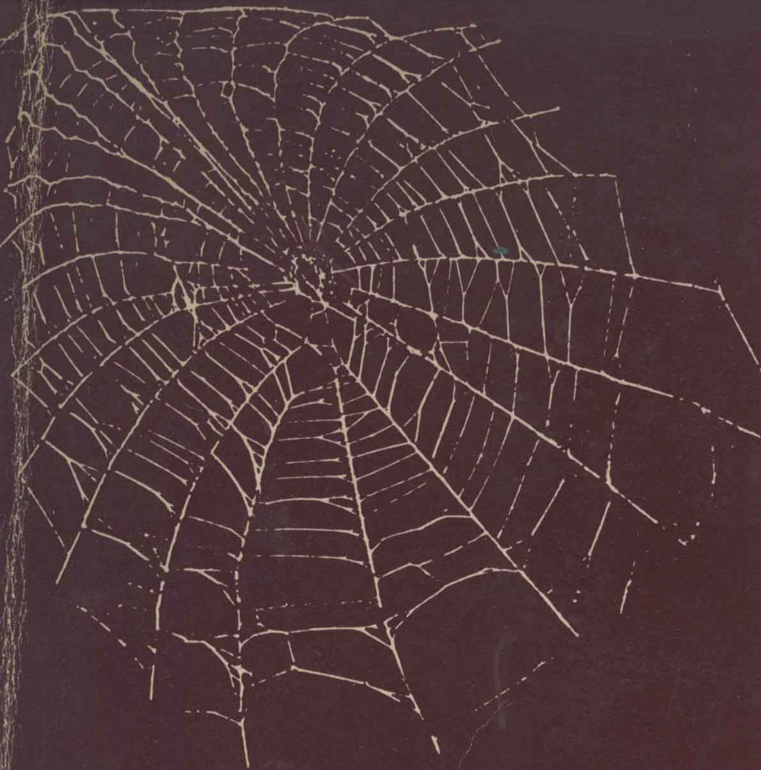

INTRODUCTION TO NATURAL SCIENCE
PART 2/THE LIFE SCIENCES

Academic Press

CHER'S GUIDE

Teacher's Guide *to*

Introduction to Natural Science

PART TWO

THE LIFE SCIENCES

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Teacher's Guide *to*

Introduction to Natural Science

Preface

This guide should be an aid to those using Part II of *Introduction to Natural Science — The Life Sciences* — and its accompanying Laboratory Manual. Suggestions are offered (based on experiences with pilot classes) for lecture themes and for questions to be discussed in class. Some currently available visual aids are listed (e.g., films, film loops, and slides) which can sometimes make the difference between a difficult or boring lecture session and an exciting one. Many references are given to articles in *Science, Scientific American,* and other journals from which additional information on current research and thinking can be obtained. Suggestions are also given for organizing classes to meet the needs of students of varied backgrounds. Since a number of instructors feel that *Introduction to Natural Science* provides a good 2-year core program for prospective science majors, recommendations of courses needed to complete their basic preparation are included.

Although the ideas offered by the guide will not be new to the teacher, it is our hope that sharing our experience will prove useful, at least the first time the text is used.

V. L. Parsegian

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General Observations

A. General Objectives

While the Introduction to Natural Science course differs substantially from conventional courses in science with respect to scope, content, emphasis, and approach, it cannot avoid being subject to the problems that attend the teaching of any important discipline. What are the objectives of the course? There is first the substantial body of information that we call *science*, especially modern science, which must be taught. As every teacher of science knows, however, the vastness of the scientific enterprise makes it exceedingly difficult to present more than a small portion of available information. In choosing that portion it is necessary both to avoid going too far afield and to avoid encompassing the topics and the approach unduly within disciplinary boundaries. As every teacher knows, it is all too easy for the study to become one of a discipline rather than of natural science. That is, considerable effort is required to integrate and interrelate topics and concepts. Moreover, since even modern science is a changing thing, its nature can be understood only in the context of its historical progress and trends and in its relationship to the progress of man and of man's society. The objective of the textbooks therefore has been to help these features to emerge from the topical content and approach of each chapter. Unfortunately there is no "right" way by which this can be achieved; and if one were to find the "right" way on some occasion, the likelihood is that the same approach would not work again. Nevertheless experience and failure do give some guide lines, at least with respect to practices that can be avoided. For example, some of the topics are best approached by resorting almost exclusively to class discussion and even debate rather than by the lecturer carrying the burden of the talking.

