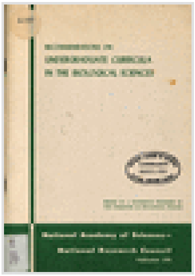

Recommendations on Undergraduate Curricula in the Biological Sciences (1958)

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Conference on Undergraduate Curricula in the Biological Sciences,
Washington, D.C., 1956, and Chapel Hill, N.C., 1957.

RECOMMENDATIONS ON UNDERGRADUATE CURRICULA IN THE BIOLOGICAL SCIENCES

REPORT OF A CONFERENCE
Held at Washington, D. C., December 8-9, 1956,
and Chapel Hill, N. C., April 1-4, 1957.

Editorial Committee

WILLIS H. JOHNSON, *Conference Chairman*
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PURPOSE AND ORGANIZATION OF THE CONFERENCE

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The rapid growth of the biological sciences and the changing intellectual and social climate in which they function necessitate continual re-examination of undergraduate teaching programs. Otherwise, biological education may suffer serious cultural lag.

This report summarizes the results of a conference called to undertake one such re-examination. Impetus for the conference was supplied by a substantial cross-section of the country's working biologists in views communicated to the Subcommittee on College Education of the Committee on Educational Policies, Division of Biology and Agriculture, National Academy of Sciences–National Research Council. Their suggestions led the Committee to plan a Conference on Undergraduate Curricula in the Biological Sciences. The Conference met in December 1956 and April 1957 under the chairmanship of Willis H. Johnson, a member of the Subcommittee on College Education. Financial support was provided by a grant from the National Science Foundation.

The principal participants were the following 16 biologists, from 14 colleges and universities, representing a wide variety of professional specialties:

Marston Bates, Professor of Zoology, University of Michigan
Wendell H. Bragonier, Chairman, Department of Botany and Plant Pathology, Iowa State College (April meeting)
Julius H. Comroe, Jr., Cardiovascular Research Institute, University of California Medical Center (formerly Professor of Physiology and Pharmacology, Graduate School of Medicine, University of Pennsylvania)
Lincoln Constance, Dean, College of Letters and Science, University of California at Berkeley
Harriet B. Creighton, Professor of Botany, Wellesley College
Donald R. Griffin, Professor of Zoology, Harvard University (April meeting)
I. C. Gunsalus, Professor of Biochemistry, University of Illinois, Urbana
James H. Hilton, President, Iowa State College (December meeting)
George W. Kidder, Stone Professor of Biology, Amherst College
Chester A. Lawson, Head, Department of Natural Science, Michigan State University
John A. Moore, Professor of Zoology, Columbia University
Henry J. Oosting, Chairman, Department of Botany, Duke University
Robert B. Platt, Professor of Biology, Emory University
Alfred S. Romer, Director, Museum of Comparative Zoology, Harvard University
I. W. Sizer, Head, Department of Biology, Massachusetts Institute of Technology
Frits W. Went, Professor of Biology, California Institute of Technology

The following officers and members of the Academy-Research Council's Division of Biology and Agriculture also attended the Conference:

L. A. Maynard, Professor of Nutrition and Biochemistry Emeritus, Cornell University; Chairman, Division of Biology and Agriculture (December meeting)
Frank L. Campbell, Executive Secretary, Division of Biology and Agriculture (December meeting)
Paul Weiss, Head, Laboratory of Developmental Biology, Rockefeller Institute for Medical Research; Chairman, Biology Council,* member, Committee on Educational Policies
Russell B. Stevens, Professor and Executive Officer, Department of Botany, George Washington University; Executive Secretary, Biology Council*
Howard M. Phillips, President, Alabama College; Chairman, Committee on Educational Policies**
Clyde H. Bailey, Dean Emeritus, Institute of Agriculture, University of Minnesota; member, Committee on Educational Policies
John A. Behnke, Vice President and Science Editor, Ronald Press Company; member, Committee on Educational Policies

* The Biology Council, of which the Committee on Educational Policies was previously a unit, was discontinued on June 30, 1957.

** One member of the Committee was unable to attend the Conference—Herbert R. Albrecht, Director, Division of University Extension, Pennsylvania State University.

Claude S. Chadwick, Head, Department of Biology, George Peabody College for Teachers; member, Committee on Educational Policies

Thomas S. Hall, Dean, College of Liberal Arts, Washington University; member, Committee on Educational Policies, chairman, Subcommittee on College Education

Milton O. Lee, Federation Secretary, Federation of American Societies for Experimental Biology; member, Committee on Educational Policies

Theophilus S. Painter, Professor of Zoology, University of Texas; member, Committee on Educational Policies

Richard E. Paulson, Executive Secretary, Committee on Educational Policies

Benson E. Ginsburg, Associate Dean of the College, University of Chicago; member, Subcommittee on College Education

Victor A. Greulach, Professor of Botany, University of North Carolina; member, Subcommittee on College Education

Willis H. Johnson, Chairman, Department of Biology, Wabash College; member, Subcommittee on College Education

John R. Raper, Professor of Botany, Harvard University; member, Subcommittee on College Education (April meeting)

The National Science Foundation was represented by Donald B. Anderson, Dean, Graduate School, North Carolina State College, NSF Program Director for Education in the Sciences, 1956-57.

The Conference met 8-9 December 1956 in Washington, D. C., and 1-4 April 1957 at Chapel Hill, North Carolina. The following members of the science faculty of the University of North Carolina were invited to join the April session:*

E. A. Cameron, Professor of Mathematics

John N. Couch, Chairman, Department of Botany

Douglas G. Humm, Associate Professor of Zoology

J. Logan Irvin, Professor of Biological Chemistry

Everett D. Palmatier, Chairman, Department of Physics

J. Harris Purks, Director of Higher Education, Board of Higher Education of the State of North Carolina

Arthur Roe, Chairman, Department of Chemistry

Clyde F. Smith, Head, Department of Entomology, North Carolina State College, Raleigh

The Conference was asked to consider three related problems:

First: Should an acquaintance with biological science be expected of all college graduates? What objectives, characteristics, and content are recommended for introductory courses in biology?

Second: Beyond the introductory program, what core of biological and other knowledge can be recommended for all future biologists, irrespective of their eventual fields of specialization?

Third: Beyond the introductory program and the common core for all prospective biologists, what is the role of undergraduate work in preparing students for different biological specialties?

In December the Conference conducted an initial survey of these problems and outlined basic parameters. After having a few months to consider the issues and discuss them with colleagues, they reconvened in April to formulate definitive recommendations.

On both occasions participants met in small groups in order that each individual might have opportunity to present his views. Recorders summarized the results of group discussions, which were also recorded on tape; recorders' reports were then presented and discussed at plenary sessions. After the December meeting, the Subcommittee on College Education prepared a synthesis of the preliminary group reports, noting areas of agreement and unresolved problems for reconsideration at the April meeting. To show the procedure, this report includes group reports and the synthesis from December and group reports from the Chapel Hill session for the first problem posed above; for the other problems it presents only the final (April) group reports. The Conference formally adopted all April reports and directed the Subcommittee on

* The Committee on Educational Policies is especially indebted to Professors Greulach, Couch, Humm and Irvin and the Extension Division of the University of North Carolina for making excellent arrangements for the April meeting.

College Education to prepare a statement for publication. All participants edited the draft and the present version bears the approval of all members of the Conference.

To give some idea of the flavor of the Conference, we have inserted a few selections from the actual discussions. A set of such "dialogues" appears immediately after the section giving summary reports on each major question considered in the discussions. To present all discussions by all groups would require a very lengthy report. The editors have elected the brevity of the summary statements while regretting the omission of the argumentation underlying conclusions. The dialogues at least give a few samples of the lively and informative talk that went on.

To be quite sure that our position is not misinterpreted, we must underscore a truism. *A report of a conference such as this is no more than an effort by one group of biologists to outline some guidelines on curriculum planning for consideration by their colleagues. Only the individual faculty member, the individual department, the individual institution can determine what programs will actually be offered to students.* Our special hope is that this report will encourage more biologists to make their own critical assessments of undergraduate curricula. The questions we faced are difficult, and the conferees did not always agree among themselves, as the report shows. We are certain that other biologists have many fresh and provocative ideas that should be contributed to a widespread effort to confront and resolve fundamental issues in biological education.

FIRST PROBLEM:
INTRODUCTORY COLLEGE BIOLOGY

INTRODUCTORY COLLEGE BIOLOGY

INTRODUCTION

At its final session, 4 April 1957, the Conference on Undergraduate Curricula in the Biological Sciences unanimously adopted the following resolution:

> We believe that every educated person should obtain a sound knowledge and appreciation of the biological sciences. This may be attained through precollege courses, introductory college courses in biology of the kind outlined in this report, or by self-study. Biologists should make every effort to maximize opportunity and motivation for young people to acquire at least this level of understanding of biology.

With but four abstentions, participants further recommended:

> This basic knowledge of biology can best be obtained through properly designed formal courses in high school or college.

The Conference voted this resolution to emphasize their conviction that the biological sciences are an important component of our culture, which should be appropriately represented in the background of every well-educated person, and that colleges and universities share with secondary schools the responsibility for supplying this understanding. The nature of the world as it appears to biological scholars, the history of scientific thought in this area, methods of investigation used, current conclusions and their applications and implications are essential aspects of a liberal education and necessary foundations for other curricular areas. Such knowledge can be obtained only through a study of biology. Once mastered, it has essential interconnections with aspects of the physical sciences, the social sciences, philosphy, medicine and agriculture, esthetics, and other humanistic disciplines. Although intimately related to the physical sciences on which it draws, biology is sufficiently unique both in subject matter and methodology to warrant separate study. It cannot be considered merely as one example of scientific achievement for which a non-biological science can be substituted. Both the physical and biological sciences should, therefore, be included in the student's curriculum. If possible, an introduction to the physical sciences, together with mathematics, should precede biology, but general college courses in biology should not be postponed on this account, for adequate high school preparation in mathematics, physics and chemistry can meet the needs of the college general biology course. The Conference was also much interested in current efforts by physical scientists and mathematicians to develop new types of introductory courses which, in prospect, seem to have increased value both for general education and as a background for biology.

The introductory program in biology recommended as part of everyone's liberal education looks toward courses in which selected major concepts of biology are examined in the light of their history (including the reasoning and evidence on which they are based) and related to the data which they help to organize. Such a program should have equal value for the potential biology major and the non-biologist. For both groups it should be challenging in intellectual content, and it should have sufficient substance to serve as prerequisite for more specialized courses for the major.

At both meetings the Conference approached the problem of introductory biology by dividing into four groups, each of which produced a report. As may be seen below, the four short reports adopted by the Conference at Chapel Hill agree closely on many points. The reasons for this become clear when group reports and the synthesis based upon them for the December meeting are taken into account. This also supplies an example of the way in which discussion developed from one session to the next. The following sections of the report therefore present 1) a statement of the problem, 2) discussion-group reports from the Washington meeting, 3) an analytical synthesis of these reports prepared for the Conference by the Subcommittee on College Education, 4) discussion-group reports from the Chapel Hill session, and 5) a synthesis and summary of the latter.

PROBLEM

What biological knowledge should constitute a fundamental core of experience for all or most students, regardless of college course of study?

a. What objectives guide instruction at this level?
b. Should it be required in the collegiate (or pre-collegiate) programs of all students, whatever their major?
c. What essential content should be included? Should this be adapted in some degree to utilitarian concepts? To what extent should it deal with how knowledge is obtained? Should students at this level have opportunities to act like scientists, acquiring some knowledge by their own investigative effort?
d. What knowledge of other fields should be prerequisite to this fundamental course or courses?
e. What, if any, optional forms of first experiences in biology are desirable?

REPORTS OF DISCUSSION GROUPS AT DECEMBER MEETING

Group A: Bates, Chadwick, Creighton, Ginsburg, Phillips, Sizer, Stevens

The objectives of biology in a school curriculum cannot be discussed without reference to the total academic organism, *i.e.*, the curriculum as a whole. Both the biological and physical sciences are, in our view, essential ingredients of every undergraduate curriculum if properly conceived and taught. The nature of the physical and biological world, the history of human thought with respect to it, the methods of investigation used in the natural sciences, and current conclusions about the universe around us are essential aspects of a college education and necessary foundations for other curricular areas. An honest understanding of science as ongoing inquiry resulting in tentative knowledge, but yet the most certain knowledge we possess, can only be arrived at through a study of the sciences themselves. The knowledge obtained in science courses provides an essential foundation for later work in some areas of philosophy, such as logic and causal analysis; for many aspects of the social sciences; and even for the humanities, where it has been said that "science is a characteristic art form of contemporary civilization."

Insofar as they deal with different aspects of our universe, the physical and biological sciences demand separate treatment, with the former preceding the latter.

