes feel resentful when I don't get my way.
7. I am always careful about my manner of dress.
8. My table manners at home are as good as when I eat in a restaurant or the school cafeteria.
9. If I could get into a movie without paying and be sure I was not seen I would probably do it.
10. On a few occasions, I have given up doing something because I thought too little of my ability.
11. I like to gossip at times.
12. There have been times when I felt like rebelling against people in authority even though I knew they were right.
13. No matter who I'm talking to, I'm always a good listener.
14. I can remember "playing sick" to get out of something.
15. There have been occasions when I took advantage of someone.
16. I'm always willing to admit it when I make a mistake.
17. I always try to practice what I preach.
18. I don't find it particularly difficult to get along with loud mouthed, obnoxious people.
19. I sometimes try to get even rather than forgive and forget.
20. When I don't know something I don't at all mind admitting it.
21. I am always courteous, even to people who are disagreeable.
22. At times I have really insisted on having things my own way.
23. There have been occasions when I felt like smashing things.
24. I would never think of letting someone else be punished for my wrongdoings.
25. I never resent being asked to return a favor.
26. I have never been irked when people expressed ideas very different from my own.
27. I never make a long trip without checking the safety of my car.
28. There have been times when I was quite jealous of the good fortune of others.
29. I have almost never felt the urge to tell someone off.
30. I am sometimes irritated by people who ask favors of me.
31. I have never felt that I was punished without cause.
32. I sometimes think when people have a misfortune they only got what they deserve
33. I have never deliberately said something that hurt someone's feelings.