With these difficulties in mind, the *Teacher's Guide* attempts to call attention to some of the ideas that have emerged from the teaching of the course to a number of pilot classes. The teacher is not likely to follow the suggestions in detail, nor should he try to do so. We do hope, however, that the Guide will encourage new and better approaches to be attempted.

For each chapter the Guide attempts to identify alternative approaches to those used in Part II. For this reason the lecturer would do well to urge the class to read the text carefully, since the spoken word may not be identical with the discussions of the texts.

B. What the Course Does Not Try to Do

The most serious weakness in the teaching of any course in science is likely to arise from a tendency to include more factual details than the student is prepared to accept. *Perhaps the most important warning we can offer to the teacher is that crowding details of science beyond that included in the text only detracts from the purpose, impact, and attractiveness of the course.* The text includes a great deal of informational material with which to develop concepts and principles of science, *but time spent on still more details is likely to dilute and confuse the concepts,* especially for the nonscience majors. That is, the time is better spent in making the most of what is already included, through discussions and analyses.

This warning should not be interpreted as discouragement of outside reading or of special interest and effort on the part of the student in specific topical areas. There is very real difference between "piling on details" as one goes along and pursuing a subject to greater depth. The latter effort, either for the purpose of interrelating the subject to other areas or simply to learn more about the subject, should always be encouraged.

Even with precautions there are occasions when students complain: "All the teacher does is to put formulas on the board." It is altogether too easy for a teacher to be so enamored with the convenience of equations for representing biochemical processes that he runs the risk of confusing symbolic representation with understanding and appreciation of the phenomena involved. We have found that comprehension comes best to most students when phenomena are analyzed through physical analogies whenever this can be done well.

In the development of the texts for *Introduction to Natural Science* we found the "feedback" from students and from student assistants to be enormously helpful. Regular meetings with the assistants, and repeated invitations to the students to express their opinions on how the course can be taught more effectively, can keep the lecturer informed on their progress and on their difficulties. This requires humility on the part of the lecturer, but the results are worth the price.

The use of a tape recorder to record our own lectures often brings surprises, as each of us knows, and brings improvements in lecture methods as well.

C. On Historical Aspects

Each topic is likely to be introduced with some historical information, without emphasizing dates or the procedures used by the early scientists. We have found that such introductions help to reveal the:

(a) progress of scientific information, and sometimes the lack of progress;
(b) *role of science* through the several periods of society's development;
(c) *relationship* of *social progress* and of *philosophic thought* to the progress of science;
(d) *trends* in scientific and technological development;
(e) *strengths, weaknesses,* and *transitory nature* of current science.

D. On the Foundations of Science

An important objective is to develop awareness of the limitations as well as the achievements of science. As every teacher knows, it is all too easy to become skillful in solving problems involving gravitational or electrostatic attention, the octet rule, or enzyme-catalyzed reactions, without giving much thought to the fact that we do not yet have understanding of the basic *causes* of such phenomena. In this course it has been useful to remind the student fairly often of this lack of understanding. The great progress that has been achieved in scientific developments stands out in even bolder relief when we point out how far we have come despite this lack of basic understanding.

Since the present volume (*Part II—The Life Sciences*) follows *Part I—The Physical Sciences,* the teacher can take advantage of physical science information as the basis for the chemistry and biochemistry topics of Part II. *Every effort should be made to relate the topics and phenomena of Part II with the material of Part I.*

E. On the Interrelationship of Natural Science to Other Sciences and to Social Progress

When discussing the progress of science through the various periods, the addition of tidbits of information on the political, military, religious events, and personalities of the period has been found to help the motivation of the student. The "tidbits" should best reflect a nonspecialized attitude toward the progress of *natural* science (that is, it is important to include items from the physical sciences as freely as from the life sciences).

F. On Relating Topics and Experiments to Each Other

We have found that there is frequent and bitter complaint from students when there seems to be an absence of *relevance* of course material to the issues that are part of the student's awareness. An absence of relevance can easily develop when the teacher fails to take the trouble to reveal the relationship of one topic to another, or the significance of an experiment to the lectures, or the relevance of the topic to larger issues of a profession or of society. While this does not necessarily mean that the teacher had indeed failed to present such relationships, it does mean that the points did not get across as clearly as one might desire.