So far as biology itself is concerned, it is more than an example of the way of science. Its object is to provide an understanding leading to an appreciation of the meaning of being an organism. It deals with a dynamic, directive, reproducing and mutable organization of matter and energy and with an order of phenomena relatable but not reducible to physical-chemical concepts. Its basic areas include the diversity and history of living forms; behavior; the description and analysis of developmental life cycles; the hereditary mechanism; the relations of structure to function from the societal to the molecular level; and a convention of teleological analysis not congenial to chemistry or physics. The ways in which biologists have approached and are approaching these problems, and the nature of current conclusions in all of these areas as deducible from evidence, form the corpus of what we mean by "biology."

A first-level course dealing with biology in these contexts and utilizing living materials, project work, and other contacts (*e.g.*, visual aids) with the actual "stuff" of biology, is what we have in mind.

Since one important objective of a liberal education is to wean the student to the point where he can obtain information on biological topics independently, beginning courses should demand the use of the library and should introduce the student to books and lay journals beyond the usual course textbooks.

The course we visualize is a proper background for every college student, regardless of his ultimate vocational intention (as are comparable courses in the physical and social sciences). In order to facilitate the evolution of such courses, there should be an exchange of teaching materials being considered to this end by various institutions. We do not have one road to salvation in mind, but if each road becomes a part of a map and the latter is available to all interested institutions, routes to the goals may more readily be found.

To have the proper courses in the proper curricular context solves a part of the problem. A prior part is to encourage people to spend time in creating such courses and to insure that they are well taught afterward. We believe that this can only be brought about in an administrative environment in which teaching at the beginning college level achieves a greater prestige level than it has now, and in which contributions to curriculum and in the classroom command respect and rewards equivalent to the publication of research papers.

Group B: Bailey, Campbell, Comroe, Hall, Lawson, Oosting, Romer

a. *Objectives*

1. Knowledge and understanding of the facts of biology.
2. Understanding of the theories and principles that relate or explain the facts.
3. Knowledge and understanding of the methods of science.

b. *Some laboratory science should be required for all college students* as a part of a cultural education and both physical and biological science should be represented (a secondary school background of high quality might partially satisfy the requirement).

c. *Essential Content.* The ideal is an integration of all phases of biology in relation to other human knowledge. By consideration of the facts, interrelating concepts and demonstrating evidence, the following major "problems" should be analyzed or evaluated: life, the cell, processes, organization (both ontogenetic and phylogenetic), reduplication, genetics, heredity and environment, maintenance and behavior, evolution. As for the utilitarian aspect, we should by all means relate subject matter to the student's everyday life.

The first course should deal both with knowledge of organisms and with the way that knowledge is obtained. Wherever practical, the nature of the evidence should be emphasized, new aspects should be introduced, and unsolved problems should be pointed out.

Whenever it is possible to do it effectively in the laboratory program, students should be given a chance to approach problems on an experimental basis (preferably, always before the subject is presented in lecture or text assignment).

d. *Prerequisites.* Ideally, biological studies should be preceded by training in physical sciences; chemistry, particularly, should precede, at least in part.

e. *Optional Forms.* It is recognized that these recommendations must be adapted to local circumstances. They are not intended to be restrictive but to satisfy the listed general objectives.

Group C: Behnke, Constance, Gunsalus, Lee, Moore, Went

a. *Objectives.* Recognizing that the field of biology is broad and impossible to cover as a whole, we recommend a course that will develop a few important topics in their historical perspective and in sufficient detail to give the student some ability to reach a verdict on the basis of evidence, teaching him science as well as biology. We recommend a vigorous year-course with an essential laboratory phase. The course should be substantial in content, and should stress aspects distinguishing biology from the physical sciences, *e.g.*, the multidimensional character of living systems, cells and other levels of organization, change and evolution, the existence of unsolved problems, what questions can be asked to obtain new information, and how these questions can be formulated.

b. *Requiring Biology*. We believe some knowledge of biology is essential for all educated people. The content of the course should be appropriate for non-biology majors in the liberal arts, for biology majors, for preprofessional students, and for prospective teachers. It should be recognized that biology is a cultural subject, and it should be taught as such. Tests might be set up around the objectives listed under "a" to measure the proficiency of those who have already had equivalent work. Some members of the group expressed concern that putting all students in the same course might dilute its quality, but the majority felt this is not an inevitable or necessary outcome.

c. *Essential Content*. The student should be made aware, first of all, of man's place in nature; of the relationship between the living and inorganic world; of the cell, its components and their functions; of the structure of the main groups of animals and plants, with a proportionately greater knowledge of the chordate or mammalian body and how it works; of genetics and evolution, with some idea of the principles of systematics. Much of the knowledge of plant and animal structure can be learned in the laboratory or field, using a reasonable array of organisms as examples in a general framework. The course should also contain meaningful demonstrations of how knowledge is obtained and applied aspects should be stressed only in the selection of meaningful examples.

d. *Prerequisites*. We believe it very desirable that the student have had some experience with physical science and mathematics in high school, but college biology should not be postponed in favor of his taking these subjects in prerequisite courses. What is essential can be included in the course, or the student can be referred to elementary textbooks.

e. *Optional Forms*. We encourage development and stimulation of natural-history interests in primary and secondary schools by using vacation experiences, collecting, museums, zoos, botanical gardens, field trips, and the like. At the high school level, it was suggested, emphasis should be placed on teaching plants and animals as such, leaving more analytical study to college and university courses.

Group D: Anderson, Greulach, Hilton, Kidder, Painter, Platt, Weiss

a. *Objectives*. The following list of objectives is undoubtedly incomplete but represents those listed by the group in the limited time available:

1. To convey the essence of the nature of the scientific process as exemplified by the life sciences, including historical perspective.

2. To develop concepts of the important basic biological principles, each illustrated and supported by a suitable selection of specific factual detail, all the factual content of the course or program being selected with this goal in mind.

3. To provide the *minimum* technical biological vocabulary necessary for expression of the substantive content of biology.

4. To create an appreciation of the contributions of the biological sciences to man's intellectual development, material progress and aesthetic sense.

5. To present biology as an open and growing field full of challenging problems for which solutions are yet to be found.

6. To provide an opportunity for introducing experience in using the techniques and methods of the biological sciences, including observation, comparison, setting up hypotheses, experimentation, analyzing and evaluating data, and drawing conclusions.

7. To orient the biological sciences in relation to the physical sciences and to the other aspects of man's intellectual and cultural activities, and to identify the unique role they play in this scheme of things.

8. To exemplify the ways in which practical applications have been derived from basic research.

b. *Requiring Biology*. The group believes that while a program with objectives such as those outlined should perhaps be designed primarily with that majority of students who will not specialize in a biological science in mind, it should also provide a very adequate and suitable basis for further study in either basic or applied biological sciences. The group therefore agreed that there should be a single introductory program for all students, regardless of their interests and plans for the future.

c. *Essential Content.* In line with the objectives stated, the group agreed substantially that the essential conent should include the following:

1. *Principles*
   (a) Metabolism and energetics.
   (b) Morphogenesis—growth and differentiation.
   (c) Regulation and control.
   (d) Organization.
   (e) Irritability and response.
   (f) Specificity (key-lock relationships).
   (g) Continuity—reproduction and heredity.
   (h) Evolution and the species concept.
   (i) Group dynamics.
2. *Forms of life*
   (a) *Types of organisms,* with examples drawn from among microorganisms, plants and animals.
   (b) *Levels of organization:* Molecules, molecular aggregates, cell structures, cells, tissues, organs, organisms, species, communities.
3. *Techniques and methods, e.g.,* observation, experimentation, critical evaluation, statistics, classification.
4. *Over-all concepts,* which should permeate and be integrated with the other aspects, *e.g.:*
   (a) Applications of biology.
   (b) Historical perspective.
   (c) Nature and methods of science.
   (d) Contributions of biological science to man's intellectual life and culture.
   (e) Aesthetic aspects.

d. *Prerequisites.* The group recognized the need for some elementary knowledge of the physical sciences, particularly chemistry and physics, for an adequate understanding of certain aspects of the biological sciences included in the introductory program. However, the majority of the group was opposed to the setting up of any formal prerequisites in these fields, or any other fields, for the introductory program in the biological sciences. The hope was expressed that eventually high school instruction in physics and chemistry would be good enough and universal enough so that all students entering college would have the desired minimum background in these fields. In the meantime, the introductory biology program itself must provide, for those students who do not possess them, the bare basic physical and chemistry concepts essential for an understanding of biological principles at an elementary level.

e. *Optional Forms.* Special provisions should be made for additional opportunities for exceptional students.

SUMMARY OF DECEMBER REPORTS

Introduction

The biological sciences and, in fact, the natural sciences are an important part of our culture in every conceivable sense and should, therefore, be adequately represented in every student's curriculum. Colleges and universities share with elementary and secondary schools responsibility for supplying this understanding.

The nature of the physical and biological world, the history of human thought with respect to it, methods of investigation in the natural sciences, and current conclusions about the universe around us, are essential aspects of a college education and necessary foundations for other curricular areas. An honest understanding of science as ongoing inquiry resulting in tentative knowledge, but yet the most certain knowledge we possess, can be attained only through study of the sciences themselves. Knowledge obtained in science courses provides an essential foundation for later work in such areas of philosophy as logic and causal analysis, for many aspects of the social sciences, for esthetics, and even for the humanities as a whole, for it has been said that "science is a characteristic art-form of contemporary civilization."

Ideally, the physical sciences and mathematics should precede the biological sciences in the student's curriculum. However, general courses in biology should not be postponed on this account, and therefore may need to cover mathematics, physics and chemistry essential to their purposes. Adequate high school preparation in these fields can meet the needs of the general biology course. Current efforts of physical scientists and mathematicians to reorganize their introductory courses are expected to make these courses even more valuable, both for general education and as a background for biology.

Should there be one program for non-majors and prospective biology majors alike? In terms of students taking them, colleges and universities now offer four kinds of introductory biological courses: (a) courses for non-majors only, often not usable as prerequisites for intermediate-level courses; (b) courses in Biology, Botany and/or Zoology, primarily for prospective majors, but sometimes for majors and non-majors; (c) courses for special groups of students (*e.g.*, Biology or Botany for pharmacy students, Physiology for physical education majors, Biology for home economics students, Biology for teachers); (d) elementary courses, given without prerequisites, in agricultural subjects, which present the same principles as biology, or botany, or zoology courses, but in terms of particular organisms (*e.g.*, Field Crops I, Animal Science I). These varied courses are assumed to "meet different student needs," but it is not certain that needs differ so much at this level. The different types may also have special virtues or faults. The better courses for non-majors sometimes achieve an effective emphasis on fundamental but documented concepts, as seen in a broad intellectual context, but they also run the hazard of superficiality. Courses in other categories may offer more substance but may also focus so largely on details as to obscure the central theme. Finally, many first-year students do not know what they want to major in; channeling them into "blind-alley" courses forces them to take a second, more acceptable, introductory program or to give up thought of further work in biology.

The Conference therefore advocates a single first *program* (not necessarily a single *course*) in biology for majors and non-majors alike. Any first course should be good enough in substance to serve as prerequisite for intermediate courses and good enough in basic orientation to serve non-majors. Different forms of first program may be offered, taking the best features of both types (a) and (b) above. They should deal with the basic biology of plants, animals and microorganisms, eliminating need for types (c) and (d). What is not part of basic biology but is now given in the vocationally oriented first courses can best be reserved for intermediate-level courses.

Objectives

The objectives of the general program are [as proposed by one or more study groups; all four groups listed the first six]:

(1) To convey the essence of the nature of scientific processes and methods of investigation, as exemplified by the life sciences, including the history of biological ideas as related to other historical events.

(2) To develop concepts of the nature of the biological world through an understanding of important basic biological principles, illustrated and supported by a suitable selection of specific factual detail; all the factual content of the course or program should be selected with this goal in mind.

(3) To create an appreciation of the contributions of the biological sciences to man's intellectual development, material progress, and esthetic sense.

(4) To present biology as an open and growing field full of challenging problems awaiting solution.

(5) To provide an opportunity for introducing experience in using the techniques and methods of the biological sciences, including observation, comparison, setting up hypotheses, experimentation, analyzing and evaluating data, and draw-

ing conclusions, and for obtaining first-hand acquaintance with organisms and biological phenomena.

(6) To orient the biological sciences in relation to the physical sciences and the other aspects of man's intellectual and cultural activities, and to identify their unique role.

(7) To exemplify the relationships of practical applications and basic research.

(8) To provide the *minimum* necessary technical vocabulary.

(9) To provide encouragement and practice in obtaining information on biological topics through independent effort on the part of the student, using the library and other readings.

(10) To provide practice in oral and written communication of the student's knowledge.

(11) To encourage the creative and superior student to independent effort by means of individual projects, science clubs, research apprenticeships, etc.

Content

Proposals on content are summarized and compared in Table 1. Omission of environmental biology from lists submitted by discussion groups was probably an unintentional oversight (certain items mentioned by some groups presumably belong to this field).

Comments and Questions For Further Consideration

In view of the diversity of descriptions stating apparently similar content for introductory programs, the Conference should make a conscious effort to formulate content items in a way that will enable it to communicate its views to all biologists.

(1) The first six objectives were proposed independently in one form or another by all four groups, the seventh by three groups, each of the remaining four by one group. Can we reach a consensus on all objectives? Should additional objectives be listed? Should any objectives be reformulated?

(2) The first four items of content were independently proposed by all four groups; items 5, 6 and 7, by three groups; item 8, by two; item 9, by only one group. How much consensus can now be achieved on these? Should environmental biology or any other items be added? What is the Conference's attitude toward different emphases seen in introductory programs, particularly the rather common practice of making man the focus?

(3) The content listed covers virtually the whole of biology. Should all items be considered, even if this means only superficial treatment of each one, or should certain items or topics be emphasized at the expense of others? If the latter, how is the choice of main topics for treatment in depth to be made?

(4) To what degree should we specify the extent to which content items should be developed in the introductory program, remembering that biology majors will receive further undergraduate training in these areas?

(5) Colleges now offer one or more of the following types of introductory programs in biology: (a) a course in general biology; (b) a semester of plant science plus a semester of animal science; (c) a year of animal science and/or a year of plant science; (d) special introductory courses in physiology, natural history, ornithology, etc. What are the relative merits of each type of program? Should we recommend one or another, or should we remain neutral, leaving the matter to local opinion?

(6) Do we want to allow students to obtain college credit or advanced standing for superior high school preparation? If so, how do we determine in any particular instance whether a high-school biology course has fulfilled the general education objectives for biology outlined above?

(7) How can we persuade administrations and senior professors to give able staff members time and encouragement to develop courses and curricula such as those we are recommending and to teach such courses in the most effective manner? How can we make sure that such vital educational activities will be rewarded comparably to research productivity?

TABLE 1.—Content of the Introductory Biology Program; Suggestions by Discussion Groups at the December Meeting.

	Group A	*Group B*	*Group C*	*Group D*
(1)	History of living forms	Evolution, phylogenetic organization	Change and evolution	Evolution
(2)	Hereditary mechanisms	Reduplication, genetics, heredity and environment	Genetics	Reproduction and heredity
(3)	Relation of structure, function and organization from molecular to societal levels	The cell, processes, ontogenetic organization, maintenance	Cells and other levels of organization	Metabolism and energetics; regulation and control; specificity; group dynamics, levels of organization
(4)	Ways biologists have approached and do approach problems and relate evidence to conclusions	Nature of evidence should be emphasized	What questions to ask to obtain new information and how to ask them	Nature and methods of science
(5)	Diversity of living forms	....	Structure of the main groups of animals and plants with emphasis on chordates; character of living systems; systematics	Types of organisms; species concept
(6)	Behavior	Behavior	....	Irritability and response
(7)	Description and analysis of developmental life cycles	Ontogenetic organization	....	Morphogenesis, growth and differentiation
(8)	....	Utilitarian aspects	....	Applications of biology
(9)	Teleological (causal) analysis	....	....	....

(8) How can we determine in specific cases whether high school courses in physics, chemistry and mathematics provide suitable background for introductory college biology courses? Should biologists lobby for the inclusion of physics, chemistry and mathematics in the high school background of every potential college student? Should we recommend that college courses in physics, chemistry and mathematics be taken before or concurrently with the introductory biology course?

REPORTS OF DISCUSSION GROUPS AT APRIL MEETING

Group A: Anderson, Constance, Griffin, Gunsalus, Hall, Humm, Platt, Stevens

Introduction

We recognize the merits of a single introductory program in biology for majors and non-majors alike. However, a single program or course within a large university may, because of the awkwardness of its mechanics, cancel its own advantages. Combining different introductory biology courses into a single program of the sort outlined below has advantages, provided it can be so administered as to preserve effective interchange between student and teacher. The instructors should be the most gifted available. Insofar as possible, they should participate in small discussion and laboratory sections, which are essential parts of the program. Inexperienced assistants and interns should teach only under adequate supervision. In planning introductory programs, moreover, diverse student abilities and attainments and the training and special enthusiasms of teachers should be considered.

Objectives

The introductory college program in biology should endeavor:

1. To convey the nature of scientific processes and methods of investigation, as exemplified by the life sciences, including some history of biology as a scientific discipline.

2. To develop an understanding of and interest in living organisms through a comprehension of important basic biological concepts. Selection of carefully limited factual detail, in lecture, laboratory and field, should be governed by this goal. Technical vocabulary should be kept at a *minimum.*

3. To present biology as an open and growing field which uses techniques and ideas from many sources.

4. To provide laboratory and field experience in applying biological techniques and methods to actual organisms.

5. To relate the biological sciences to man's other intellectual and cultural activities, developing an appreciation of the contributions of biology to man's understanding of his world and to his material progress. How attempts to solve practical problems have led to the development of theoretical concepts and how basic research has contributed to the solution of practical problems should both be exemplified.

6. To instruct and encourage students in independent and intelligent use of the library as a source of ideas and information.

7. To encourage the habit, in the hope that it may last, of reading and evaluating non-technical biological literature.

8. To improve skill in written and oral communication of organized biological knowledge.

9. To provide opportunities beyond the classroom for interested students to carry on some independent activities, on an individual or small group basis, which will stimulate a continuing interest in biology (*e.g.*, investigation, reading and writing projects, research apprenticeships, science clubs, etc.). Special efforts should be made to identify superior students and encourage them through such activities.

Content

A statement on the content of the introductory program should define (1) a basic core which should be included in every course and (2) optional materials, the inclusion of which would be determined by the instructor and by local conditions. After discussion, the group decided to list only the core topics, believing that a list of optional topics would not only be voluminous but might lead to misunderstanding because of close interrelationships between some optional items and the essential items listed below. We subscribe to the principle of intensive or searching study of a few topics, in contrast to a more superficial study of many items. The examples should be chosen judiciously so as to include representatives of plants, animals, and microorganisms.

1. Evolution and genetics, including population and biochemical genetics. Some modern concepts of population and biochemical genetics can be taught at the introductory level by use of a few well-selected examples. As for evolution, all but one of us (Platt) believe that there is insufficient time in the introductory program for even a brief phylogenetic survey of organisms. Thus, even more significance is attached to the approach suggested here.
2. Major features of cells, emphasizing current concepts of the significance of the nucleus, mitochondria, chromosomes, membranes and other components, with respect to metabolism, energetics, regulation, control and development.
3. Structure, function, and development at the tissue, organ, organ-system and organism levels.
4. Thorough study of structure and function of a few well-chosen examples of

organisms, as they operate in their natural environments.

The emphasis being on principles rather than techniques and derivations, college chemistry and mathematics are not necessary prerequisites for this program.

Comments

Man may be used as a starting point for topics as a motivational device, if necessary, but the introductory program should not revolve about man.

Although all the above items should be covered, the degree of emphasis should be governed by the particular interest and competence of the teacher and the ability and attainment of students.

How the objectives are achieved and the content represented should be determined by the local situation, provided biologists from all major fields represented at the institution are involved in the planning and execution of the program. The introductory biology program should be preparatory to any second-level courses in biology as well as suitable for non-majors.

Advanced standing for students who have had superior preparation in high school biology should be granted, but only on the basis of examinations which indicate substantial achievement in the listed objectives.

We strongly recommend that colleagues and administrators encourage, support, and grant recognition for experimentation in teaching.

Group B: Bailey, Chadwick, Greulach, Lawson, Moore, Oosting, Sizer, Weiss

Objectives

A. General objectives:

1. To convey the nature of scientific processes and methods of investigation, as exemplified by the life sciences, including the evolutionary history of biological ideas.

2. To develop understanding of the nature of the biological world through important basic biological concepts, illustrated and supported by a suitable selection of specific and detailed factual evidence, all of the factual content of the course or program being selected with this goal in mind.

3. To create an appreciation of the contributions of the biological sciences to man's intellectual development, well-being and esthetic sense.

4. To present biology as an open and growing field full of challenging problems for which solutions are yet to be found.

5. To provide an opportunity for personal experience in applying the techniques and methods of the biological sciences, including observation, comparison, formulation of hypotheses, experimentation, analysis, correlation and evaluation of data, and formulation of conclusions.

B. Specific objectives:

1. To relate the biological sciences to the physical and social sciences.

2. To exemplify the ways in which practical applications have developed from basic research.

3. To provide a minimum technical vocabulary necessary for the communication of the essential facts and ideas in biology.

4. To encourage the independent use of the library as a supplementary source of ideas and information.

5. To create opportunities for oral and written expression by the students.

6. To encourage the superior student to participate in research.

Content

1. Types of organisms and their diversity.
2. Reproduction and heredity.
3. Structural and functional organization from molecular to organismal levels.
4. Philosophy and methods of biological science.
5. Behavior of individuals and of groups in their relations to the environment.
6. Developmental biology.

Comments

Man may serve as a starting point for topics as a motivational device, but the entire course should not revolve about man.

All the content topics we list should be covered and this can be done penetratingly, even though not comprehensively.

The precise nature of the courses used to achieve any objectives should be determined by the local situation.

Although training in high school physics, chemistry or mathematics is desirable, it should *not* be prerequisite to the introductory program in college biology. Any necessary background material in physics, chemistry and mathematics can be included in the introductory biology program.

Group C: Creighton, Couch, Ginsburg, Kidder, Lee, Painter, Romer, Went

Objectives

1. To convey the nature of the scientific process and methods of investigation as exemplified by the life sciences, including the history of biological ideas and their relation to other historical ideas.

2. To develop an understanding of and interest in the nature of organisms through an understanding of important basic biological concepts, illustrated and supported by a suitable, carefully limited selection of examples. All the content and vocabulary of the course, whether presented in lecture, laboratory or field, should be selected with these goals in mind.

3. To develop an appreciation of the contributions of the biological sciences to man's understanding of the world he lives in, to his material progress and to his appreciation of the order, harmony and beauty of the world.

4. To present biology as an open and growing field by including modern developments, some of which have arisen from the concepts and methods of biology and some of which have come from the physical sciences and mathematics.

5. To provide an opportunity for actual experience with organisms in applying the techniques and methods of the biological sciences, including observation, comparison, formulation of hypotheses, experimentation, analysis, correlation and evaluation of data, and drawing of conclusions.

6. To exemplify the ways in which attempts to solve practical problems have led to the development of theoretical concepts and, also, the ways in which basic research has contributed to the solution of practical problems.

7. To encourage independence in the use of the library as a source of ideas and information.

8. To encourage the superior student to develop his interest and abilities with reference to biology.

Content

The selection of material to be included should be determined by its relevance to the objectives. The items mentioned below should not be considered as topics to be treated separately, or in the sequence in which they are listed; rather, they should be woven into the course when relevant, the amount of emphasis and the sequence being determined by the teachers.

1. Phylogentic organization and evolutionary theory; structure of the main groups of plants and animals.
2. Reproduction and hereditary mechanisms, the latter related both to evolutionary theory and to growth and development.
3. Cells and other levels of organization; metabolism and energetics, relationship of structure and function.
4. The ways in which biologists have approached and do approach problems and relate evidence to conclusions.
5. The responses of organisms to internal and external environments.
6. Ecology.
7. Growth and differentiation.

Group D: Bates, Behnke, Bragonier, Comroe, Irvin, Phillips, Raper, Smith

Objectives

The group agreed with the general content and spirit of the drafts of objectives prepared by the other groups, but thought these should be bolstered by examples and so stated as to allow measurement of progress toward meeting them. The group felt that the objectives could be combined and reduced to a single statement of principles. The only substantive change suggested was an addition: there should be more overt expression of the need to stimulate a continuing interest in biology on the part of students not going on with additional formal education in biological subjects. This could be done by exposing students to non-technical literature—periodicals like the *Scientific American* and trade books on biological subjects. The hobby possibilities in biological fields should also be brought to the attention of these non-specializing students.

Content

1. History and diversity of living forms.
2. Reproduction and hereditary mechanisms.
3. Relation of structure, function and organization from molecular to societal levels, with stress upon metabolism and regulatory and control mechanisms.
4. Ways biologists approach problems and relate evidence to conclusions.
5. Behavior and interrelations among organisms and between organisms and the physical environment.
6. Description and analysis of developmental life cycles.

Comments

The objectives (and content and methods) of biological teaching should be a matter of continuing open discussion among biology teachers and special efforts should be made to encourage publication on this topic. For college teachers, the *AIBS Bulletin* would be an appropriate medium for publication on these questions.

Foundations might appropriately receive proposals for freeing time for curricular planning and experimentation and for the writing of texts along new and experimental lines.

Applications of biology should not be a separate item of content but should be mentioned at appropriate points in the general treatment.

Man should not be a primary focus of an introductory biology course. On the other hand, the older tendency to ignore man completely is deplored.

As for relative emphasis on different topics in the course, most of the group felt that this should be determined by the instructor in accord with his interests and enthusiasms and his feeling for the needs of his students (one member strongly demurred on this point, saying that the instructor would ride his hobbies anyway and should not be especially encouraged to do so).

The group unanimously rejected the idea of an exclusively zoological or botanical introduction to biology. If the departmental system separates plant and animal biologists in the college or university, mechanisms for cooperation on the introductory program should be found.

College recognition should be given for superior high school preparation in biology. Advanced standing could readily be established by examination.

Administrative interest in curricular development could be stimulated in many ways: conferences; inter-university experiments, testing the results of diverging systems; wider exchange of teachers; broad foundation support of teaching experimentation; recognition of teaching achievement by professional scientific organizations; and giving the director of a course a planning and budgetary responsibility comparable to that of the director of a research project.

SYNTHESIS AND SUMMARY

The introductory course or course-sequence that emerges from this Conference differs from conventional courses in emphasizing modern and dynamic aspects of biology—especially physiology, development, genetics, evolutionary mechanisms, behavior, and interactions with environment. To give time for this, detailed studies of anatomy and extensive class-by-class surveys, it was felt, must be severely restricted. One group argued (with one dissenter) that no attempt should be made to present even a brief phylogenetic survey of the plant and animal kingdoms, believing that the inclusion of other indispensable materials would not leave time for adequate treatment. Other groups proposed brief surveys to provide some idea of the range and diversity of organisms. The Conference generally agreed that such surveys have been overemphasized in introductory courses in the past. Because of the vast increase of significant biological knowledge, any attempt to include the more modern developments in the introductory program requires deletion of topics which were previously included and sometimes even dominated courses. However, the recommended emphasis upon modern concepts drew a fairly strong caveat from some members of the Conference: namely, that we should not become so focused upon analytical and biochemical procedures—upon what may be called the physiological dissection of the organism—that we forget the organism as a whole. This explains the strong insistence in several groups upon behavioral and ecological studies. The Conference urged in strongest terms that the first course or course-sequence for all students—whether future biologists or not—should select its examples from all the major groups—microorganisms, plants, and animals—and should clearly show their respective roles in the biological scheme. Finally, concentration on important basic concepts and principles through the *intensive* study of a few judiciously selected examples, rather than attempts at *extensive* cataloguing of facts and terms, is essential, especially if the stated objectives are to be attained within a year's study.

The introductory biology program visualized by the Conference is conceived to be an essential component in the education of every student. The same course or courses should serve the needs of biology majors and non-majors alike. Although discussion focused largely upon objectives and content, conferees emphasized that the curriculum is not the only important factor. Far from it. The quality of teaching, opportunities for effective interchange between students and an experienced teacher, and opportunities for field and laboratory experience are equally significant. The introductory program should also permit those who teach it to capitalize upon their own special competences, interests and enthusiasms, but within the boundaries of the recommended objectives. To have introductory courses center in large part around man was deemed an undesirable instructional device.

The conferees believe, and some groups specifically recommended, that college and university administrators and professional colleagues should give more recognition for curricular accomplishments and superior teaching.

Encouraging adequate high school preparation in the physical sciences and mathematics was strongly urged. Advanced college standing for superior high school preparation in biology was discussed; the consensus favored advanced standing on the basis of superior high school courses, provided standards are adequately safeguarded by examination.

College work in the physical sciences and mathematics in relation to the biology program is considered on pp. 43-45 of this report. Some groups discussing particular subject matters within biology (*e.g.*, botany, genetics) also made concrete suggestions on the content of introductory programs (see pp. 61-62 and 67-68).

DIALOGUES ON THE INTRODUCTORY BIOLOGY PROGRAM

I.

Group C at the December meeting; discussion of the objectives of the introductory program in biology (cf. pp. 11-12).

Moore: To start discussion, I would like to say rather dogmatically that for the beginning course in biology our objective should be this: we should recognize that biology is a very broad field; that it's impossible to cover the whole in any meaningful detail in one year and it might be undesirable to do so if we had a longer period of time; and that our objective should be to develop a few important topics in their historical perspective and in sufficient detail to give the student some ability to reach a verdict on the basis of the evidence. In a sense, we should attempt to teach science as well as to teach biology.

Behnke: And by teaching science I assume you mean, at least in part, the scientific process. I say "process" deliberately, rather than "scientific method."

Moore: What I mean is exactly that. If one reads the philosophers on what are the methods in science, one reads what they are: one, two, three, four. But all of us are very much aware of the fact that when you go into any particular topic in sufficient detail, it just doesn't happen that way. It's extremely important for a student to know that there are no hard and fast rules. They so often have the notion that if you inevitably abide by the rules, you are going to make scientific progress. That, of course, is nonsense, a caricature of the methods of science.

Went: I really feel that biology has a content which is quite different from all other sciences and I think that that should be presented to students. Show how the most difficult problems in biology differentiate it from physics, chemistry, geology, so the student gets immediately the concept that we are not dealing merely with applied chemistry or applied physics. Also what I would like to see is that after a student has gone through such a course, then walks outside and sees a tree or a bird, he has some concept of what makes such a thing tick.

Moore: That would certainly be the teaching of biology from the organizational level of the living system and not, as you so aptly put it, as applied chemistry.

Gunsalus: I think I can subscribe to part of both statements. I'm not so sure that the historical perspective should come early. I have a feeling that it comes later, as part of the evolutionary development of the science. You can get interested in things in relation after you have some interest in the particular. I don't mean to say that the perspective isn't important. I am more inclined to think that the core of the problem for biology is the structure, not the structural material but the structure of biology in the sense of Dr. Went. What is biology? It's the living thing, the evolving thing. It can be studied at the cellular level and the address of chemistry to biology is to consider its molecules. But it is not solely molecules. Chemistry is thus a tool that may be valuable in looking at one aspect. Beyond the cell level we have different kinds of organization. Perhaps cells and differentiation are among the primary things in biology. But the main thing that is biology is the ability to evolve. Of course, the rest of science has evolution in it, too.

Moore: But it's a different type of evolution. When you speak of the evolution of the American kitchen, you don't mean quite the same type of thing.

Gunsalus: And astronomy has evolution, too, but it's a different type. It's obviously a directive thing, but it's not in response to certain kinds of environment. It's difficult to explain what a living thing is, but that's the core of it. As you put it, when the person who has had the course sees a bird, he may ask what color it is, but he ought to want to know and know more than this.

Moore: May I ask about your questioning of putting this in its historical perspective? When one is discussing the problem of differentiation—one of the things you mentioned—it helps to some extent when you go over the history of the idea. When I mentioned historical perspective, I didn't mean to relate that this man in that year held such-and-so, but to begin, perhaps, with the whole problem of preformation versus epigenesis and develop the historical perspective of the idea rather than the man. In so many instances, if the student is given only the end result of the long train of ideas and data that lead to the present concept of the subject, he will be on very insecure grounds. Do you feel that way?

Gunsalus: I think perhaps what you are saying means more to me as a method of teaching based on the historical process of getting facts, extracting hypotheses from these, and testing of the hypotheses. One of the teachers who so impressed me, C. B. van Niel, is a man who teaches by this method. It's a very provocative and very forceful one for some people. It may not be for others. I consider it a matter of teaching method rather than part of the substance of biology.

Lee: Isn't it a matter of your perspective—whether you are getting across the history or the substance?

Gunsalus: I think the substance is the important thing. If this is a weapon that allows you to do so, it's a very good method.

Behnke: This also gives the student the idea that science isn't fixed. It's a moving process. So often students are learning a series of facts as though they were static.

Gunsalus: A lot of it comes back to how science progresses. At the start there are a number of observations, which there is a tendency to generalize. What you're really doing is stating hypotheses. You have not demonstrated anything or established anything because your hypotheses may not be compatible with each other. The question is whether you can design an experiment to get new information. If this can be done and it falls into line with your hypothesis, then you may be moving toward a generalization. More than likely—in fact, almost always—the hypothesis has to be modified two or three times; then it has merely been a weapon to guide you to design experiments, you build a house of cards, knock that down; build one of slightly stiffer pasteboard, knock it down; and so on.

Contance: I think that your general themes are unexceptionable and one would not be likely to quarrel with them until one came to the question, what are the few important topics that you are going to tell them?

Moore: The point was—you may or may not agree—that you should not attempt a once-over-lightly of the whole field—and in many courses and textbooks that is done. Would you rather have that or a little strength in depth?

Constance: I wouldn't want extremes of either. Take one approach mentioned this morning—picking out a single idea, seeing what was known about it at one time, jumping perhaps two hundred years, studying what was known about it then, and so on. I'm not sure that's what I would like.

Moore: No. What I meant is this. In the old biology course you went over all the phyla of plants, and then all the phyla of animals; at the end, if you had time, you had perhaps two lectures on Mendelism, one on embryology, and maybe one on ecology and importance to man.

Constance: No, I don't like that. But there again the question is, what do you want to include? I think we could all say that the basic facts of heredity must be included, the basic physiological processes, and so on. Then you come to the question of structure. Everyone would agree that cells and the differentiation of cells is important. Some may then say that the structure of organisms is not important—that's just a detail. But certainly to the layman—and we're talking about the same kind of course for students whether they go on in biology or not—if you fail to relate the basic, common things you're talking about to the world around you, I think you are somehow not carrying all the way along. These people, in general, are not going to see cells differentiating *in vitro* or something of that sort. If you stop at this point and don't go on to a tree trunk, let's say, I don't think you've really made the contact. I don't know how you do this without in a sense getting involved in this tremendous survey. However, perhaps we're really talking about the same thing. I certainly do not believe that the student should learn all the names of all the organisms or all the groups of all the organisms. I do think they have to have somewhere, sometime, a sampling of them, so they make the full contact. As Dr. Went said, so that when they see a plant, they look at it not just as a plant, but as something in which a lot of interesting things are going on.

Went: Isn't a thing like that more effective and possible in a practical [laboratory] course? I don't see that it can be taught in any other way.

Constance: Well, I'm afraid many of our general biology courses don't have any laboratory.

Went: But without it, doing what you say is completely impossible.

Constance: We do have a one-semester general biology course which has no laboratory. It has optional demonstration sections.

Moore: Maybe we should take a stand on this right off.

Behnke: I think we should.

Went: The beginning biology course should have a practical laboratory, without any doubt.

Gunsalus: If a student doesn't understand when he looks at the tree that certain elements from the soil are taken in by the roots and move up into the stem, and that foods are manufactured in the leaf and move down to the root, then there is something wrong. But I don't know that we can agree as to what detail he should know about the xylem and the phloem. Language is a real barrier to these people. What you do about it I don't know.

Constance: Now let me pose this: I would doubt that anything we would regard as an adequate introduction to biology can be taught in less than a year.

Lee: Do we agree that we should like to recommend a year's course as a minimum?

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Lee: I'd suggest an extension of your first statement to include enabling the students to have a solid, basic grounding that will not have to be repeated in other courses in biology, that will apply to any portion of biology that they go into later, whether it's application in biology or medicine or further work in biology itself.

Moore: I think we would all agree that there should be something about inheritance in the first course. But do you think that all of the inheritance should be included in the first course? That there is no need for genetics as a later full course?

Behnke: No. What he means is that the student would have a basic understanding of the major process; he would be able to build upon it, would not have to go back and learn the fundamentals again.

Gunsalus: Mendelian principles in themselves aren't enough, either, because this is just one level on which we see genetics. I wonder if, for the initial problem, we wish as an objective to have students understand the kinds of questions that we want to ask of biology, the terms in which we describe it, the various levels on which we look a biological systems. Mendelian genetics is one of them. To me it means that there must be apparatus that remembers things—the principle of information and information transfer comes in. Next, something of what we know about the requisites for information transfer and for multiple transfer. Then, what does this tell you about the apparatus? What kinds of things are there in the cell, just from the standpoint of chemical composition, which could possibly do this? Here are three levels of operation in terms of defining biological materials. And don't we wish them in defining this to handle it so that all this is not just words?

Behnke: One other thing I think should be added, one thing I think has been very sadly neglected. The student should realize that there are many unsolved problems, unsolved questions. I don't think that in the first course students are often introduced to this idea. You don't give them the answers but at least raise the points.

Gunsalus: Make them aware of what questions you would like to address to biological materials.

Behnke: And that these are in the future, that we haven't reached the millennium.

Gunsalus: Well, getting back to the genetics topic, what I meant is that Mendelian genetics is one of the pieces, but it's not all.

Lee: I quite agree that the things you've just mentioned should perhaps be the highlight of what comes out in the section of the basic course dealing with genetics. But shouldn't enough detailed material be given to enable the student to see these principles and applications? Then could you go one step further and say that, if once given, they need not be repeated in subsequent courses?

Gunsalus: Yes. You might spend a few minutes in the later course telling them what they are expected to know, that if they don't they should go back and look it up. But don't spend days doing the job all over again.

Lee: Shouldn't this basic course be something that you build on from then on, that you don't have to go over again in advanced courses? In other words, should it be hard, have substance?

Gunsalus: I think that if it isn't, you have done harm to both science and the individual. You've told them there is nature the way it is and then there is nature some other way, which is what we talk about.

Behnke: By hard you mean it must deal with the real meat, not too hard to comprehend but dealing with things as they are.

II.

Group D at the December meeting; part of a discussion on the introductory program in biology (cf. pp. 12-13).

Anderson: If I may, I should like to approach this problem by considering some of the kinds of people for whom our course would be given if it did indeed attempt to serve students in all fields. I happen to come from a university with a very large engineering school, a large school of agriculture, and a growing school of architecture. No engineer even approximates any interest in biology, and they are the largest single group that we have. In trying to provide a general biology course that might give a "fundamental core" for engineers, we have given quite a lot of thought to what kind of biological experience engineers, who are steeped in mathematics, physics, applications, should have. Once you have decided this, then the big problem is, how in the world can you get engineers to want to take advantage of it? While this is not the purpose of our discussion here, I think it might be something we could think about. Once we have decided what to give, how can we persuade groups who need this kind of education to come into it? Neither the architects nor the engineers have very much interest in adding this kind of experience to the very rich program they have.

Greulach: They are interested in more general cultural courses, aren't they?

Anderson: They are, indeed.

Greulach: But they don't count biology among them.

Weiss: I think part of this is our failure to introduce into the course certain segments, at least, which will appeal to that type of group. I am particularly conscious of this. I don't know how many of you have seen the article I wrote in the *Scientific Monthly* a couple of years ago—"Life and the Rule of Order"—where I showed the aesthetic content of biological objects and how their forms correspond to the rules of architecture. That article has elicited more interest in biology among architects and engineers and such groups than anything else in my experience. It would be quite easy to introduce this in a course. As a matter of fact, one of the failures of many of our biological courses is that we do not exploit the aesthetic content of biological objects. I think there is here a wide-open field, which we should use. If we did this, we would immediately interest people in architecture or in art in general. The same thing is true on the structural engineering side. Introduce just a little material—perhaps only a half-lecture—on the body, its architectural, structural features, fiber structures, comparisons to the building of girders and bridges, the mechanical functions of the skeleton and muscles, and so on. If we can get a few of these things listed right down the line, this will form by itself the irreducible core.

Anderson: I hope that this might be one approach, to recognize the areas where we are missing fire now. This problem has rather forced itself upon me because ours is a rather small institution with a heavy preponderance of engineers. I was thinking of trying to find content that might have an appeal and then using it as an avenue to draw the group into biology.

Greulach: Are you thinking of a special general biology course just for engineers?

Anderson: Not necessarily. I would like to think of some way of bringing an appreciation, an understanding of the biological sciences, to this big group.

Weiss: Is it your idea that the course would have to be tailored to the engineers particularly?

Anderson: I don't know that it would; just a good course. But one might have the kinds of background that they have in mind in order to exploit them.

Platt: I'll take a flyer at an objective that we all might not agree on. That is, that we should have one first course to meet the primary objectives for all students. In other words, we don't need a course for engineers, a course for would-be biologists, a course for non-biologists. One course should satisfy the needs of all these groups.

Anderson: I would buy that.

Weiss: I would agree, and including the specialists.

Platt: Especially including the specialists in biology!

Kidder: From a practical standpoint we must consider the diversity of institutions we shall be appealing to. You have the situation at California that we heard about this morning; you have the small liberal arts college. Take the university with its multiplicity of biological disciplines; are you going to be able to convince them that a single course in biology will do for the various subdisciplines? This is just a practical thing. I don't mean that it wouldn't be ideally suited. In the liberal arts college there is no problem at all. You have a smaller group and I would suppose that, in most liberal arts colleges, the barriers between departments are much weaker than they would be in a university.

Weiss: Would it answer that question if, instead of calling it a course, we call it a program? And say a single program. It may be given in one course or in many courses; but, if many, the program will still have to be coordinated. That can be done—you can expand the content or you can shrink it and it will retain its proportions. This I think is basic, and what we want.

Greulach: I would like to say something on the other side of this problem of the same course for everyone. We have two different introductory botany courses. They really don't differ in material covered but they differ in difficulty. One is for science majors, the other for people who are not science majors. I really think that if we made the course for non-science majors much more difficult than we do, practically all of them would be failing. But it isn't a good enough course, we think, for the people who are really interested and want to learn more.

Weiss: Couldn't you extract the part common to both courses as the core element, and make the differentiation by tacking on something for the science students?

Anderson: What we're thinking of is an attempt to get the broad biological picture across to those who are interested in considerably wider horizons than just the botany part.

Greulach: Our course for non-majors really makes up part of a general biology course. The people in zoology give a one-semester zoology course and the two together make up a year of biology.

Johnson: What happens if a student taking this course for non-majors gets interested and wants to go on?

Greulach: If he makes a B or better, we let him use it as a prerequisite for advanced courses.

Kidder: Does this work out in practice? Is the student handicapped? If not, why can't you drop the other course?

Greulach: I think the other course is better for those who are going on. You can give them more difficult material, can challenge them more.

Kidder: Do we all agree on the meaning of the term "biology" here? The program mentioned is botany plus zoology. Is it biology? What are we going to say about that?

Weiss: I raise serious objections to the notion that biology is just some botany and some zoology. You have microbiology, including virology, botany, zoology, physiology, anatomy, histology, a whole range; when we speak of biology here, I have taken it for granted that the whole spectrum is what we're talking about.

Platt: I would not like to see us equivocate on this point. And it will take strong leadership. We in our department think a biology course should be offered. There are many campuses where this isn't yet done, but there are many people on those campuses who are just waiting for some ammunition to convert their botany and zoology courses into a biology course. And ultimately, if this is the direction in which we think we ought to go, then I don't think we should give anybody a way out by saying that we think biology is preferable, but it's alright if you keep the material in different categories. We should state it very strongly: There is but one really good way to give the basic program for all students and that is in an integrated biology course.

Greulach: My feeling is that you can do it better in separate courses, at least in some places. I feel that either one can work; one system will work better one place, the other system in another place. But the objection many botanists have to general biology courses is that very often the course ends up with little or no botany at all in it, and becomes just a zoology course.

Weiss: May I ask, however, how many students who follow your scheme will end up without having had any microbiology, physiology, down-to-earth cytology, and so on? Don't let's think in terms of whether this is preferable to another incomplete type. Don't we have to develop a third, higher type? This is what we are talking about; it would be all-inclusive and you could not raise those objections against it. . . .

Greulach: I feel that it is better for a student to have a good course in general botany and a good course in general zoology than to have one course in general biology which may not be good. I have the feeling that entirely too often a general biology course is inferior in quality to courses taught by people who really know the more specific field well. The reason is that there are so many people who just aren't qualified to teach the whole scope of biology. Either the botanist teaching the course doesn't know enough zoology or the zoologist teaching it doesn't know enough botany. . . . The objection to general biology is that very often all these other fields—the microbiology, perhaps much of the botany, much of the physiology, and so on—are squeezed out. What seems good in theory is not what you get in practice in a good many places.

Kidder: I think I agree that for this discussion we should take the ideal, not what you fear might happen in specific situations. If we expect to have any influence, we must state what we think is the best situation.

Greulach: I, too, will concede theoretically the general biology approach is preferable. But I do think that, while any biologist should know something about the whole range, he will know more about one thing or area.

Weiss: What you are really against is having one person teach the course. What we are after is the proper proportions of the areas. Then the botany can be taught by a botanist, the microbiology by a microbiologist, and so on. We want to get in the whole spectrum of the life sciences, lay it before the student. Let's put it down on a map; then each institution will find its own way to salvation.

Johnson: What Dr. Greulach is talking about can happen and does happen. But a group of men working together may well each do a better job than they would do separately in their own areas. Moreover, can we in the future visualize that time will be alloted for the student to take a course in botany and a course in zoology? Actually the situation now is that they often don't have to take any biology at all; they merely have to take one year of science—any science. It seems to me that our job really is to shoot for what we believe is ideal.

Platt: When I first spoke, what I meant is a strong biology *program*. How each individual school provides this is its own problem. One place might find it best to divide responsibility for different quarters among different departments. Others would do it differently. But what we here would say is that the ideal course should be biologically oriented and should have the relative balance of content which we will attempt to define.

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Greulach: We could have more good general biology courses—there are good ones already but some aren't good—but the trouble is we don't have enough people who are really biologists. If you want a biology course you need biologists to teach it, not botanists and zoologists, and what we have is botanists and zoologists.

Weiss: How are you going to get biologists to teach if you don't train them as biologists, but keep on training them as botanists and zoologists?

Greulach: I'll support that. Everybody ought to have a much broader training than he has had.

Anderson: Another factor in the situation, a very pragmatic one, is that a biology course usually is a one-semester thing, sometimes two, while, when you have a course in botany and a course in zoology, you usually have two full years devoted to the area of biological science. The fear on the part of many of the botanists and zoologists is that a biology course may be so compressed in content that it will defeat the purposes now served by the broader treatment. The same thing is opposed vigorously by the chemists and physicists when a similar suggestion is made for a physical sciences course. With the very limited time now available to the undergraduate student, this is a very serious problem. Can we compress things into more limited focus? If we could bring them into a biology course without duplication, give enough time to develop the various aspects that you are talking about, then some of the resistance would be overcome.

Weiss: I quite agree. But this is largely due to the fact that too little thought has been given to choosing the proper types of examples. You can take one thing which is pregnant with meaning and get it across in half an hour or you can talk for a whole week about the same subject without getting it across. This selection of examples is what is not being done. I think we ought to lead people gradually to be much more careful in selecting critical and crucial examples, thereby getting away with less time per unit or per discipline.

Greulach: It certainly ought to be a whole year's course.

Anderson: More than that, perhaps.

Weiss: Could I make a practical suggestion? Let's first try to put down on paper what we collectively think is the irreducible minimum that any person who takes biology, the life sciences, ought to get. I would suggest that we put it down under three viewpoints: 1) principles, areas; 2) forms of life; 3) techniques. These are the three parameters with which you can triangulate practically every item in biology.

Kidder: Do you mean every student or a biologically oriented one?

Weiss: I mean every student, across the board.

Greulach: May I go back to what started all this—Dr. Platt's statement about general biology and my argument for separate courses. I think I would agree on this: One course for everyone is a good idea if you gear it to the non-majors. They constitute the vast majority of the students in the introductory course. The majors are going to go on and get a lot more anyway. It seems to me that if we have one course for everyone it ought to be designed primarily with—pardon the word—general education in mind.

Kidder: In my institution nobody majors until they have had mathematics, chemistry, physics and biology. That takes away your problem.

Johnson: We have exactly the same situation.

Kidder: The general course, we find, is quite adequate as training for those who later go into the fields of biology or biochemistry or what not.

Johnson: One of the things that has amazed me is the concept, in operation for many years now, that students major by taking a certain beginning course. It's not so at all. You major by going up a stairs. One small liberal arts college of less than 1,000 students has four introductory biology courses. This seems most amazing.

Greulach: Can I record consensus on one program for all?

Platt: Yes, I like this idea of "program" because we can't predicate what's good in terms of what we have been able to do in the past. Certain words are anathema in almost any biology planning. One is "survey" course. And this idea of "general biology" as a course is anathema to a lot of people. The minute they see the word, they are through with it. But if we talk in terms of a program and the fact that what we teach in this program should be biologically oriented, we get away from the difficulty.

Kidder: Going on, in this single program what do we consider the irreducible minimum?

Weiss: There is one difficulty inherent in our academic system, one of its curses. That is the limitation of present time standards. That's where your course comes in, as opposed to a program. To squeeze it into a Procrustes bed you either chop it off at one end or expand it quite illogically at the other in order to make it fit either a quarter or a semester. It's a ridiculous system. But you can allocate the biological content in terms of proportions, then leave it to the institution as to how they establish it—perhaps by conjoint programming, one person lecturing for two weeks, another for three, another for six, within a program. Thus, we might set a pattern which would be much better in proportions than what we have when we consider the course as a unit. I think we could be freer in designing a program if we did this.

Kidder: The list might be agreed upon but the proportionality might not.

Weiss: That will depend, anyway, on the people you have. All I suggest is an example. It would have the merit that you could expand it into two years or contract it into one year and still retain the proportions. It would be a much more flexible scheme than what we have now when we talk in terms of a course of this and a course of that.

Kidder: On the other hand, our idea of what should be the biggest unit might not satisfy the majority of biologists. But the list of areas might.

Weiss: We certainly wouldn't presume to propose any standard pattern, but only give an example of what at least one group might consider a fair allocation. Maybe others wouldn't buy it, but is there any harm in trying such a thing?

Anderson: If we go to the great biological principles, the great facts that come out of the experience of students of life, I don't think there will be much problem in agreeing on some of them—evolution, for instance; continuity of life, the problem of mechanisms of continuity would be another.

Greulach: You can center another one around the subject of food—how it's made, how it's used; the whole field of metabolism.

Weiss: Yes. However, there is a seriation which I consider important. The student must first get an idea of the uniqueness, the individuality of the species, the individual, and so on; the idea that food does not shape the frog—rather, the frog shapes the food. The same food is shaped in different ways by different organisms. We've got to get this across first. The reason I mention it is because of the impact it has had on our whole social structure, educational structure included, this idea that man is a product solely of his environment. Students come to think the environment is shaping the product, instead of getting the idea that you start out with something to begin with, genetically and otherwise, and all you're doing is transforming, not forming.

Greulach: One of the main concepts, of course, is the interaction of heredity and environment.

Weiss: Well, "interaction" is not as the physicist would use it in that case. The primary thing is that the organism, the cell and so on, comes out with a certain definite individuality, a constitution, as we call it, and we can't do to that just whatever we want. Whatever it does in relation to the environment is selectively picked out, selectively transformed. There is a very important lesson in a seriation of these two things; that's why I would not want to start with food before I give an idea of what the cell is and what it does.

Anderson: The whole problem of differentiation involves these two concepts.

Platt: Maybe we can use the broader term, energy balance, or energetics.

Kidder: My own experience is a little warped because the students I get have all gone through a course in chemistry and at least been introduced to organic chemistry. I do start out with your energetics in relation to organisms in general, picking out one or two types only for illustrations of metabolism and energetics. Then we go on from there to the specialized expressions, the different types.

Weiss: There is, however, one omission in our biology programs now. That is the one-sided treatment of that end of metabolism which furnishes energy—energy consumption, energy production, metabolism, respiration, and so on, while leaving out the other part of the story, specific synthesis. In one case it's important for the organism to recover energy from certain sources; it merely throws away the products. In the other case it's unimportant what sort of thing is used; what is important is the structure the organism builds out of it.

Kidder: That leads on in your metabolic scheme to how the different organisms do build up their own characterstic composition.

Weiss: This, of course, is an area where we know very little. We know very little because it isn't emphasized in biochemical research or anywhere else.

Kidder: Evidently, we can't teach what we don't know. We can only do the best we can at the level we are on at the present time.

Greulach: Well, we know enough to teach them everything they can absorb at the introductory level.

Weiss: Can't they absorb polymerization, fiber formation, formation of structure? They can do that just as well or better than energetics, if it were presented. The physical side of these things is mostly completely dropped out. That's why I make a plea here to introduce from molecular biology both its aspects—the energetics as well as the structural aspects.

Anderson: All of these things can be taught at various levels. If we can get the general types of things that are to be done, then the levels will take care of themselves.

Kidder: Would it be helpful to list, without regard to chronology, the various principles? We have evolution, continuity, growth, genetics, metabolism, structure-formation.

Weiss: Let's call it morphogenesis—meaning growth, differentiation, structure-formation at levels from the molecular up. Then how about group dynamics?

Anderson: You're thinking of ecological relationships?

Weiss: It really goes all the way from ecology of molecular groupings and cells and tissues. It includes statistics. It includes the apparent emergent properties that come when you deal with groups as against individuals. This is becoming a really separate area of biology.

Platt: We don't have systematics in our list.

Weiss: That's a technique.

Platt: I was thinking of the evolutionary aspects of systematics, but that is evolution and

I'll agree that we can put the rest under techniques.

Weiss: How about irritability; more than that, individual and cellular response to stimuli?

Anderson: We ought to find some way of expressing briefly the idea of organismal control of all of its various activities. This seems to me one of the great biological problems.

Weiss: Make it regulation and regulatory mechanisms, including homeostasis, feedback, and so on. It's intimately related to the problem of individuality, for it makes it possible for an individual to exist as such.

Anderson: It's one of the important principles which every biology student should learn.

Greulach: In a way it's an aspect of metabolism.

Anderson: It's more than that because metabolism is under the control of the regulatory mechanism. It goes one way in this organism, another in that.

Weiss: They may or may not work through metabolic mechanisms, but regulatory mechanisms are of an entirely different logical order. Coordination is perhaps one of our major principles in biological activity, group activity of any kind.

Anderson: At least it's a big area—regulatory control we can call it.

Weiss: How about individuality and variability, the whole principle of recurrence of type as against variability of its expression?

Kidder: Can you separate this from genetics?

Weiss: Each genome is put into an entirely novel constellation of circumstance which is new, unique, only there while the particular individual develops, will never be the same again. Then what leeway, what latitude has it while still being viable? . . . How about mutualism? Would that go under group dynamics? Parasitism? Symbiosis?

Anderson: We might put it down to make clear what we mean. Under group dynamics we have everything from the sociological relationship of plants and animals to such things as symbiotic and parasitic relationships. But group dynamics is a very nice word to get them altogether.

Weiss: Cell interactions such as the organizer actions would also come in, as well as protozoan colonies, properties of tissues in culture, etc. Perhaps the problem of organization might be the simplest way to put it.

Platt: And you can have organization at various levels. Going back to your original proposition, Dr. Anderson, let's appeal to the architect now. How about the architectural aspects of organisms?

Weiss: That's part of morphogenesis as I refer to it. Part is something I used to call biotechnology, as opposed to biochemistry and biophysics. It's much more related to building a machine than it is to physical principles as the physicist studies them.

Painter: Under these several titles, where do you get in the fundamental structure of an organism, animal or plant? That's not a principle, yet in a way it is.

Anderson: The formation of this comes under our topic, growth, differentiation and control. The specific details of anatomy and so on, I imagine, would come under our second large category—forms of life. The way they are determined would come back under the principles. Have we exhausted the principles? For the moment I don't think of any that can't be placed under one of those we have. Under this head you can go not only into the organisms but their parts, from species all the way down.

Weiss: Actually, the principles define the framework within which life has to hold itself. Next we describe the specific expressions which we find; they are of interest because they are here.

Kidder: Under your forms or items were you thinking of molecular organization, too?

Weiss: Yes, all the way down from species. I would take up a very disciplined study of a few examples: corn, frog, sea urchin, bacteria, viruses; definite cell types—plant cell, animal cell, protozoan; cell inclusions—nucleus, chromosomes, mitochondria, chondriosomes, some cell products; muscles, brain, roots, leaves, vascular bundles. This is the type of thing we have to get in somewhere.

Greulach: I wonder if this is really a separate topic from category 1 or just the structural and morphogenetic angle of the first main category?

Anderson: It's the physical expression of the operation of these principles.

Weiss: When I speak of "morphogenesis," I mean certain general principles that operate in various settings—aggregation of molecules in building a muscle fiber, a nerve fiber, a plant cell wall, and so on; perfectly general principles, just like metabolism, that are quite independent of the particular system in which they are expressed. Moreover, I am not afraid, from my didactic experience, of bringing the same objects in twice: once as structural description, a second time when that particular description is an expression, an illustration of a much more general principle.

Kidder: Could you differentiate for us between your items and your techniques?

Weiss: Techniques are such things as observation, experiments, history, classification—the scientific process, how it works. What is science? An ordering process for phenomena.

Anderson: Nature doesn't have any arbitrary boundaries at all. Man, because his mind can't operate on a broad canvas, has to set up categories of things. That he does this is an unfortunate consequence of his mental limitations. It tends oftentimes to produce a fragmentation of the individual expression and interest which is destructive to biological progress.

Weiss: And this should be made explicit to the student, even as a citizen, to learn how this process works, how we got to all this knowledge.

Anderson: This impresses me very much. May I expand a little more as one who has been struggling with some administrative problems? In universities you set up departments, which are again highly artificial. They become barriers to intellectual progress. People don't step over the boundaries. We must get people to realize that these departmental lines are highly arbitrary lines set up in recognition of man's mental limitations.

Weiss: Really, much of what we are doing now in biology is rediscovering that, by an artificial process of abstraction, we have singled out from nature certain objects like genes or cell components or cells or organisms; we've artificially dissected them from their connections in their environments and treated them as if they existed in a vacuum in isolation. Now we find out they don't. And we are surprised to find they interact.

Anderson: Yes, and departments become little empires. They're surrounded by fences, and graduate students cannot step over the fences, and so on. So you've compartmentalized artificially areas which could contribute richness and values to one another.

Platt: Where would history come in?

Weiss: All through. When you talk about evolution, don't just give the facts; show how the idea developed. You shouldn't distill the history of science off from the rest of it. I would like to make a fourth dimension which runs through all three of our categories. It would have such points as history, conceptual basis, aesthetic content, application—things to keep in mind whenever you deal with a subject. Those are facets of each one of our topics.

Painter: One thing that bears on this list. You've got to be practical along with theoretical. You face it in this way. In zoology, let's say, we are going to give a common core of courses which we require of all majors in zoology. We have no difficulty at all in arriving at those. Everybody agrees you start out with general biology. Then the major will have invertebrates, vertebrate zoology, cellular biology, development and embryology, genetics, and physiology. That makes a lot of courses. Now you could, by introducing the physiology into your general biology course, take care of part of that need; then introduce it in the invertebrate zoology, where you talk not merely about what's present in an animal but how the thing works. If you keep that in mind, it wouldn't be necessary to offer a separate course in physiology, and the other courses would be very much the better. We face very much the same problem as you were thinking of in your zoology-botany contrast; that is, so many of these people have been narrowly trained and they stick to morphology rather than morphology and physiology, or they want to go entirely into physiology. Blending the two is much the more desirable thing.

Wiess: I can think along that line that this would be quite feasible. First, the principles: suppose we have some general notion of what metabolism consists of, and you give this in a standard example, then structure-formation, energetics, growth, and so on. Second, you deal with specific objects—frog or muscle. When you talk about these, use the concepts and tell the whole story. For muscle, tell how it forms; how myosin and actin and so on are arranged; how coordination of events leads to a contractile apparatus; how, with energy put in, this thing can contract; how this contractile affair is used and changed in the service of muscular adaption in locomotion. In the first part you use a variety of objects that are useful to illuminate the particular concepts. Then you go through the same thing using different concepts to see how they work out in a particular object. This dual type of going through the material can really be done;

in each case students would also study techniques.

Anderson: One thing here has for me a particular appeal. It's been included, but I would like to mention it specifically so that it is not lost. I'm thinking of a general appreciation and understanding by the student of how a scientist thinks and works, including what I call the contributions science has made to man's intellectual resources. Everybody knows the products of applied science, but very few people know what science is and how it works. They are afraid of it, sometimes, and they don't understand. So more than just the scientific method is needed. Show that it gives some joy and satisfaction to people to add to the record of achievements of man's mind. Show how the reach of man's mind has been stretched. This is just not comprehended by most people. To me this is the great central contribution of all scientific work. I'm more and more impressed with this as I talk to people outside of science. Take the lack of understanding of a man who teaches history and English, the statement that the scientists on a college faculty are the most anti-intellectual, backward-looking, mechanically minded members of the faculty. This is thinking of the scientist as a technician, restrained by a rigid discipline into narrow channels of thought. Actually, the scientist is a most creative and imaginative person, as imaginative and creative as the poet or the artist or the novelist. This aspect of science needs attention at every level. . . . When you stop to reflect on how much man has been able to do—the reach of the mind out into space—and how little real pleasure this achievement seems to have given people in general, you see what is needed.

Weiss: We tend to talk a lot about squabbles. But look at the community of interest that makes it possible for a titanic artifact like New York to work at all, or such a thing as the United States to stand up and grow. Consider the human ingenuity and tolerance involved. This is really what science has done. And this is just the beginning. Imagine where we are going.

Anderson: This lift to the spirit is what the student needs to get not only from biology but from chemistry and physics as well—an awareness and understanding of the way science has exploited and expanded man's intellectual resources. And we need to show how long and hard the road has been, how arduous the labor, in establishing the things we regard today as accepted and routine.

Platt: I've recently heard that 1 out of every 20 people who've ever lived is alive today. That makes you stop and think. This is what science has made possible. And what of the future? This is the kind of thing we should show when we talk about teaching science in its historical perspective.

Weiss: But you must do this without again giving rise to an exaggerated arrogance of the scientist. Show students enough of the humility so they realize not only this expanding universe of science but also understand that no matter how much it expands, it is not going to take over all of our human activities.

III.

Group D at the April meeting; part of a discussion on objectives of the introductory program in biology (cf. pp. 19-20).

Bragonier: My idea was to indicate that the scientific process should be primarily illustrated by the examples used.

Bates: Conant's case history method, for instance.

Bragonier: Yes, that would be one kind. But the case-history approach seems to work better in the physical sciences. That may be a reflection of the fact that we haven't really got biological principles. The physical scientist has at least a few more principles.

Phillips: I think this might be an important statement to make in our report. Still, in the beginning course we don't want to convey to the student that biology is in chaos.

Bates: I disagree with that. At least, I've been trying to follow the idea that as educators we ought to rebel against the standard pattern. It seems to me that the story of education in biology now starts out with Biology 1, where everything is clear, but by the time you're ready to write your Ph.D. thesis, it becomes obvious that everything is unclear. Why do you have to go through this slow process of learning in embryology or entomology or whatever that the statements you learned in Biology 1 really aren't quite true? It's become a continuing process of all these things you've learned being gradually unlearned.

Behnke: I rather take a middle position: let's go further with showing them the process, but still we don't want to leave them with the idea that we don't know anything.

Comroe: Part of the problem may be how you teach. Do you teach broad generalizations first and then point out the exceptions, or do you teach from the exceptions or the observations to the broad generalizations?

Bragonier: There is probably some of both.

Bates: Yes, some teachers do one very well, some do the other very well.

Bragonier: I don't see why there has to be or can be one way of doing this. There are probably a lot of ways. Some students can catch it if you give them the observations, then ask "What do you generalize from this?" Others you have to give both the observations and the generalizations, take them by both hands at the same time; otherwise they don't catch it.

Comroe: Can I ask a question here? In the field of teaching college biology, what journals are there?

Bates: Well, the *American Biology Teacher*, but it has a very limited circulation among college teachers.

Comroe: It seems to me that there are many things being discussed in these meetings that ought to be presented and debated somewhere. They can't all be put in the conference report. Some people may have thought of these same things, others may not, others may think of things we haven't. It seems to me there ought to be some place where such ideas can be printed.

Phillips: The Committee on Educational Policies has been considering this problem and some ideas on what to do about it are given in the forthcoming publication, *Improving College Biology Teaching*. Moreover, this is an area to which we hope to give more attention if we obtain a new grant-in-aid for continuing our work.

Behnke: The *AIBS Bulletin* has inaugurated a column on education which may become increasingly important as a medium for the exchange of information and ideas.

Comroe: I think it would be very valuable to have a continuing open discussion of things like those discussed at this conference, perhaps through the AIBS journal.

Behnke: One of the most successful journals in the field of science education is the *Journal of Chemical Education*. This is due to two things: you have a well-organized group of college people interested in educational matters, and you have a brilliant editor over a number of years. Biology so far has nothing like this.

Comroe: Would we like to go on record as favoring some effort to getting out in printed form ideas people have on biological education?

Bragonier: I've heard discussion on this point in meetings of the Botanical Society, the Mycological Society, the Phytopathologists' Society and so on, and we always end up by saying, "Well, we'd better have a journal." And there is no argument, but that's where it stops.

Phillips: I think some small group must be designated to see what can be done about this, perhaps the AIBS Publications Committee.

Bragonier: There is just a little of this kind of material coming out in the *Plant Science Bulletin*. And it's effective. I think anyone who can cause two particular members of our staff to prepare a rebuttal to a paper on teaching—whether they ever get it published or not—has really done a lot.

Behnke: One advantage of an AIBS source is that you would reach a wider group of biologists. Discussion of botanical problems will often bear on the teaching of zoology, and so on.

Bragonier: Do we have any other suggestions on objectives?

Bates: In going over the working paper this morning I noticed that we hadn't included what I have finally gotten around to in my own teaching as the only real objective which I should cling to: the hope that they will go on reading about biology. In an introductory course the big hope is not so much what they'll learn now but that they'll occasionally pick up a book afterward.

Phillips: This did come up at the December meeting and we had a statement in the reports, but you've made it more explicit.

Bates: It still seems to me a good objective. Education, we say, is an introduction to a process that should be on-going through life. This is the aim in English courses, for instance. I don't think they achieve it; people may not too often follow what's being published because of a college course in the Contemporary Novel, but maybe it helps. We could hope they would pick up some of the Mentor paperbacks on science, for example, rather than a whodunit, or the *Scientific American* (an extremely successful teaching aid, by the way), show some interest in the current books in science for the layman.

Bragonier: To this we might add other things students might do in biology instead of forgetting it all after the final exam—hobby interests, for example. In the introductory biology course why shouldn't some mention be made of hobby activities? Moreover, hobbyists have been among the great contributors to the science, those who have gone off the deep end and gotten fascinated by a problem. Where would we have been in botany without the early-day amateurs?

Behnke: In that connection, the AAAS travelling science library needs to be used in college as well as high school!

Bates: Somewhere in here, too, we ought to make a statement about the need for the course creating an interest among those not going on in biology. And that is 90% or 95% or 99% or so of our students.

Smith: Is there anywhere a list of books for the lay reader?

Bates: Well, the beginning of this is the AAAS library. Then there is a book by Raymond Pearl, now out of print, listing and briefly describing 100 books in biology. Let the teacher have this to pass it on to the students. The list is a bit old, but many of the books mentioned are still fascinating things to read.

Raper: All this comes down to another objective: to create an interest, an enthusiasm. Without that you don't get the other things.

Behnke: Yes, that's understood, but we probably ought to make it explicit.

Bragonier: The thing we are getting at is the situation of a woman in our town who has reared three children. She said to me not long ago that the only course she had in college that she really enjoyed was the course in botany. From it she has carried along an active interest in plants and some of this has rubbed off on her children.

Bates: And I think the botanists of my acquaintance have generally done better with this than the zoologists.

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Comroe: May I raise a question here? We are listing the areas we think ought to be included in the general biology course. But how is the college teacher going to know just what we have in mind. For instance, one of the topics is "history of living forms"; looking at the list he may say to himself, "I cover that," check it off, and go on. Yet what he does may not be at all the kind of selection and approach we have in mind.

Behnke: Yes, I think perhaps a quantitative element is missing here, the proportion of time alloted to topics.

Bates: You can't tell them exactly how to go about this business but again there ought to be some way of saying what this group believes.

Behnke: This is a question that another member of the conference was greatly concerned about. You can get a list like this [Summary of December meeting] out of any four or five college catalogs. We need to show what we think should be emphasized, and what other things should be eliminated. These topics in themselves are not going to put across what we are really concerned about. I don't know just how we're going to go about doing it.

Phillips: I think you have raised a very fundamental point and I hope we come out with something more definite either in this meeting or subsequently.

Comroe: The job is too big to tackle in this conference but a special program could easily be developed under one of the large foundations to do the job.

Phillips: We already have one framework for this in the sourcebooks and panels on courses organized by the CEP. We could get a group of people, seek a grant-in-aid after this conference to make a rather detailed study on the selection of material for the introductory program.

Behnke: We've talked about setting up a panel on general courses to carry on just such a more intensive examination of what topics should go into a course.

Bates: Of course, one of the things we need in biology departments across the board, I think, is more emphasis on education.

IV.

Group A at the April meeting, discussing content of the introductory program on the basis of the lists of broad topics proposed in December (cf. pp. 16-18).

Hall: Isn't there perhaps another principle which I gather you would subscribe to, and which we might all subscribe to, and that is this: the proliferation within all of these major biological areas has been so vast that a goal which might have been legitimate, let's say in Huxley's time—to talk about all of these, to sample them pretty thoroughly—is now self-defeating, so that within these areas once again we would hope that each teacher would pick one or a few to him very important subjects and explore them thoroughly, rather than trying to cover all the ground. Now even saying that, I recognize a difficulty. That is, there is a kind of factual matrix in which you have to imbed the consideration of any particular topic. So to me there's a kind of dilemma between coverage and really thorough, significant understanding. But I wonder if the group as a whole would feel that intensive pursuit of a limited number of subjects within the core fields is better than trying to cover everything.

Constance: I think that's what you said before. That's why I was trying to find out what you [Griffin] meant when you said you would eliminate a great deal. I take it you would not eliminate, by and large, the kinds of things that are here but you want to say you can't expect exhaustive coverage of each. You can do genetics by matching pennies; you can do a lot of physiology without ever mentioning an organism. It seems to me this doesn't meet the requirements because there is this matrix, and it seems to me that's what we want to get at.

Griffin: But it seems to me that you don't have to go into all the kinds of diversity that might be represented. When I said "omit" I really meant it. I tried to answer that by saying that I thought there are certain things that should never be omitted from any of these courses and that there are certain other things that should never be included; then there is a second list for which I don't have a good term, things of which a few should be included, but not all, the choice being up to the individual.

Stevens: The second list would be like elective courses—you take a certain number of electives.

Griffin: I wonder if I, at least, haven't been too much influenced by Huxley; that is, having the feeling that it is a shame that we don't give them at least a little about this or that specific type or group or topic. I think that's very self-defeating.

Constance: The feeling that they really ought to know about the Laboubenniales, for instance.

Gunsalus: This is wide of the mark, yet it isn't: if you read the examinations they give to the boys applying for National Science Foundation predoctoral fellowships, you find this same diversity. I can remember the boys arguing about whether they needed to know about the temperature at which something hibernates or estivates. Rather, I think this is the general thing: what are the principles? What is it you need to use, to select from, in illustrating your principles? Or in expanding your principles?

Griffin: There is one guiding concept that might be helpful. It is sort of practical but it is very real. There are certain things that are much more difficult for a student to read up on his own, and these perhaps should be favored in a selection for the course, while there are other things that he can read about more easily.

Hall: Can I ask whether this would be true? If we took this particular list and said there was a spectrum of imperativeness about the topics (perhaps say that genetics is basic in some way), we would then also say that it is true that we should try to give those that are highly imperative better coverage; if a whole field is sort of optional, that is one where we would be more selective. The block-and-gap principle would apply less in a field like general physiology than it would in a field like ecology or behavior.

Griffin: Yes, I should think so. Incidentally, I hate that term "block-and-gap." Isn't it really "block-and-bridge"? That is, we hope to bridge the gap.

Hall: Well, it's really the idea that we feel the student would profit more from intensive consideration of a few topics in a general field than trying to cover them all, but with relationships to others shown. That's where the bridge comes in.

Griffin: Here is a question that troubled me. Do you still have to sell evolution?

Constance: I don't think you have to sell it, but can you teach biology without it?

Griffin: No, I don't think you can, but I think a great deal of the rationale behind evolution, at least as it has been taught, was to demonstrate evolution. The students that I've been fortunate enough to be associated with, I've come to realize, grew up with this idea. You don't need to sell it any more.

Gunsalus: I think probably the salesmanship has been done before they get to college. The college level handed out the material to teachers so students will get it in high school.

Griffin: But this is a nationwide problem and it may very well be that at a large share of the colleges one still has to sell the idea.

I just don't know. Is it something that you can assume people will have without having to sell the conviction?

Hall: I think that I come from perhaps as little enlightened a part of the country as anyone here, and I would think that 89% of of my students are previously convinced.

Griffin: But don't you get a very select group of students?

Hall: At least half of our student body comes from the upper quarter of the local high schools. Incidentally, the objection to evolution is not related to intellect or attainment but to religious background. I get students from a local seminary who come from taking a course in evolutionary apologetics, in how to argue against evolution.

Constance: To me the important thing is that there are certain things about evolution that are basic; you don't have to sell it but should teach the basic things—genetics, for instance.

Hall: Should we say anything about *what* genetics? First there was statistical genetics, then there was cytogenetics, and now there are population and physiological genetics. Do we want to go that far? The reason I think this is a valid question is that I am pretty sure it would be correct to say that in many colleges, particularly smaller ones somewhat far from the frontier, most of the genetics gets about as far as the statistical treatment of linkage, say about 1918, and that's already about forty years out of date.

Constance: Mendel's second law—that's about where many of them get.

Hall: Could we then say "including modern concepts from population and physiological or environmental genetics"?

Griffin: Yes, since this is one of our core subjects, which we are trying to strengthen by the omission of certain other subjects, we can, I think, hope to go beyond the traditional textbook chapter that gets only to Mendel's second law.

Hall: And in regard to evolution, there really has been a new chapter beginning with, let's say, gene-frequency studies. There might be some courses that stop with a sort of Darwinism.

Constance: Well, would you hit it with your population genetics?

Gunsalus: That's where these two fields, genetics and evolution, fuse into one.

Griffin: Could we perhaps reflect that by stating that they are one?

Platt: That's not a bad idea, because you can't talk about one without talking about the other.

Griffin: Of course, there is a certain parochial interest among students in genetics—"Will my four children be idiots if I marry that handsome man down the street?" But this is not the real scientific interest, which is very closely linked to evolution.

Stevens: I think it demonstrates your intent if you put them together as if they were automatically one.

Griffin: What do we mean by environmental genetics, or what would we be understood to mean, and by physiological genetics?

Constance: I think biochemical is more specific.

Gunsalus: This is also bridging the gap again.

Platt: Actually, environmental would be included within population genetics.

Hall: You see, this is again a very positive recommendation, maybe even utopian, because it assumes a certain familiarity with chemical concepts to be acquired before or perhaps concurrently with these elementary courses.

Griffin: Yes, but I wonder if you will comment on this. We have been thinking about some changes in this direction and it occurs to us that perhaps you could get a little way into some biochemical genetics without expecting students to know more than a very limited amount of chemistry. To be sure, you have to name a few complicated compounds but, unlike traditional organ physiology and things of that kind, you don't really have to give very much chemistry.

Gunsalus: Well, we have been doing just this, and the thing that to us is important is that you don't take large *A* and small *a* and move them around, but that you say "adenine" and draw it on the board once. Or, if you say amino acids, you say we're going to talk about this particular one, alanine, perhaps draw it. Students get along fine with this. Another advantage is that this tells the people what they may see if they go ahead. I think very definitely that it should be done.

Griffin: Of course, you do get into some troublesome details here. For instance, what about textbooks?

Hall: That was my purpose in wondering whether we should take, under these very general rubrics, rather specific things which might cause a revolution if taken seriously. I think including biochemical genetics under genetics is a first step.

Griffin: Yes, and could we include the thought that this really can be done at the elementary level, that it doesn't require a course in organic chemistry?

Gunsalus: For an introduction to basic principles.

Griffin: Using a few selected but important examples.

Hall: It seems to me that this same problem, the degree of sophistication on the biochemical level, requires even greater clarification when you get to [structure and function at different levels]. To what extent would we feel that the Krebs cycle with a few structural formulas is something that all people, no matter what their future plans, should go through at some time?

Gunsalus: I think that the basic principle you can distill out of this is that nature moves by single steps and very frequently in cyclical series. Now, if you want to use the Krebs cycle to illustrate the point, you may. If you want to use others you may, such as CO_2 fixation if a botanist wants to do photosynthesis. But everywhere you look you find these chains and cycles of single steps, which are interlinked.

Griffin: But your question is, should a degree of detail, actual names and structures of compounds, be included in this common core which will include many people without chemistry? I find this a little more difficult to see being effectively done without chemistry than I do biochemical genetics.

Gunsalus: I think yes and no. It's impossible to go forward without it. This doesn't mean that you have to teach them what citric acid is and write out the formula for glycerylphosphate, but you may teach one or the other.

Griffin: Yes, but using some real cycle, not a hypothetical one.

Gunsalus: Certainly.

Griffin: And how specifically? If it is the Krebs cycle, should it be all of it, with the names of all the enzymes for all the steps?

Constance: I think there are more people who can reproduce the Krebs cycle than can explain it.

Stevens: Doesn't the *Scientific American* in some of its articles achieve this?

Gunsalus: The names of the enzymes to me would not be important. The principle that would be important is that in biology energy is derived or accumulated in terms of oxidations which are dehydrogenations. The fact that you have a lot of specific dehydrogenases isn't so important but that you have catalytic proteins is. If you know the chemistry, these processes can be studied in detail. But the essential point is to illustrate a way of mobilizing energy into a useful form.

Hall: I have a very great difficulty here. When I start talking about metabolism, I can't stop until I get to this point. Yet, I am very reluctant to say that all elementary biology courses have to go this far. I have a sort of schizophrenia about it. I can see that there might be a perfectly marvelous general biology course which didn't do this.

Griffin: I would agree, much as I think this is important, especially when I think of students who are not disposed toward science. I am thinking of a college-wide course. What does it really mean to have all these formulas? You must really give them a little chemistry along with it—which probably isn't a bad idea.

Constance: You have to do it anyway.

Gunsalus: The thing that seems to me to be wrong is to have the student come out of biology without understanding that an animal or a cell or an organism or whatever level must do certain things to live, functional things, physiology. In what detail you do this is your own business. It seems to me that it might be wrong to say that they should at least have the Krebs cycle. After all, those who come out of our advanced biochemistry course, which we call "The Processes," often still don't understand it.

Constance: Well, it seems to me that students ought to be able to push function down to the point where they can at least eliminate vitalism, and a lot of courses don't.

Griffin: What I try to do is not go through the Krebs cycle but at least take muscle, give the old lactic acid story, tell them about ATP, show a very reduced cycle with glucose, pyruvic acid and high-energy phosphates.

Gunsalus: I don't object to this stage of reduction but I want to put in the principle. We try to generalize at each stage of biochemical advance, but I think ATP has been greatly overrated. It is a side shunt and I think we want to follow the main lines. ATP is a retriever. The basic principle is that there are molecules that can transfer their energy one way or the other, double-ended operators; the one that you give is an example of this principle, one that operates very widely.

Platt: I like that approach because it counteracts what used to be a trend in biology, namely, teach a little course in organic chemistry at the beginning. You can wade through all this but it still doesn't mean anything to the student who hasn't had it before. But if you start at the other end and assume he doesn't have to know anything about balancing equations and so on, he can come to understand that life consists of biochemical change, and then you can give some examples of the way biochemical change goes on. You can say, "This is the way you can move your arm," and go a certain way into the story.

Gunsalus: And then you get to the problem that not all biological work is mechanical work; there are others. Yes, I think we are agreed on the general principle.

SECOND PROBLEM:
CORE PROGRAM FOR PROSPECTIVE BIOLOGISTS

CORE PROGRAM FOR PROSPECTIVE BIOLOGISTS

Further Common Studies in Biology

INTRODUCTION

The conferees agreed that all prospective biologists, after completing the introductory program, should have more intensive training in areas basic to modern biology than first courses can give. Extending through and interconnecting the wide array of biological sciences are a number of basic concepts and phenomena, mastery of which would provide both a comprehensive knowledge of biological principles as currently understood and a desirable background for future specialization. The student's future needs are unknown and indeterminable: his goals and ambitions may change and future discoveries cannot be foreseen; we should therefore give him a solid core of information and understanding early in his career and an inquiring attitude toward biological phenomena that can accommodate expanding, changing interests.

The content and extent of this more intensive training were considered by discussion groups at both the December and April meetings. Group reports from the April meeting, as adopted by the Conference, are presented below.

REPORTS OF DISCUSSION GROUPS

Group A: Anderson, Constance, Griffin, Gunsalus, Hall, Humm, Platt, Stevens

The group believes that five areas should be included in the common core of training for all biologists beyond the level of the beginning course or courses:

1. Genetics, growth and development.
2. Cellular and molecular biology, both structural and functional. The group wishes to call attention to the usefulness of microbiological materials and techniques in the elucidation of major problems in cell biology.

Items 1) and 2) might well be given in the form of courses which all prospective biologists take.

3. Physiological and biochemical principles above the cellular level.
4. Broad education with regard to (a) the variety of living organisms—plants, animals, and microorganisms—and (b) their environmental setting.
5. Some acquaintance with the philosophy and history of ideas in biology and with the evaluation of evidence.

Items 3), 4) and 5) are three necessary areas of experience but they probably should be obtained through study of different material in each biological curriculum, depending upon student interests and the local situation.

Biology students should be encouraged to undertake self-instruction in additional areas of biology.

Group B: Bailey, Chadwick, Greulach, Lawson, Moore, Oosting, Sizer, Weiss

We felt that there should be a common core of biological education for all biology majors irrespective of their plans for future specialization. That is, if a person is majoring in biology, we assume that his primary goal as part of his liberal arts program is a broad knowledge of general biology. Perhaps our meaning can be made clear by this example. In some institutions the prospective medical student takes a prescribed sequence of courses described as a "premedical" major. This is not our concern. However, if a premedical student wishes to major in biology, then our remarks would apply.

First, some general statements will be made:

1. At the intermediate level under discussion, the student should further his acquaintance with animals and plants. This could be accomplished by a survey of the major groups of plants, animals and microorganisms with emphasis on comparative biology, ecology and noteworthy biological phenomena

exemplified by each group. The conventional treatment of the animal and plant kingdoms with emphasis on systematics and morphology should be modified.

2. There should be additional training beyond that required in the first course in searching and critical use of the literature, in making and recording observations in the field and laboratory, in the design and execution of experiments, in the use of logic and statistics in evaluating data and hypotheses, in reaching conclusions, and in the preparation of written and oral reports.
3. In the treatment of each segment of biology there should be emphasis on the modern theoretical aspects of the field and the historical development of its concepts. Facts should be related to conceptual frameworks.
4. There is no "best," and certainly no "single" way to design a curriculum in biology. These suggestions should be adapted to the local situation (size of department, abilities and interests of the teachers, facilities for laboratory and field work, and adequacy of the library).

Our more specific suggestions can be stated as follows:

All biology majors should have, in addition to the first course, further work in:

1. Genetics
2. Cell biology
3. Physiology
4. Developmental biology
5. Ecology

This list would be more helpful to biologists at large if some of the topics that might be included in a given area were enumerated. For example, these topics, in addition to those already presented, have a place in genetics: gene action, the relation of genes to cell metabolism, the use of mutants in dissecting biochemical reactions, transformation and transduction, and population genetics.

Group C: Couch, Creighton, Ginsburg, Kidder, Lee, Painter, Romer, Went

Group C agreed that all biology majors should have, in addition to the basic background of the introductory course, further work in genetics, ecology, cell physiology and cell morphology, and that plants and animals should both be considered in this study. Additional work in systematics, growth and development, physiology, and morphology of plants and animals should be included. During their training students should obtain experience in experimentation and in evaluation of scientific publications.

Although all prospective biologists should study the areas listed above, the group believes that no specific curriculum should be required of all biology students irrespective of future specialization. That is to say, the essential content can be obtained through (a) separate courses for each area (genetics, ecology, etc.), (b) integrated courses, each covering more than one of these areas, or (c) courses in botany, zoology, microbiology and other traditional fields which contain the stipulated material.

Group D: Bates, Behnke, Bragonier, Comroe, Irvin, Phillips, Raper

Group D believes that, following the initial course prescribed in the preceding section of the report, students continuing the study of biology should have a further common educational experience in biology which would include studies in some depth in *all* of the following:

1. Genetics
2. Cellular biology, by which we mean the study of molecular biology and of cellular structure (cytology) and function (physiology).
3. Development, growth, and regulatory mechanisms.
4. Environmental biology, by which we mean the study of the response and reaction to their environment of individuals, populations and communities, and interactions among these entities.

It is recommended:

1. that one-fourth of the student's second-year program be devoted to this study;

2. that the study be arranged either as a single course of one year's duration or its equivalent in several shorter courses;
3. that both plants and animals be considered throughout the study.

The group suggests that in some cases this program might best be achieved through a cooperative effort by a number of faculty members.

SYNTHESIS AND SUMMARY

There was marked agreement on the content of the common core of training which all prospective biologists should have beyond the introductory course or program. Each group advocated genetics, growth and development, cell biology, physiology, and ecology or environmental biology. These terms were intended to identify broad topics, not traditional courses. After discussion on just what material from each area should be included, the consensus was (as also for the introductory program) that suggestions for detailed content could be made only after spending more time on the problem than this Conference could do. In any case, intensive treatment in depth was visualized. Three groups advocated the equivalent of at least two year-courses for this additional core of biological study, while one proposed a one-year integrated course at sophomore level. Both plants and animals, it was generally agreed, should be considered in at least part of this common core. Some groups recommended that both plants and animals be used throughout. One group agreed that both plants and animals should be used in the work on genetics, ecology, cell physiology and cell morphology, but indicated that the additional work in systematics, growth and development, physiology, and morphology might be taken in courses based on either plants or animals, thus permitting a beginning on specialization at this level; another group agreed to a certain extent. No single method of organizing and presenting the materials of the additional common studies was recommended. Some institutions may need to offer one or more courses in each basic area, but with provision for good articulation of courses into a definite program; others might offer one or more fully integrated courses.

Required Work in Related Fields

The Conference agreed that adequate training in biology requires the attainment of sound knowledge of chemistry, physics, and mathematics. Reports of discussion groups for these fields, as adopted by the Conference, follow:

Mathematics Group: Cameron (consultant), Bragonier, Ginsburg, Hall, Phillips, Purks, Weiss

Dr. Cameron recommended the following texts as illustrations of modern approaches in basic mathematics and suggested that familiarity with them would be useful in negotiations with mathematics departments:

Kansas University, Department of Mathematics, 1954 Summer Writing Group. *Universal Mathematics, Part I: Functions and Limits. Part II. Structure and Sets.* 2 vols. Student Union Book Store, University of Kansas, Lawrence, Kansas, 1954-55.

Allendoerfer, C. B., and C. O. