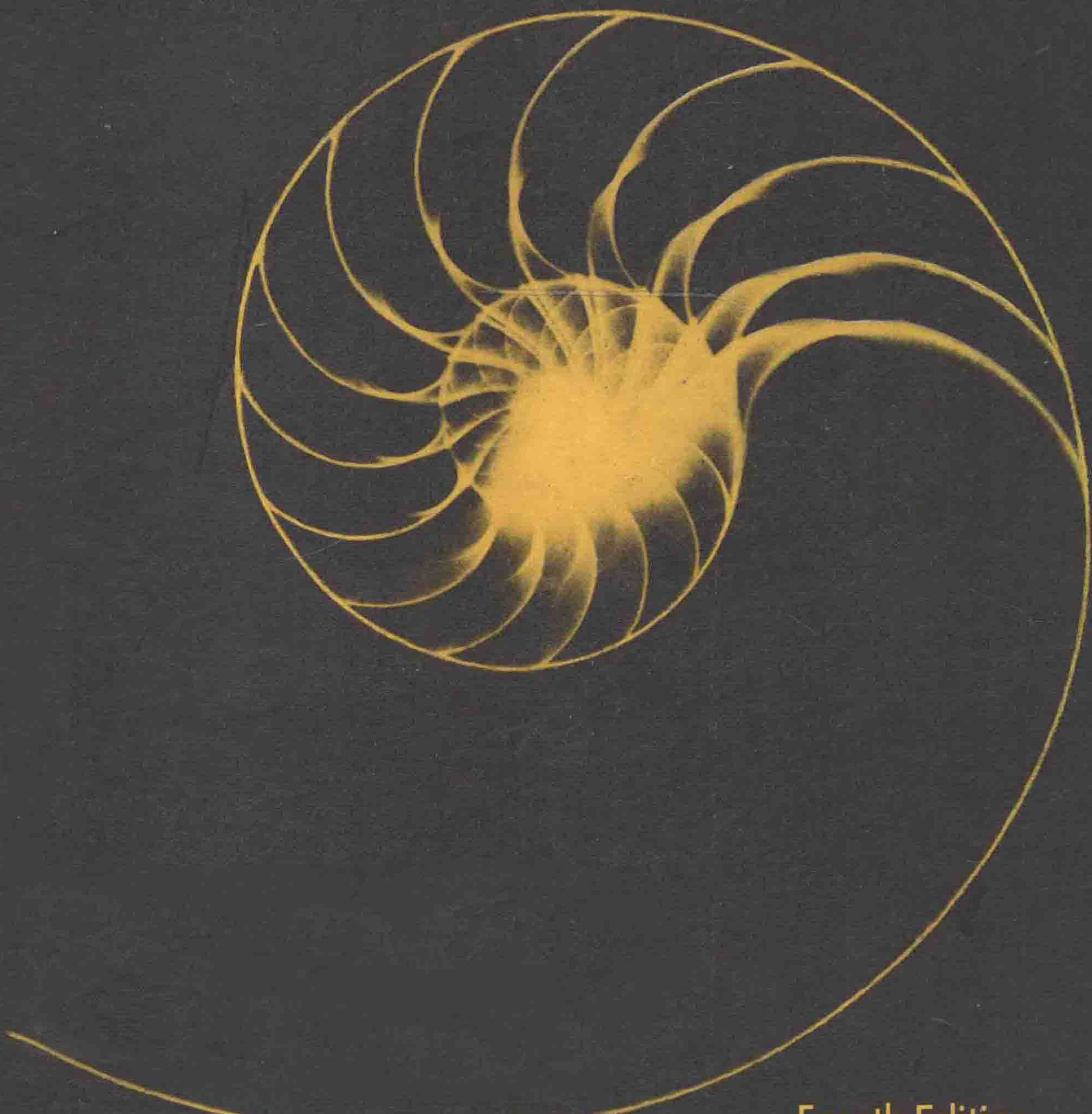
BIOLOGY

AN INQUIRY INTO THE NATURE OF LIFE

ANNOTATED TEACHER'S EDITION



Fourth Edition

TEACHER'S HANDBOOK
FOR

BIOLOGY: AN INQUIRY INTO THE NATURE OF LIFE

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PART 1
Teaching Modern Biology

A. THE WEINBERG BIOLOGY PROGRAM

1. THE PROGRAM

The program provides an integrated set of printed materials for a one-year biology course.

In many American schools the textbook is central in the program of instruction. It sets the tone of the teaching; it is the principal instructional resource; and it is used as a guide both by teachers and by students. The text is central in the Weinberg program also, but it does not stand alone. Complementary parts of the program include the following:

Annotated Teacher's Edition of textbook.
Student text, *Biology: An Inquiry into the Nature of Life.*
Biology Laboratory Manual.
Teacher's Guidebook to the Laboratory Manual.
Chapter and unit *Tests.*
Teacher's Edition of the *Tests.*
Alpha Biology Transparencies: Evolution, Cells, Microbiology, Molecular Biology, Genetics.
Action Biology, by Weinberg and Stoltze, an easy-reading, combined text and laboratory manual.

Wide use in the United States and Canada of earlier editions of *Biology: An Inquiry into the Nature of Life* indicates that the book is suitable for 60% to 70% of the 10th grade population. The lower third of the school population will find the text difficult reading. For these poorer readers, *Action Biology* is suggested.

2. ANNOTATED TEACHER'S EDITION OF TEXTBOOK

This edition includes the student text, marginal annotations to the student text, and a *Teacher's Handbook* section.

Marginal annotations to the student text include the following kinds of items:

a. Indications of BASIC (elementary) and OPTIONAL (advanced) sections of the text.

b. References to correlated lesson plans in the *Teacher's Handbook.* Lesson plans are numbered by chapter, and lettered within the chapter. Thus, the first marginal reference to a lesson plan is

See LP 1A, TH p. 19.

This means lesson plan 1A in the *Teacher's Handbook,* page 19.

c. References to correlated exercises in the *Biology Laboratory Manual.* The style of reference is:

Do Lab Ex 1, The Snail.

d. Teaching notes for each section suggest teaching procedures and student activities; call attention to highlights which should be stressed; supplement the text with additional items of information; warn about possible stumbling blocks; and give cross-references to other relevant sections.

e. Key answers to text questions. The answers are brief. Where questions invite variation in response, sample answers are supplied.

The *Teacher's Handbook* is a separate, bound-in section. Part I provides general information on biology teaching. Thoroughly experienced teachers will find here familiar material, as well as useful hints or newer methods.

This part will perhaps be most useful to the young teacher who wants to broaden his or her range of skills, as well as to the experienced teacher whose techniques may be rusty, or whose training may have been in some other field. It does not substitute for a full course in science teaching, and is therefore not adequate for a wholly inexperienced teacher. Dealing with teaching methods in general, and with specific aims, themes, and curricula in biology, it provides guidelines for using the textbook as the basis for a stimulating course in modern biology.

The sections dealing with use of materials are important in the context of the current emphasis on laboratory work in science teaching. Thus emphasis is shifting from the facts and conclusions of biological science to the methods of inquiry by which these facts are acquired. Increasingly students are being guided to use the laboratory and the classroom to conduct investigations of their own. Such investigation demands freer and more abundant use of demonstration and laboratory materials.

Part II contains teaching suggestions for each chapter in the text, including a rationale for the chapter and appropriate behavioral objectives. Detailed lesson plans cover key lessons, and additional lesson plans are included in thumbnail form. Finally, there are convenient listings of audio-visual aids. Some of the films listed may no longer be available from the suppliers listed, but may be found in film libraries.

Part III is a Directory of Suppliers, the most comprehensive yet made available to high school biology teachers. Part IV is a useful Audio-Visual Directory.

Part V is a comprehensive classified bibliography. This list, intended for the teacher, is more extensive than the student bibliographies found in the textbook, although many titles appear in both volumes.

3. STUDENT TEXT—BIOLOGY: AN INQUIRY INTO THE NATURE OF LIFE

The student edition of the text is identical to the student text part of the *Annotated Teacher's Edition.*

The textbook consists of seven units and 30 chapters. Each chapter contains from two to six divisions, indicated by letters. These major division groupings all have brief, descriptive titles. Each division contains from two to seven sections numbered in sequence within each chapter. A division contains about 1500 words, and may be assigned as one day's reading for the purpose of obtaining an overview. For careful study, the more difficult divisions will each have to be broken into several assignments.