We have found it helpful for the teacher to adopt the following procedures:

1. Take a few moments to summarize the main points of each lecture before dismissing the class.
2. Begin each lecture with a reference or quick summary of earlier lecture or lectures. Be careful that by their questions a few students do not draw the teacher into repeating the earlier lecture. It is useful to limit the review to 5 minutes so that your "prime lecture time" (which is the first half of the lecture) will not be used up on old material.

3. Begin each new topic with discussion of its relationship (or lack of relationship) to earlier topics.
4. Discuss the significance of each experiment both before and after the experiment is attempted. This can be done either at the time reserved for discussion of experiments or at an appropriate point in the lecture period.
5. In the course of lectures, occasionally throw out questions to the class, such as: "What is the relevance of this topic to ________________ which we have discussed?" Or: "How do you explain this in the light of ________________?" It has been found useful to let students offer some wrong answers before the lecturer gives fuller explanation.

Note: We have had no difficulty in inviting and discussing questions even before large classes, *providing the questions have general interest.* When the questions do not have general appeal, it is better to invite interested students to private discussion.

G. *On Lecture Aids*

Invariably the lectures have been more interesting and instructive when aids such as an overhead transparency projector, slides, tapes, film strips, and films have been used. There are certain topics that gain from use of all these devices in the course of a single lecture, and it has been found useful to keep the equipment available on short notice. It does not interfere to ask the help of one or two students of the class to operate the slides and film projectors when the use does not involve too much time. (A small amount of interference sometimes helps to break the routine of a lecture.) Each film should have a purpose that is clear to the teacher and explainable to the class before or after the showing (or both). Some films require repeated showings to get full value.

The overhead projector can easily become more useful than the blackboard for presenting illustrations to a large class with a minimum of interference to their view.

H. *On Organization of Classes*

Very few colleges are sufficiently staffed to permit teaching courses in sciences to only small classes. For this reason the economics of teaching as well as the effectiveness of teaching must be kept in mind in arranging class schedules. This usually requires that lectures be given to large groups so that the laboratory and recitation classes can be kept small. Of course a teacher finds it more comfortable, and less demanding of preparation and planning, if even lecture classes are small and informal, but this is a luxury that few colleges can afford. Moreover, an experienced teacher derives little pleasure from repeating the same lecture several times a week to small classes if he can combine them for one or two good lecture periods. We find that with preparation, even a beginning lecturer can soon feel as comfortable facing a class of 400 as a class of 40.

This suggests that the course be taught according to the following weekly schedule when on the two-semester system:

(a) Two 1-hour (or 50-minute sessions in most cases) for formal lectures to as large classes as the lecture hall will hold.

(b) Another 1-hour session for large groups for showing of films, quizzes, and for discussion of laboratory work or of other topics in a manner that is somewhat less formal than the lecture meetings. In the chapter discussions that follow, these sessions are identified as "film-discussion sessions."

(c) A 2-hour session with small classes (20 to 30) alternating between recitation periods and laboratory periods.

With such a schedule of meetings it becomes possible to entrust recitation, laboratory groups, proctoring of quizzes, and showing of films to graduate (or even undergraduate) assistants when necessary, while the senior lecturer gives the lectures, discusses experiments, and maintains general awareness of the progress and problems of the course. It is important to require that *the assistants attend all lectures* and other meetings of the large classes whenever possible.

I. On Homogeneity of Classes

From experience, we know that a recitation class which includes extremes in student capability and background preparation risks boring the advanced students and losing the slower ones. The following thoughts are pertinent to this problem.

It can be helpful both to the teacher and to the class to make the small laboratory and recitation classes as homogeneous as possible. Homogeneity is less important for lecture meetings, although when there must be more than one lecture group there is some advantage to offering separate classes for those who have had good high school courses in chemistry and those who have not.

The grouping of recitation and laboratory classes may be guided by two considerations:

(a) Students who have had good high school courses in chemistry and biology can give more time to class discussion of topics. In some cases it has been desirable to excuse them from repeating experiments with which they are familiar; or better still, to ask them to help other students with the experiments.

(b) Students who plan to major in chemistry or biology can gain more from the course, and can be required to "deliver" more, if they are not "lost" among classes that do not plan to major in science.

We have found, however, that some of the most exciting exchanges of ideas take place in classes that include both science majors and students whose interests are in law or social studies or the humanities.

It is a good idea to publicize the recitation groups according to the above distinctions so that students may elect one or another group according to their own needs, whenever choice is possible.

It has been found very helpful to get the "advanced" students to work with students who need extra help. Advanced students who become assistants are prevented from becoming bored and discontented members of the class while they also help students who need extra attention. Studies have shown that students often gain at least as much from each other's help as from the teacher.

J. On Laboratory Experiments

As noted earlier, it helps to have some class discussion of each experiment before students attempt the experiment in the laboratory. This may be done by the senior lecturer during the third hour session of the week. The laboratory sessions can thereafter be left to the supervision of assistants. At some later time the senior lecturer can again discuss the experiment *in terms of its relationship to the lecture material.*

We have found that the experiments are best undertaken in an informal manner, more with the idea of giving opportunity to satisfy curiosity than to go through a formalized routine. (How to arouse this curiosity is a challenge to the teacher, of course.) Data are collected in a systematic manner and given to the assistant in charge, but it is not considered desirable to develop formal reports on experiments.

It can be profitable to present some of the experiments as demonstrations conducted by the laboratory instructor with the help of one or two students assisting and recording data on the blackboard. Pilot classes have generally rated this type of laboratory experience as more valuable than any other. Sometimes phenomena are demonstrated "live" and then reinforced with film loops. These require an experienced demonstrator's rather than a student's presentation. The laboratory instructor can maintain a running dialogue of comment and questions, *inviting predictions of what will happen when parameters are varied.* He may also urge students to suggest alterations in procedure, which can be discussed and tried immediately by the instructor and the students themselves when it is safe to do so.

Since for some students this may be the first exposure to chemicals every precaution must be observed to prevent accidents.

Demonstrations have considerable value for the lecturer and the class when:

(a) they are not so complicated as to resemble the proverbial "black box";
(b) the main features are explained to the class in comprehensible terms;
(c) they do not attempt to illustrate too many principles at one time.

Frequently it is well to demonstrate with the identical equipment that will be used for student experiments. We have found that while elaborate electronic demonstrations lend theatrical attraction to lectures, they are less effective than are simpler demonstrations for explaining phenomena.

K. On Term Papers

In most pilot classes we required one or two term papers (or independent studies) of each student during each of the four semesters of the two-year course. The papers did not have to be longer than four typewritten pages for each, but they were expected to have substance of a kind that clearly represented significant thinking or gathering of information on the part of the student.

In the first semester, one of these two papers was the assignment of Chapter 6 (systems). The second could be on any topic selected by the student and acceptable to the teacher. The second year presents an even wider range of topics for term papers. These may be a comparison (and contrasting) of industrial chemical processes with biochemical processes in the plant or in the animal body, control systems involving neurological involvement, the origin of life, integration or computational or perceptual functions of the nervous system, ecological systems, etc.

L. On Cooperative Effort among Students

We have found it helpful to encourage joint efforts by pairs or groups of students for discussions, for doing homework assignments, term papers, and laboratory experiments. Of course the term papers are expected to be different in that each should pursue a different emphasis or topic.

As with any other course, some students have difficulty in getting into step at the beginning. Sometimes the students who have the most difficulty are those who have not yet found comfortable association with other students. The teacher can help the situation by giving a few minutes' time during a recitation session for students to identify and establish partnerships for the term or the year.

M. On Examinations

Students have expressed preference for half-hour or 1-hour quizzes every three or four weeks, expecting a longer examination at the end of each semester.

Because Introduction to Natural Science is more a "thinking" than a memorizing or strictly problem-solving course, it requires an approach different from those commonly used in science courses. *This difference, with emphasis on thinking and identifying relationships in natural phenomena, must be explained to the class.* The results of the first quizzes are likely to jolt students. (As one of them complained, "This is no kind of quiz; you expect me to think.") The teacher will have to be on guard (and very firm) against students who try to pass the course by exercising the "gift of gab." Students who talk "philosophy" without giving much thought or time to the course may be even worse. Objective questions or tests that include facts can be followed by essay-type questions.

There is no single form of examination to be preferred above others. It is suggested that the teacher vary the form from time to time and in each case when announcing it *explain to the class the reasons for his selection.*

Some teachers have had success with examinations that are prepared as homework and brought in on the assigned day. This is worthy of trial.

In any case, examinations should be used as a means for revealing the successes and failures of the course. As every teacher knows, it takes both teacher and student to succeed or fail. Frank discussions with the class will often reveal how the course can be made more meaningful and successful.

Open-book quizzes offer relief from the fear of forgetting details, but they have the disadvantage of making many students overconfident about finding answers during the examination period, thus encouraging them to give less time to preparation. For these two reasons the students of pilot classes have been divided in their preferences, many of them admitting frankly that they study less for open-book quizzes. Nevertheless we believe that the teacher can impress the importance of adequate study even for open-book quizzes.

There is a strong tendency for students to wander and to be wordy in their replies to open-book questions. Both to save the time of the examiner and to help the student to collect his thoughts more effectively, it is useful to offer extra credit when students reply to questions with concise, cogent summaries.

We have given a few *yes-no* quizzes successfully along with a very few trick questions (against which students are warned in advance).

It is suggested that final examinations be of the open-book type.

N. Grading of the Class

While each teacher is likely to use his own criteria for grading students, our practices may be of some interest. One teacher has based final grades on the following relative values for the work: about ⅕ of the total for the final examination; ⅓ for other quizzes; ⅙ for laboratory work; the remainder for term papers, homework assignments, and general attitude.

Of course there is often need to raise or lower the grades somewhat because of factors such as attendance, attitude, progress, and supplementary work as expressed in class participation.

In any case we find it important to give the class early and adequate explanation of what will be the general criteria for grading their performance. Do not underestimate the seriousness of absence from lectures and from other class meetings.

O. On Independent Study by Students

Occasionally a student becomes interested in pursuing some topic to greater depth, an activity deserving of the title of "student research." The work may involve additional laboratory experimentation, library search, study of some phenomenon in the field, study of organizational operations, or pursuit of philosophical topics. The *Systems, Feedback, Cybernetics* concepts (Chapter Six, Part I), for example, often excite interest to pursue such studies.

We believe that every opportunity should be given to students to pursue independent or unusual studies, to the point of substituting these for attendance at laboratory and recitation sessions. Or one large effort can take the place of smaller term papers. Sometimes it is feasible to hold small group meetings where topics can be discussed at greater length and where students can discuss their supplementary work. It would not be out of place to reward such interest and initiative with good grades that may cancel poorer performance in other aspects of student performance.

P. Film Distributors

Each chapter of this Guide notes films that are presently available and which may be useful. There are being produced very many new films that cannot be included in current listings, however. The instructor should remain alert to available films and should make use of them when they present a new approach to a topic or when they enrich the course with additional, related materials. It is desirable to show one film of 20 minutes or longer duration every week if possible.

The list of film distributors changes every day. *Some films are distributed by several organizations from various regions of the country.* While the following listing will be useful, the teacher should look for new distributors as alternative sources in his geographic area. The list given herein, as well as the listings in the separate chapters, are likely to be out of date very quickly because new and better films and film loops are in preparation.

Films may be purchased or rented (without charge in the case of government agencies and nonprofit organizations) from the groups listed here. In most cases the teacher can ask to be included in mailing lists to receive information on new films. Also, new organizations can be added to the list each year.

Note the symbols of the distributors in the left column. These appear in the chapter listings. The list includes producers and distributors of films which in some cases relate to physics only. The categories are not clearly defined, however. In view of this, the instructor will have to describe his range of interests when writing to the film distributors.

The entries that are preceded by an asterisk are likely to be especially important as sources for slides, transparencies, films, film loops, and film strips for the lecturer of Part II. It is useful to be closely associated with the university distribution center nearest you.

ACA	Academy Films, 748 North Seward Street, Los Angeles, Calif. 90028
AEC	See USAEC
*AIBS	American Institute of Biological Sciences, 2000 P Street N.W., Washington, D.C. 20006
AIP	American Institute of Physics, 335 East 45th Street, New York, N.Y. 10017
AMS	American Meteorological Society, 45 Beacon Street, Boston, Mass. 02108