Since the text has nationwide distribution, it contains more material than any individual teacher or individual school will want to use. While the writing is clear, vivid, and interesting, it is pitched on two levels. Difficult areas such as cell respiration, photosynthesis, and genetics are covered first, briefly, on an elementary level, then more extensively on an advanced level.

The general vocabulary is straightforward. Important technical terms are printed in *italics*. They are also listed in the *Vocabulary* at the end of each chapter, and are listed again, defined, and pronounced in the *Glossary*.

Aids to study include questions in Groups A and B at the end of each division, and in *For Thought and Discussion* at the end of each chapter. End-of-division questions serve as study guides, and can be answered by reference to the text. Group A questions are easier, Group B questions more difficult. Questions *For Thought and Discussion* generally cannot be answered directly from the text. In many cases, rather than calling for specific factual answers, they require that a problem be considered, an opinion stated and supported, or evidence evaluated. They may be assigned for written answers, or may be used as the basis for class discussion.

The illustrations, many in color, are among the strong features of this textbook. They include photographs, photomicrographs, electron micrographs, drawings, charts and diagrams, graphs, tables, and an eight-page color insert illustrating taxonomy. Photographs were selected for artistic quality as well as for content. Some were provided for this book by the scientists whose work they portray.

No illustration in the book is merely decorative. All have teaching value, and should be used for teaching. Figures are numbered in sequence within each chapter. There are frequent cross-references between text and figures. Text references to a series of lettered parts within a figure (for example, Fig. 3-15) serve as study guides: the student can go back and forth between text and figure.

4. LABORATORY MANUAL

This manual provides the biology class using the Weinberg program with a series of 75 laboratory exercises tied in with the textbook. The various exercises are listed in the *Things to Do* sections of appropriate chapters in the text. Each laboratory exercise is listed at least once, and a number are listed several times. Provision of more exercises than can normally be done within the school year gives the teacher considerable choice among them. The *Laboratory Manual* may also be used with other texts.

The format of the exercises is standardized, with each set of instructions divided into these categories:

Problem: A clear-cut problem or question to which the student is encouraged to find an answer, or several answers.

Introduction: Background information to help the student understand problem and methodology.

Materials: Listed for every part of the exercise, even though all parts may not be done.

Procedure: Broken down into steps. Many paragraphs include guiding questions. Many of the exercises include basic and extra parts. Space is provided after each procedure for note-taking if desired.

Results: Instructions here are open-ended where qualitative results are called for. Where appro priate, blank tables are given for quantitative results.

Conclusions and Discussion: Although guic questions are included in every exercise, the student is also given scope to form conclu sions and make evaluations for himself.

The *Manual* is a guide to problem-solving in the labo ratory; it is not a workbook or a laboratory "cook book." There are no blanks to be filled in by refer ence to the textbook. Rather, the exercises ar exploratory and experimental in nature. Indeed man of them are far enough off the beaten track so tha the average student cannot "look up the answer" i any book readily accessible to him. Solutions mus be found by observation and experimentation.

Yet the exercises are not "experiments" and ar not so called. They are "experimental exercises" o "laboratory activities." They take into account th difficulty, within the rigid time limitations of a schoo period, of doing a genuine experiment involving the framing and careful testing of a hypothesis. Indeed, mature scientists often do not attempt to frame such hypotheses until after a good deal of preliminary "fooling around" with the material and the general problem. All the more for a young teen-ager, good laboratory experiences often must be exploratory.

However, invitations to investigate problems in depth are extended to the student through *Extra* parts of the laboratory exercises, and through *Things to Do* in the textbook.

Exercises may be written up in several different ways. Sufficient space is provided so that laboratory notes may be taken directly in the *Manual*. Or, if the *Manual* is school property, the student should take notes in a separate, bound, laboratory notebook. The *Results* and *Conclusions and Discussion* sections provide guidance for the final report on the exercise. Whatever method is used, the teacher should give precise and definite instructions as to how exercises are to be written up.

The exercises are to be done by students individually or in small groups. Most of the basic exercises can be completed within a single 50-minute laboratory period each. They are flexible, so that sections can be eliminated, or additional optional parts added, in order to take advantage of periods of different length. In some cases the student continues at home the work begun in the school laboratory. About 20%

of the exercises extend over more than one period each.

The exercises mostly involve the study of living forms. Some call for a study of the student's own body, or freshly prepared material, or simple chemical or physiological phenomena. They are within the capacities of students of a wide range of ability. Slow pupils can be guided to parts of the exercises that they understand and can deal with, while the brighter are challenged by the more difficult and experimental aspects.

The *Manual* is designed to take into account physical and administrative difficulties in doing laboratory work. The organisms called for are readily and cheaply available. Suggestions for substitutions are included. The exercises require a minimum of preparation time, and no expensive or elaborate setups. Demands on storage space for continuing exercises are minimal.

The *Teacher's Guidebook to the Laboratory Manual* contains key answers to questions in the exercises, as well as hints on teaching them, safety precautions, and sources of special supplies.

TESTS

Standardized objective tests to accompany the textbook are available in spirit duplicator master form. A test is provided for each unit. A shorter test is provided for each chapter. There are 37 tests in all.

Test questions are predominantly multiple choice. For variety there are also matching and fill-in questions, and identification questions relating to diagrams. Some groups of multiple choice and fill-in questions relate to reading selections. Questions vary as to level of difficulty, and as to the objectives for which they test. Some questions call for recall of factual information; others call for grasp of concepts, or for application of concepts to the solution of problems.

Chapter tests comprise from 20 to 25 questions each, depending on the length of the chapter. None need take more than half an hour to administer. Each unit test comprises 50 questions; a full period should be allowed for it. Tests may be marked with the help of the key answers provided on the spirit duplicator masters.

Many questions in the *Conclusions and Discussion* sections of the *Laboratory Manual* exercises may be used for testing purposes. Questions *For Thought and Discussion* in the text may also be used, either by themselves, or with an open book. Questions in the text that have been assigned for homework may be used the next day in a quiz.

When you reproduce your own tests to supplement the printed standardized objective tests, it is good practice, after running off a set of tests, to write key answers on the stencil or master and run it off again. After administering the test, or upon returning the papers, the keyed set can then be distributed. Students will thus have available for immediate review the test questions, their own answers, and the correct answers.

B. BIOLOGY CURRICULA

1. THE AIMS OF BIOLOGY TEACHING

The professed aims of biology teaching have changed with changing times. Stress has shifted variously from an understanding of plant and animal morphology and physiology. to nature study, civic biology, health education, or basic principles of biology. Teachers have followed guidelines in the *Cardinal Principles of Secondary Education* and in the various Yearbooks of the National Society for the Study of Education. There is much current emphasis on teaching biology (and science in general) as a process of inquiry.

Stressing any preconceived single aim or group of aims has a certain degree of unreality. The aims of any subject must be multiple and flexible. In every class, however homogeneous, the students still vary widely in needs and background. A subject has meaning for an individual student only as it fills needs or satisfies drives. The real aims of a subject are those which are meaningful to the individual student, not necessarily the preconceived aims of a curriculum, a textbook, or a teacher.

The wise biology teacher does not slight any potential aim of the subject. You know that often it is the things you did not deliberately try to teach, or perhaps did not even know you were teaching, that for years afterward stick most vividly in the student's mind. An understanding of the process of scientific inquiry can be valuable to anybody. But the development of friendly familiarity with animals and plants may have equal or greater value to some youngsters.

Ability to read expository material, some skill in working with the hands, development of esthetic appreciation, or a diminution of adolescent squeamishness in handling animals, may be the most valuable product a student takes from biology class. The most cherished memory may reflect nothing that appears in the course's printed resource material.

As the biology teacher you must build your strategy to fulfill a variety of potential aims. You must be resourceful in adapting *a priori* printed aims, or your own preconceived notions, to the needs, interests, capacities, and backgrounds of the boys and girls who confront you. You can best pursue your avowed aims by indirection, making them implicit in the material you present.

2. AIMS OF WEINBERG BIOLOGY PROGRAM

The following aims are built into the Weinberg program:

a. Conceptual understanding of the main problems and generalizations of biological science. Underlying all specific problems is the general purpose of trying to understand the nature of life and of living beings. Ten subsidiary themes also run throughout the text.

b. Development of an understanding of all science as a process of inquiry, an enterprise devoted to attacking problems presented by the natural world.

Throughout the text the emphasis is on the methods by which biologists deal with the problems of nature, and the control that comes from solution of such problems.

The attitude of inquiry pervades the text. Investigations of key subjects are presented in depth, often by means of historical narratives. Topics presented in this manner include the cell theory, atomic structure, oxidation, vitamins, photosynthesis, paleontology, evolution, classification, insulin and diabetes, plant hormones, insect hormones, control of development, Mendelian genetics, biochemical and bacterial genetics, virology, biogenesis, the germ theory, and radiation biology.

The habit of inquiry is taught not alone verbally in the classroom, but even more effectively by actual experience in the laboratory. In each chapter of *Biology: An Inquiry into the Nature of Life,* the *Things to Do* section invites students to investigate concrete problems; specific references are given to help them get started. Most exercises in the *Laboratory* are guided investigations into simple problems; many of the exercises are open-ended.

c. Biology, like other subjects, has potential for teaching attitudes of good citizenship, and of civilized moral and ethical standards. The text stresses these aims, especially in discussing conservation, the careers of great biologists, and the ethical criteria that guide the scientific community.

d. Nurturing a sense of beauty also has a place in biology teaching. Chapter 30, The Human Environment, stresses esthetic appreciation of the beauty of nature. Photographs in the textbook were selected partly on the basis of their esthetic appeal.

e. Teaching English is the province of all courses in school. The style of the text sets an example of literate communication. The many essay-type questions give the student opportunities to profit from this example. In discussing and making student answers and laboratory reports, and in conducting class discussions, the teacher can keep students aware that all oral and written schoolwork constitutes training in language arts. The textbook's *Vocabulary* lists, *Glossary,* and *Index* should be utilized, as well as classroom dictionaries. Titles on the reading lists were selected for literary as well as content value, and may be used for outside reading.

f. Acquisition of biological and scientific skills has general education value. These skills may involve laboratory manipulation, careful observation, accurate record keeping, manipulation of quantitative data, or critical evaluation of evidence.

g. Acquisition of specific factual knowledge is probably not the most important aim of the biology course, but it is not to be slighted. The teacher should stress the importance of examining data critically. But in honesty and fairness, you should not leave the student with the impression that the facts, once established, are themselves of no importance. Even those facts learned by rote do have value. They may be useful in building a common fund of everyday information, in promoting good health, in providing a background for further courses in school or college, in the students' later employment, or in helping them pass examinations.

h. For the adolescent the world is opening wide. Any high school course may awaken a lifelong interest. Biology has potential for stimulating interest in nature, in biology as a science, or in possible vocations. The text contains many suggestions for nature activities. Vocational fields based on biology include agriculture, forestry, the medical professions, and biological science.

3. THEMES IN THE TEXTBOOK

BASIC THEME: Biology as an inquiry into the nature of life.

SUBSIDIARY THEMES

Theme Number	Description
1	The unity of pattern underlying the variety of life forms: plants, animals, and protists.
2	Levels of organization: macromolecules, cells, organisms, communities.
3	Adaptation to the environment.
4	Metabolism and energy flow.
5	Correlation of structure and function.
6	Homeostasis as maintenance of stability at all levels from cell to community.
7	Interdependence of organisms in a community.
8	Reproduction and genetic continuity.
9	Evolution.
10	Humankind as part of nature.

These themes are distributed throughout the book as follows:

Unit		Themes Stressed
1	LIFE This unit emphasizes cell biology: Biology as an inquiry into the nature of life. Cell structure and function. Metabolism and energy flow.	1, 2, 4
2	ORGANISMS This unit emphasizes organismal biology: Evidence for evolution. The variety of living things. The relation between structure and function. Adaptation.	1, 2, 3, 5, 9
3	MAINTENANCE Emphasizes organismal biology: the physiology of organs, organ systems, and organisms. Food as the source of energy. Metabolism. The relation between structure and function. Interdependence. Adaptation. Homeostasis.	3, 4, 5, 6, 7
4	COORDINATION Stresses various aspects of behavior: Regulation, integration, and homeostasis. Structural basis of behavior. Behavior as adaptation. Human behavior. Interdependence.	3, 5, 6, 7, 10
5	CONTINUITY This unit ties together biology on the cellular, organismal, and group levels: Reproduction and development. Genetic continuity.	2, 8

6 EVOLUTION 1, 9, 10
This unit, and the next, stress group or "skin-out" biology: Theory of evolution. The origin, nature, and history of life. Evolution of humans.

7 ECOLOGY 3, 7, 10
Stresses community biology: Adaptation. Interdependence. Disease as an ecological relationship. Humankind and nature.

4. BASIC AND OPTIONAL SECTIONS

All sections in the textbook are either BASIC or OPTIONAL. BASIC sections in general cover minimal, familiar, less difficult material. OPTIONAL sections expand on the more elementary material, and deal with newer, more advanced, more sophisticated topics. BASIC and OPTIONAL sections are marked only in the *Annotated Teachers' Edition,* not in the students' edition.

Using this listing, the teacher can readily select material adapted to the level and interest of each particular class. A class that reads BASIC sections throughout the book can follow a condensed, comprehensive, introductory course at an easy reading level, with the emphasis on traditional biology. For slower than average classes, a good plan is to use primarily the BASIC reading material, and then add to it selected OPTIONAL sections in at least a few areas.

Sequences of sections in the following listing are inclusive.

BASIC SECTIONS	OPTIONAL SECTIONS
1-1 to 1-2	1-3 to 1-8
2-1 to 2-3	2-4 to 2-6
2-7 to 2-10	2-11 to 2-15
2-16	2-17 to 2-18
3-1 to 3-15	
4-1 to 4-5	4-6
4-7	4-8 to 4-10
4-11	4-12 to 4-15
4-16	
5-1 to 5-11	5-12 to 5-14
5-15 to 5-16	5-17
5-18 to 5-19	
6-1 to 6-2	6-3 to 6-6
6-7	6-8 to 6-9
6-10 to 6-11	6-12
7-1	7-2 to 7-3
7-4	7-5
7-6 to 7-10	7-11
8-1	8-2
8-3 to 8-5	8-6
8-7 to 8-11	8-12 to 8-13
8-14	8-15 to 8-17
8-18 to 8-22	
9-1 to 9-11	9-12
9-13	9-14 to 9-16
10-1 to 10-3	10-4 to 10-10
10-11	10-12 to 10-22
11-1 to 11-2	11-3 to 11-7
11-8 to 11-14	11-15
12-1	12-2 to 12-3
12-4 to 12-11	12-12 to 12-17
13-1	13-2 to 13-5
13-6 to 13-9	13-10
13-11 to 13-13	13-14 to 13-15
14-1 to 14-2	14-3
14-4 to 14-6	14-7
14-8 to 14-11	14-12 to 14-13
15-1 to 15-2	15-3 to 15-5
15-6 to 15-11	15-12 to 15-16
15-17	15-18 to 15-20
16-1 to 16-2	16-3
16-4 to 16-5	16-6
16-7 to 16-9	16-10
16-11	16-12
16-13 to 16-15	
	17-1 to 17-9
17-10 to 17-14	17-15
18-1	18-2
18-3 to 18-5	18-6
18-7	18-8
18-9 to 18-12	18-13
19-1 to 19-2	19-3 to 19-17
20-1 to 20-5	20-6 to 20-7
20-8 to 20-9	
21-1 to 21-4	21-5 to 21-7
21-8	21-9
21-10 to 21-11	21-12
21-13 to 21-14	21-15 to 21-17
21-18 to 21-21	21-22
21-23 to 21-26	21-27 to 21-28
21-29	
22-1 to 22-7	22-8 to 22-11
22-12	22-13 to 22-19
23-1 to 23-9	23-10 to 23-13
23-14	23-15 to 23-16
24-1 to 24-8	24-9 to 24-11
25-1	25-2 to 25-5
25-6 to 25-10	25-11 to 25-14
25-15 to 25-17	25-18
26-1 to 26-4	26-5
26-6	26-7 to 26-12
27-1 to 27-4	27-5
27-6	27-7
27-8	27-9
27-10 to 27-11	27-12 to 27-15

BASIC SECTIONS			OPTIONAL SECTIONS		
28-1	to	28-2	28-3	to	28-4
28-5	to	28-6	28-7		
28-8	to	28-12	28-13	to	28-15
29-1	to	29-2	29-3	to	29-9
30-1	to	30-3	30-4		
30-5	to	30-8	30-9		
30-10	to	30-13	30-14	to	30-15
30-16			30-17		
30-18	to	30-22	30-23		
30-24	to	30-25			

C. SOME HINTS ON TEACHING BIOLOGY

1. TYPES OF LESSONS

Teaching is a personal relationship between teacher and student. It is a paradoxical relationship, in that the teacher appears to have the commanding role, yet the success of the partnership depends on the activity of the pupil. Learning is an active process; it involves a change in behavior, a reorganization of experience. Hence, no teacher ever really teaches anybody anything. Rather the teacher persuades, coaxes, stimulates, invites, or induces the student to learn. This is what is implied by the old pedagogical saws that *to educate means to draw out, not to pour in; that the good teacher uncovers a subject, rather than covers it.*

Achieving these miraculous outcomes is an art which each successful teacher masters in a very personal way. For this reason the present section talks about *hints* on teaching. We cannot lay down rules for good teaching. We can only offer suggestions which have worked well for some.

Successful biology lessons seem to take several different forms, briefly described in this section. A lesson need not conform precisely to any one of the patterns sketched below; it may be an amalgam of several different types, or a modification of one of them. Yet the following categories offer a base from which you can develop your own unique modifications.

a. The developmental lesson is the backbone of formal classroom instruction. Its aim is the solution of some concrete problem. Its method is the Socratic dialogue, in which the teacher uses questions to elicit responses, stimulate thinking, and guide the class in a collective attack on the problem. Demonstrations and visual aids help illuminate the subject. This basic lesson type is examined at length in 2 below.

b. The laboratory lesson is crucial in science teaching, because it is here that problems are dealt with experientially rather than verbally. Work in the laboratory involves doing rather than talking, putting questions to nature rather than talking about them. A laboratory lesson requires planning and direction, but the amount of latitude permitted students varies greatly. The cookbook type of laboratory exercise allows little leeway, yet it is useful for teaching skills such as chemical manipulation or use of the microscope. (See Weinberg *Laboratory Manual,* Exercise 3, The Compound Microscope.)

A more valuable type of laboratory exercise involves problem solving. The amount of guidance offered may vary. The teacher may, by means of a manual or a worksheet, set up the problem and outline a method of attacking it (Exercise 27, Chromatography of Chlorophyll). Or the teacher may present an open-ended problem and leave it to the student to devise means of dealing with it (Exercise 28, Carbon Dioxide in Photosynthesis). Students enjoy the widest latitude when they set up problems and design experiments themselves, either individually, in groups, or cooperatively with the teacher. Extra parts of exercises in the *Laboratory Manual,* and *Things to Do* in the textbook, offer many such opportunities.

c. The lecture is used extensively in college. While it is frowned on in high school, many teachers use it deliberately, surreptitiously, or unthinkingly. Primary objections to lecturing in high school are that high school teachers often are ineffective lecturers, their students do not know how to concentrate attention effectively on a lecture, and there are better ways of teaching at the high school level.

Yet the good lecture has certain values. The effective lecturer can dramatize a subject. You can place meaningful stress on important aspects: underscoring points, clearing up ambiguities, orienting the subject in the framework of the students' experience, swiftly uncovering and bringing to life a field of knowledge. A rambling talk is not a lecture. The good lecture is a structured presentation, skillfully delivered.

The good lecturer has a personality strong enough to impress the class. If you don't have such a personality, don't lecture. Stand, move about, gesture moderately. A good lecture builds a certain tension in the audience. If you relax, so will the audience. The lecture must be carefully planned and well organized. Don't read your lecture; few people can do this with effect. Lecture notes should consist of brief reminders in the form of an outline. Repeat important points. Close the lecture with a review or summary. In the words of one successful lecturer: "Tell 'em what you're going to tell 'em. Tell 'em. Then tell 'em what you told 'em!"

Prepare your class for the lecture. When possible, give an advance assignment. The more they know about the subject the more they are likely to get from the lecture. Teach the class how to take notes, systematically, in abbreviated form, without losing the thread of the lecture. Outline the lecture on the chalkboard, since many people learn better visually than aurally. Demonstrations and visual aids can be trenchant supplements to the lecture.

Oral reports by students are in essence little lectures. Treat them as such and train students to deliver them tellingly. Insist that students talk only with brief notes; "explain" their reports, not read them. Challenge the student who delivers some incomprehensible nugget of wisdom with the apology that "I don't understand it, but this is what the book said." If the reporter cannot understand the report, how can the class be expected to?

d. The recitation is a re-citation: its purpose is consolidation and mastery, rather than exploration of new material. The old-fashioned recitation in which the teacher grilled students on a prepared assignment has justifiably fallen out of favor. Nevertheless the recitation still has its place. It may be a socialized discussion, a relatively unstructured inquiry into questions such as those in *For Thought and Discussion*. Guidance by the teacher keeps the discussion coherent.

The recitation may be devoted to review. A good review is more than a mechanical reiteration. Material is presented in a new light, re-cited from a new point of view. Drill, which is relatively mechanical, also has its place in a recitation lesson.

e. The film lesson is unique in that the film, a carefully structured production, usually consumes a major part of the period, while the teacher retreats into the background. Nevertheless the film should be taught, not just shown. The presentation must be planned for, motivated, and used to solve a problem. Standards that govern the developmental lesson also in large part apply to the film lesson (see 2, below).

f. The reading lesson plays an important role in science teaching, in spite of the reluctance of some teachers to "waste time" on it. Reading is a vital skill in contemporary life, yet many high school students read poorly. If you, the teacher, think it is important for students to use a dictionary in studying the textbook, or to learn to make use of the index and other study aids, convince the students of your concern by taking class time to teach these skills. The reading lesson may take the form of supervised study of the textbook.

Can you, in one brief statement, summarize the paragraph just above? Many students lack this ability. Show them how to read for meaning. Show them the difference between detailed study, reading, and scanning. Use the textbook to teach them how to study.

g. Field trips may be half-day excursions to nature sanctuaries, museums, or research laboratories; or they may be brief walks during the class period to examine plant communities at the curb or in a corner of the school campus. In either case the trip should be planned, and should focus on an explicit problem. A trip without aim can easily degenerate into a picnic or an exercise in discipline.

Planning for an extensive trip must cover such administrative items as obtaining parental consent, transportation, time schedule for the trip, guides, meal arrangements, supervision, rendezvous, and necessary head counts. Time the trip to end before interest flags and the students become exhausted. Follow up with reports, analyses, and discussion.

h. A test is a lesson. For the many uses to which it may be put, see A5 above. Do not neglect open book tests, and tests for review and diagnosis. Teach your students how to take tests. A good device for this purpose is the sample test which is marked but not collected or recorded. A useful procedure that adds variety is to make up some tests from questions submitted by students.

i. Individualized instruction has developed extensively in recent years as an alternative teaching design to class instruction. The Weinberg text and laboratory manual have proven adaptable in programs that use several of the following modes:

1. Team teaching combines several normal size classes under a group of teachers, who may have equivalent status or who may instead consist of a highly skilled master teacher and several junior instructors. The teaching methods are not unique. However, at different times the classes may be taught separately; or they may be combined into a single large group for lectures, AV presentations, tests, and the like. Other variations in group size are possible, permitting some members of the team to deal with small groups or even with individual students.

The system is designed to take advantage of the differing talents of the various team members. It loses much of its value when it breaks down into a today-you-lecture-tomorrow-I-lecture procedure.

2. Learning packets are similar to the contracts of two generations ago. Basically they are self-contained modules each focusing on a single concept, designed for independent study, and capable of being combined into continuous progress or ungraded curricula. A packet contains as a minimum a pre-test, behavioral objectives, a study guide, and a post-test. Students work at their own pace and take the tests when they are ready for them.

In the audio-tutorial system, students work in carrels that are stocked with textbooks, study guides, self-tests, AV media, demonstrations, and set-ups for individual experiments.

In these, as in other individualized instructional modes, there is likely to be a loss of the interaction among students which is a valuable component of good class teaching. This handicap is sometimes dealt with by combining some independent study with some class instruction.

3. Programmed instruction is not new, but in the 1960's it expanded greatly under the influence of B. F. Skinner's work in operant conditioning. Half a dozen large corporations developed teaching machines, and programs to put into the machines.

A program consists of a carefully sequenced series of steps to which the student responds one step at a time. An incorrect response is immediately corrected; a correct response is reinforced or rewarded, often by means of a click or a flashing light. The machine at which the student works is essentially a projector or a small computer. But programs may also be incorporated into tapes, cards, or books.

Programs may be linear or branched. A linear program is fixed; after correction of an incorrect response, the student continues along the predetermined course. A branched program utilizes feedback.

A series of correct responses may lead to skipping some steps. An incorrect response may lead into a branch or remedial loop. The instructional mode in programming is a Socratic dialogue between the student and the program. The fact that students proceed at their own pace is a strength of the method.

Computer aided instruction (CAI) depends on student terminals connected to a large central computer. More flexible programs are possible than in the relatively rigid teaching machines. Computers, teaching machines, and programs certainly allow learning to occur; yet the systems are far from fulfilling their early promise. The corporations that jumped into the field have largely backed off. Two problems have been the initial expense of the systems, and the paucity of software. A third factor has been the reliance on engineers and psychologists to set up the systems, and the slighting of the perhaps humbler expertise of experienced classroom teachers.

2. TEACHING THE DEVELOPMENTAL LESSON

a. Lesson planning applies to every type of lesson. An airplane pilot files a flight plan before every takeoff; the successful salesman plans the approach to a customer; and the successful teacher carefully plans each lesson. The lesson plan provides the assurance that is so valuable in the classroom, and it helps give direction to the lesson.

Old hands in school may seem to teach off the top of their heads, without any formulated plan. This impression usually is misleading. Long experience may enable them to construct a plan quickly. But rarely do effective teachers begin a lesson without a clear conception of where they want to lead the class, and of the tactics they intend using to get there. Young teachers do their best planning at leisure, and on paper. Having written and studied the plan, they need not take it to class. A few notes of reminder will do as well, and may lend spontaneity to the teaching.

After the lesson, write a critique, noting things that went well or badly in class, and modifications you would now make. File the plan for next year—but don't teach from it next year! Use it as the basis for preparing a new plan. Students are quick to note, to resent, and to gossip about, teachers who teach from dogeared notes of years gone by.

Following is a suitable outline for the lesson plan:

- Aim.
- Motivation.
- Review.
- Development, including Content and Procedures.
- Materials: list in the plan, and order or prepare beforehand, all materials that must be at hand during the lesson.
- Assignment.
- Windup.

b. The aim ideally unifies the lesson by presenting a problem. The purpose of the lesson is to try to solve the problem. A problem, in the present context, is not only clear and interesting to the students, it is one they can identify with because it relates to their lives. It has meaning; it is immediate and significant.

For teaching purposes, the following artificial or labored questions are not valid problems:

How do we breathe?
What are the needs of cells?
What is the value of a balanced diet?

Better, because they focus more sharply on the interests of the students, are these problem questions:

Why can you not hold your breath indefinitely?
How can twins be of different sex?
How do racing pigeons find their way home?

Better still are problems which arise from demonstrations:

DEMONSTRATION: Use diastase to digest completely a thin suspension of starch.
PROBLEM: Where did the starch go?

DEMONSTRATION: Fossil.
PROBLEM: How did this fish get into the rock?

Note that a usable problem is concrete, it is limited in scope and difficulty so that it can be examined within the limits of class time, it arouses quick interest, and it has biological implications beyond that of a mere puzzle. A good problem is one that youngsters accept as vital and significant to themselves. Their imagination is as insatiable as their appetite, and life on Mars or fossils of the past can be as absorbing and immediate as the approaching lunch hour.

c. How does the teacher focus adolescent energies on the aim of the lesson? *Motivation* is used to arouse interest. But a more basic function of the motivation is to guide the student to accept the teacher's aim as his own.

A good motivation is simple, brief, ingenious, and natural; not labored, drawn-out, or far-fetched. It is socially desirable and suited to the age and maturity of the class. It may be a story (preferably one relating to the personal experience of teacher or pupils), a question, device, gimmick, or demonstration. Ideally, it leads directly and quickly to the aim. A lesson on enzymes may be motivated by stirring a few drops of blood in a beaker of hydrogen peroxide. The froth of oxygen that results is exciting. The demonstration immediately evokes the aim: Why did the blood release the oxygen from hydrogen peroxide?

d. The purpose of the review is to insure an adequate apperceptive base for the new lesson. It connects the day's work with previous knowledge, pupil experience, current events, or other subject areas. Preferably it stimulates reflective thinking about the old material rather than mechanical reiteration of it.

e. The development is the heart of the lesson. It is the attack on the aim or problem. The attack is carried on mainly by questioning, but also by telling, showing, and doing. In writing the plan for the development, a good practice is to list in parallel columns the *content or concepts to be dealt with, pupil and teacher procedures, and estimated time allotments.* Select content that is significant, relevant to the aim, and appropriate to the age and ability level of the class. Emphasize the high spots. Lead into them with renewed motivation, and underline them with medial summaries.

Although teacher activities guide the lesson, the crux of it is *pupil activity*. Plan for pupil activity, and allow time for it. A laboratory or reading lesson consists primarily of pupil activity. But provide also for active student participation in a developmental lesson. Students answer questions, criticize each other, and ask questions of their own. They participate in class or small group discussions. Students may assist in demonstrations. They take notes, and time must be allowed for this. Indeed, your plan should foresee and provide time for a variety of activities during the lesson.

f. The assignment grows out of the lesson. It may call for review and reinforcement of the day's lesson; it may be advance work; or it may provide for enriched and individualized work. It should be challenging, interesting, and well motivated.

g. The windup of the lesson clinches the day's learning activities. It may involve an oral or written summary by teacher or pupil. The summary should refer to the aim, and should either review explicitly how the problem was solved, or should state that it is still open and there is more to be learned in this area. In either case, leave the students with some feeling of progress and accomplishment.

3. THE ART OF QUESTIONING

a. Questions bulk large in a developmental lesson and play a role in all types of teaching. The responses they elicit are designed to start a student thinking, and to guide the class in a joint attack on a problem. Questions are not used to grill the students, nor to extract from them information which they do not have. Questions are invitations, not punishments. Each key question crystallizes the thought: "What information do we need at this point in order to go on?"

Write specific key or pivotal questions in your lesson plan. Key questions provoke thoughtful and discursive responses. They begin usually with *How? Why? Explain, Compare;* sometimes with *What?* or *Where?* They are clear, definite, interesting, and concise. A logical sequence of questions helps to focus the lesson.

b. Avoid certain types of questions:

Vague, indefinite, or ambiguous questions, as "What about chromosomes?" (Well, what about them?)

Questions calling for one-word answers, as "What color results from the starch test?" (I don't have to think, only remember.)

Categorical questions, as "Is protein digested in the stomach?" (I don't know, but I have a 50-50 chance of being right.)

Double, multiple, involved, or overladen questions, as "Who was Darwin, tell about his life, and explain his theory." (Where do I begin?)

Leading or elliptical questions, as "The structure with the same name as the central part of an atom, that controls cell reproduction, is what?" (Is this a biology class or a guessing game?)

Guessing questions, as "How do you think this gadget works?" (I haven't the vaguest idea. Why not tell us and then ask us to apply the information?)

Echo questions, as "This is called a centromere. What is this called?" (Do you think we are babies?)

Questions calling for unison or chorus answers, as "How is starch digested, class?" (This if fun! It's a shouting contest!)

Repeated questions. (I wish you would stop talking and give me a chance to answer.)

Rapid fire questions. (Too fast for me! I give up!)

c. How you deal with responses is as important as the questions themselves. Listen to the students. Encourage them with a word of appreciation: "Good!" "That's a thoughtful answer," "An interesting idea." Do not repeat answers; train the students to listen to each other. Insure that responses are audible to the whole class.

Beyond these mechanics, deal with student responses as the conceptual raw material of the development. Evaluate them. Ask other students to evaluate them. Appraise a wrong answer and try to get the student to revise his or her thinking. Milk a correct or thoughtful answer: probe further to extend the thought beyond the point where the respondent left it.

d. An interesting lesson provokes student questions. How do you deal with them? One effective way is to throw the question back to the class for examination. But if the class is unable to make progress, and your knowledge can be helpful, do not hesitate to contribute to the discussion. There is no particular virtue in extracting information from a student which the teacher can supply more readily. The purpose of eliciting responses is to get students to participate and to think; the quizzing itself is of little value.

In conveying information to the class, be clear, interesting, and concise. Talk at the students' level. Make sure your information is correct. If you fall into error and a student corrects you, accept the correction with good grace and with a word of praise for the alert student. Talk to the class with a sense of humor and a sense of drama.

4. DEMONSTRATIONS

a. In the science classroom, the developmental lesson often examines the actual demonstration of some natural phenomenon.

When and why demonstrate? Demonstrate to motivate and to evoke interest. Demonstrate to present a problem and to invite discussion. Demonstrate to collect data needed to check a hypothesis. Demonstrate to illustrate a concept concretely and visually, and to save words. Because most students respond to action better than to words, demonstrate to bring life into your biology class. Use demonstrations for review, for testing, or to clarify an assignment. Demonstrate when the class needs a change of pace.

b. What do you demonstrate? Following is a useful order of priorities.

Use live specimens before preserved or dead ones. Children are interested in living things. Use this interest to bring animation into the class. Remember that biology is the science of living things.

Use fresh specimens before preserved. If you have to use dead material, try to get it fresh. Sometimes you must resort to preserved material, but this is often unattractive or repulsive to children. Woods and gardens; the local butcher, grocer, or fish market; streams, lakes, and the seashore—from all these sources biological material may be readily obtained, used for demonstration, and quickly discarded.

Plastic-embedded specimens are an attractive type of preserved material. They do not decolorize as specimens in alcohol-filled museum jars often do, and they do not have the unpleasant odor and appearance of formalin-pickled specimens. (For laboratory dissections you sometimes must depend on formalin-preserved specimens; however, such dissections have a minimal place in the Weinberg *Laboratory Manual*.)

Use large demonstrations in preference to small ones. To be useful, a demonstration must be visible, even to the student in the last row. Demonstrate a chemical test in a large cylinder rather than a small test tube. Elevate and illuminate the demonstration if necessary.

Use demonstrations that show action, before motionless ones. A working model of the heart, through which "blood" flows, is more striking than an anatomical model. Use actual objects before representations of them.

Use demonstrations in which students can participate in preference to hands-off ones. Simple, homemade setups which pupils can manipulate are preferable to elaborate, awe-inspiring pieces of technical equipment. Concentrate on the problem rather than on gadgetry.

Since learning is an active process, the more students can do, the better the chance that they will learn. Let Mary come to the demonstration table and hold the test tube in the bunsen flame in front of the class. (Susie is thinking: Maybe I can do the next test.)

c. How do you demonstrate? Choose demonstrations that focus on the aim of the lesson. Do not let the demonstration become a show. Keep it simple so that students can follow it, and so that it moves the lesson forward. Avoid the "Gosh, isn't science wonderful!" reaction.

Prepare carefully, and test each demonstration beforehand. Then if something goes wrong in class, don't get rattled. The demonstration is never wrong, only our interpretation of it. Get the class to help you explain whatever it was that actually happened. Don't bother to apologize and explain what should have happened. Show this the next day, *after* you have found the gremlin.

Keep the demonstration table neat, orderly, spare, and artful. Have no distracting hardware on it. Take a hint from the successful storekeeper: dress up your exhibit and you will do a better selling job.

Dramatize your demonstration. Keep it out of sight until it is needed. Then bring it out from under the table. Or, at the psychological moment, take the key item out of your pocket with a flourish.

Be conscious of safety. Check apparatus for safe hookups. Use a safety-glass shield when necessary; or empty the front rows.

Conserve equipment. Demonstrate with deliberation and reduce breakage; let nothing rush you. As you finish with items, place them in a cleanup tray.

At first sight of a demonstration, do not plunge headlong into manipulation. Give the students time to familiarize themselves with it. Point out general features before going into details.

Use the demonstration to teach the method of inquiry. Gather evidence with it, or test hypotheses. Working with a demonstration can be a group exercise in critical thinking.

Teach the students to observe. Call attention to important aspects, preferably by means of questions. Did the class see all there was to see?

Support the demonstration with other audio-visual aids. Place a diagram of the setup on the chalkboard. Use multiple sense appeal. If a radioisotope can sound a buzzer as well as flash on an oscilloscope, let it do both.

Keep demonstrations open-ended. Invite suggestions for variations. With the class, develop demonstrations to test growing hypotheses.

Do not curb your own enthusiasm for an elegant demonstration. Your thrill will carry over to the class.

5. AUDIO-VISUAL MEDIA

a. Audio-visual devices play a large role in American life. Children, teen-agers, and adults depend on radio and television for hours of daily entertainment. Business uses these media not only for advertising, but as training aids, and for internal communications of all sorts. Television appearances are believed to have decided several elections.

Audio-visual methodology also has an assured place in the schools, but rarely do teachers develop its full potential. You can enrich your teaching by utilizing and exploiting the AV media listed below.

In any utilization of AV media three types of problems arise:

1. *Selection of type of device and of material.* Are these suitable to the aim of the lesson? Appropriate to the class? Likely to be effective? Should several media be used jointly, for example, lantern slide projector and tape recorder, overhead projector and mimeographed copies of the transparencies, model and chalkboard? Are the materials sufficient in quantity? Excessive?
2. *Mechanics of presentation.* Are the projector lamp powerful enough and the room dark enough for good visibility of projected materials? Are the acoustics good enough for audio materials? Can I operate the equipment competently? Or is there a trained student operator? Is the equipment in good repair? Have I arranged for conservation of the equipment? For safety of the students? Do I have a substitute lesson plan in case the equipment fails?

3. *Pedagogy*. Have I previewed the material? Prepared myself adequately for the lesson? Have I prepared the class suitably? Will the presentation be a lesson and not a show? Will there be appropriate follow-up? Have I taken advantage of the flexibility of AV media, adapting it to small group or individual use?

b. The chalkboard is the familiar blackboard, which nowadays is likely to be made of green glass rather than black slate. The "chalk" sticks are now lithium carbonate. Despite these superficial changes, the chalkboard remains the teacher's most useful AV tool.

Keep in mind always that the chalkboard is a visual device, and material placed on it must be highly visible to be useful. Use soft chalk; if it squeaks, hold it at a sharper angle to the board. Write or print with large, bold, clear, neat, legible letters; do not scribble. Be alert to visibility from the back and sides of the room. Use only the top half, not the entire board down to the chalk trough. Illuminate the board, with ceiling lights if necessary. Be careful to eliminate glare reflected from the windows. Make diagrams and drawings neatly and with care. Title and label them. Colored chalks add to their effectiveness. But use color with discrimination if you want the class to copy your diagrams; students are not likely to have available the same array of colors that you have.

As you work at the board, talk to the class, not to the board; and don't stand in front of material that students must copy. Making these precautions routine will increase the effectiveness with which you use the chalkboard as a teaching medium.

c. Films in schools are primarily 16 mm sound films, though 8 mm films in various formats are coming into wider use. These materials are the classroom's window on the world. Films can show personalities, rare objects, unique and difficult demonstrations, distant scenes, and dramatic events that it would be otherwise impossible to bring into the classroom. Films at their best have an immediacy, a versatility, a capacity to concentrate interest that give them a vital dimension unique in teaching materials.

Since large numbers of films are available, of varying quality, selection may be a problem. Films may be purchased, rented, or borrowed. Film libraries, from which films may be borrowed at no charge except postage, are available in all parts of the country. Kinescopes, films made from television programs, are included in many libraries. For help in locating films and film libraries, see the *Audio-Visual Directory* in this *Handbook*. Part II, below recommends specific films related to each chapter in the textbook.

The mechanics of the presentation are important; if projection is not carried on smoothly and without distraction, the value of the films is lost. Projectors should be bought carefully; if possible, after tryout in the school situation. Provision for adequate maintenance and repair service is as important as the original purchase. Buy adequate stocks of accessories, such as screens, splicers, reels, film storage cabinets, rewind sets, and spare lamps.

Who is to do the projection? If you, as the teacher, are also the projectionist, take the time to learn how to operate the equipment expertly. This involves more than threading the film, turning the switches, and rewinding. Be alert to the quality of projection, including such factors as sharp focus and framing; optimum size of picture; volume, tone, and quality of sound, and correct size of film loop to give accurate synchronization. Be prepared to do routine classroom maintenance such as correctly rewinding a reversed reel, splicing torn film, cleaning the film gate and lens, or replacing a burnt out projection lamp, exciter lamp, or fuse. A student projectionist often can do a better job than the teacher, since the student can concentrate on running the projector and is not concerned with the class.

Be resourceful in your use of films. When using film as the body of the lesson, plan the showing as a real lesson. An effective motivation and a clear aim are essential. Prepare the class beforehand for difficulties in the film. A brief chalkboard outline or a list of terms and concepts may be useful.

If it is feasible, you can heighten the dramatic impact of the film by adjusting the shades, threading and focusing the projector, and making other physical arrangements, before the class assembles. When the class is motivated, ready, and attentive, throw the switch and start projection. The film itself constitutes the presentation; it should furnish the evidence around which all effective science teaching revolves.

d. Film loops are a relatively new and extremely useful medium. They are continuous loops of film, silent or sound, 8 or 16 mm (the 8 mm size is more common), which are mounted in plastic cartridges. No threading or rewinding is required, and setting up the projector is a fast and simple process. To start projection, the cartridge is inserted and the switch is thrown. When the end is reached, the film loop is instantly available for reshowing. The projector has a short throw so that it may be used for rear projection, with projector and screen placed together on a table in front of the room.

Film loops in general cover single concepts, and usually run $3\frac{1}{2}$ to 15 minutes. Their versatility makes them suitable not only for class use, but also for viewing and study by individual students. They are not rented but are for sale only. For this reason, and also because listings are growing rapidly, this handbook does not give individual titles. The *Audio-Visual Directory* lists the principal producers.

There are various makes of projectors, not all of which are compatible, that is, one projector may not take film suitable for another. Before buying a projector, therefore, it would be well to check the "software" available for it. Note that Super 8 film gives a larger and brighter image than Standard 8.

You can make your own film loops from homemade 8 mm films. Suppliers will mount your film, or will sell do-it-yourself plastic cartridges.

e. Filmstrips are motionless compilations of photographs, drawings, and captions, and are usually in color. They are invariably sold rather than rented or loaned; some are available free. They come in 35 mm width. Two-way projectors may be used either for filmstrips or for 2 × 2 inch slides. Some filmstrips, including many produced in Europe, come in a double-frame format. These double-frame strips may be shown with certain projectors that have a special aperture plate as an easily inserted accessory.

Filmstrips are adapted for showing logical sequences, or step-by-step development where motion is not essential. They can be used for testing or review by omitting the captions. Commercial filmstrips are often much too long, sometimes running to as many as 75–80 frames. About 20 frames is the maximum that can be shown effectively, with discussion, at one time. The impact may be lost if the same filmstrip is continued the next day; better to use just part of a long filmstrip, selectively.

f. The overhead projector is a relatively new visual aid which has come into wide use because of its flexibility and versatility. Principally it projects transparencies, also called projectuals or visuals. These are commercially available from many producers. You can also easily prepare them yourself, either beforehand or right in class. Advantages of the projector are that it is easy to operate, it may be used in a lighted room, and the operator faces the class.

Transparencies may be in black and white or in color. Commercially prepared visuals often are very detailed. A useful technique is to cover all but one corner, and disclose additional parts of the visual progressively. Transparent overlays hinged to the basic visual also add information progressively. Swiftly flipping a series of overlays produces a kind of animation.

The Weinberg *Alpha Biology Transparencies* vary somewhat from common commercial practice. While the usual size is 8 × 10 inches, the *Alpha Biology* visuals are $10\frac{1}{2} \times 10\frac{1}{2}$ to take advantage of the full area of the projector stage. Instead of being hinged, the transparencies in each unit are separate to permit greater flexibility. A positioning bar insures accurate registration of overlays. Various commercial series have different combinations of these features.

The projector can substitute for the chalkboard, with grease pencils (china marking pencils) or brush pens (magic markers) taking the place of chalk. For this use, rolls of thin plastic film which attach to the projector may be better adapted than the transparencies. Brush pen marks may quickly be erased either with water or with organic solvents, depending on the brand.

Overhead projection is well adapted to multimedial use. Tests and other materials can be marked in view of the class while students compare their own papers with these standards. Students use the projector as readily as the chalkboard.

Permanent home-made visuals may be prepared before-hand either very simply or quite elaborately. Photocopiers and duplicators make almost unlimited possibilities available for reproducing graphic materials.

You can increase the effectiveness of your visuals by adhering to these standards: Concentrate on one basic point in each visual. Limit the number that you plan to project during any one period. In captions and copy, make lettering large. In visuals that consist largely of copy, limit wordage to 10 lines or less, with from 3 to 7 words on a line.

The overhead projector may also be used for direct demonstration of procedures in which the objects are transparent, or observable in silhouette. Blood typing and polarization may be shown on the illuminated stage.

g. Lantern slides are available in two sizes: $3\frac{1}{4} \times 4$ inches, and 2 × 2 (or $2\frac{1}{4} \times 2\frac{1}{4}$) inches. Like filmstrips and overhead transparencies, they are basically a means of projecting a still picture in view of the whole class. They are less flexible and versatile than transparencies, but more so than filmstrips, since you can select and arrange slides as you wish.

Blackboard or daylight slides are a new and useful medium. They are similar to 2 × 2 lantern slides but give a much brighter image and can be projected on the chalkboard in a lighted room. Chalk markings can be added.

For the small slides, as well as for filmstrips, automatic or semi-automatic projectors are available. Changing is effected automatically at pre-set intervals, or by hand with a remote control switch. Use of an automatic slide or filmstrip projector in conjunction with a tape recorder gives an impressive, dual-medium effect.

Many thousands of slides are available commercially. Nevertheless the choice of slides suitable for a modern biology course as exemplified by *Biology: An Inquiry into the Nature of Life* is still rather limited.

Supplies and instructions for preparing homemade slides are readily available, however, from many sources. Your own mounted Kodachromes may be very useful. A relatively new technique is to prepare a drawing or other graphic material of approximately 6 × 8 inches, and then photograph it with a Polaroid camera. Use a copying lens, copying stand, and new type process-film on transparent base. There are two varieties of this film, one suitable for reproducing photographs, the other for text and line drawings.

h. Microprojection is a procedure by which ordinary microscope slides are magnified and projected for class viewing. The principal difficulty is that of obtaining enough light for a good image, especially at high magnifications. Satisfactory microprojectors typically use carbon arc lamps as light sources; a well-darkened room is essential.

Another relatively new device is the slidestrip, which consists of biological specimens mounted in series on strips of film. The mounts may be viewed with a filmstrip projector or through a microscope.

There has been extensive debate over the relative pedagogical values of class study of projected material, as compared to individual microscope study. Where the purpose is simply to illustrate a discussion point, there is no question of the value of projection. But when the process of inquiry is emphasized, projection is no substitution for individual microscope work in which students do their own searching and gather their own evidence.

i. Charts, models, mock-ups, magnet boards, and flannel boards are grouped together because, as used in teaching, they can be manipulated to a greater extent than other visual aids. Thus they resemble demonstrations.

In choosing these materials, make sure that they are large enough and uncluttered enough to be meaningful to the viewer. (Many commercial charts contain far too much material.) Give the students time to become oriented to the device you are showing them.

Assist this orientation by means of questions and explanations. What is this device designed to show? Is it a faithful reproduction, or is it diagrammatic? What is the real size of the object represented? What do the symbols mean?

In class, use the visual aid to furnish evidence or to illustrate the discussion. Your questions can clarify the points illustrated. To insure that the evidence presented is visible to the class, do not get in the way of the visual aid, or allow students to do so; stand beside it and use a pointer.

Involve students in the demonstration. Send them to the chart to illustrate their contributions. Have them take apart the model, manipulate the cutouts on the magnet board. Be sure also to give them time to take necessary notes.

Dramatize the use of these visual aids by keeping them out of sight until the psychological moment. When the moment is timely, bring the model up from under the demonstration table. Remove some parts, or keep them covered. With a flourish, pull the string on the rolled-up chart hanging on the wall. Hang the bare flannel board or magnet board beforehand, but do not reveal the cutouts until they are needed.

j. The opaque projector is used to project three-dimensional objects, flat pictures, or pages from a book. It is probably the least effective of the various types of projectors. Its principal value is that it saves time when you want to quickly show a variety of small pictures or opaque objects.

k. The bulletin board and exhibit case not only contribute to the biological atmosphere of the classroom; they can also serve specific teaching purposes.

Bulletin boards may be used for notices, current science news, students' written work, or charts and pictures relevant to the topic being studied. Students often eagerly participate in maintaining bulletin boards; but their interest will lag if you do not also show interest.

Exhibit cases may hold demonstration material, book exhibits, large photographs, student projects or classwork, or current laboratory setups. In many areas loan exhibits may be borrowed from local or state natural history museums. As with bulletin boards, dress up your exhibits, label them informatively, and keep them current. Take a leaf from window dressers in downtown stores: dramatize your exhibits and keep them sparse. A few things well highlighted are far more effective than a cluttered display with no object on which the eye can rest.

A moderately extensive display on such a subject as plant or animal classification can be used for a kind of indoor field trip.

l. Educational television has enormous potential, as evidenced by the success of *Sesame Street*, and by the heavy viewing schedules of most children. Extensive evaluations of the medium have been undertaken in Maryland, Florida, American Samoa, and elsewhere. In 1974 a telecast program by satellite was initiated in the Rocky Mountain region, aimed primarily at rural schools.

How to use this powerful tool most effectively in the classroom is still a baffling question, however. One problem is the high cost of good TV programs. Another is scheduling, when the class and the telecast do not coincide. Videotaping the telecast for later rebroadcast on closed circuit TV is one way around the latter problem.

A more fundamental question involves the educational role of television in the biology class. It is argued that children learn with TV as well as they do with a teacher, and that TV often produces greater motivation and concentration. Yet the author, who has been a TV teacher, feels that the values of television are far overshadowed by the give and take of a class discussion led by a competent teacher, or by the physical, intellectual, and emotional experience that a student gets in a good laboratory exercise.

Television is probably most valuable as a supplement to present methods. One way of using it is to recommend outside viewing of biology programs on commercial TV stations, or on the National Educational Television Network.

m. Audio media include radio, tape recorder, and record player. Recorded material that is available includes talks by scientists, and records of bird songs and other animal sounds. Playback by tape recorder is a great help in training students to give reports. Videotape may be used for the same purpose.

n. Resource centers, also called media centers or instructional materials centers, are a must in a school which attempts to individualize instruction. At a minimum the centers contain books; AV machines, including TV, videotape, and audiotape players; AV software; and photocopy and reproduction equipment. A center operates either as an adjunct to the school library or independently, and should be available to students throughout the day. Full-time staffing, whether by teachers, librarians, or paraprofessionals, as well as personnel and facilities for servicing the equipment, are essential.

D. THE TEACHING ENVIRONMENT

1. STANDARDS FOR TEACHING BIOLOGY

In 1969 the Biostandards Committee of the National Association of Biology Teachers issued a series of guidelines for standards in biology teaching.* This section draws on the NABT guidelines.

* NABT *News and Views*, Vol. 13, No. 5, Oct. 1969, p. 5.

2. THE TEACHING LOAD

The teaching load must be restricted in order to provide for efficient instruction, adequate pupil-teacher contact, proper care for student safety, and sufficient preparation by the teacher.

a. Since modern biology teaching is based on a laboratory approach, all students should have the opportunity to participate fully in laboratory experiences.

b. Class size in laboratory sections should be limited to a maximum of 24–28 students. The standard teaching load should be four classes for a maximum of 96–112 students.

c. Minimum class time in biology should be 275 minutes per week.

d. The teacher should have adequate time, amounting to approximately one-third of the teaching day, for preparation of laboratory and class materials. This necessary work includes pedagogical preparation; design and evaluation of tests and assignments; preparing and maintaining demonstration, laboratory, and audio-visual equipment; and ordering supplies.

e. Provision should be made for employing and supervising paraprofessional technicians and student aides.

3. FACILITIES FOR BIOLOGY INSTRUCTION

a. Room arrangements must fulfill several different needs:

A desk and seat grouping for class discussion.
Provision for use of audio-visual media.
Laboratory facilities.
Special-purpose facilities.

These needs may be met in several different ways. First, an all-purpose room may take care of all or most of them; this general classroom may be used for other sciences as well as for biology. Second, the classroom and laboratory may be separate rooms. Third, biology facilities may be included in a science suite consisting of a number of general and special-purpose rooms equipped to handle several different sciences.

A special projection room may be useful for large-group showings or for special events. But for regular use of audio-visual materials with a single class, the usual classroom setting is a more suitable environment for a productive lesson.

b. The biology classroom, whether it is a separate room or is combined with the laboratory, should provide for class discussion and for use of audio-visual media. It will need the following equipment:

Grouping of desks and chairs.
Chalkboard, at least 15 feet. Sliding chalkboards will provide more writing surface within a limited wallspace.
Tackboard, at least 6 feet. Additional tackboard may be mounted above the chalkboard.
Hooks or racks for hanging charts.
Window-darkening equipment to permit projection.
A screen: hanging, standing, or rear projection
One or more convenience outlets accessible to the audio-visual equipment. Permanently mounted speakers with built-in wiring might be considered.
Teacher's desk.
Demonstration table, either built-in or movable type. It should provide these facilities, if possible: hot and cold water, waste water disposal connected to building plumbing lines, gas, AC and DC outlets, vacuum, compressed air, overhead lighting, garbage disposal, flush bench rod supports, drawers for permanent standard stock of demonstration apparatus and supplies, large under-the-surface space for temporary storage of models and demonstrations.
Storage cabinets, shelves, and cupboards.
Window shelves and other display facilities.
Safety equipment including first-aid cabinet, fire extinguishers, fire blanket, master shutoffs for gas and electricity.

For safety reasons, the demonstration table should not be on a platform.

Some of the special-purpose facilities listed in (d) below may also be in the classroom rather than in separate rooms.

c. The laboratory is a focal center of instruction in a course which emphasizes biology as an inquiry into the nature of life. The laboratory should be a well-equipped, safe, comfortable, pleasant workroom. It may be combined with the classroom in a dual-purpose facility, or it may be a separate room. Minimum provision for laboratory floor space should be 35 square feet per student.

Each student station should be equipped, at a minimum, with gas, an AC outlet, flush bench rod supports, a shelf or cupboard for storing books, secure storage space for laboratory supplies and for setups in continuing use, and access to cold water and a small sink that drains into the school waste lines. Where these utilities do not exist and cannot be permanently installed, substitutes may be improvised. Bottled gas or portable propane burners may be used in place of city gas. Electric lines may be stripped in, or flexible cable can provide convenience outlets. Water can be supplied from overhead tanks, and portable tubs may replace sinks.

Students should also have access to auxiliary work stations with the following equipment: balance; distribution center for supplies and reagents (see 4 below); deep sink for cleanup, with hot water, and at least one garbage disposal unit in the room; fume hood with good venting; major pieces of equipment (see e. below).

The laboratory itself should be equipped with an adequate demonstration table; 12 feet of chalkboard; 6 feet of tackboard; side benches, adequately supplied with electric outlets for major equipment; adequate storage space both for laboratory supplies and for student projects; some shelf room for books; cubbyholes for collection and distribution of student notebooks and reports; and display space for model setups.

Because safety is of paramount importance, there should be prominently mounted on the labora-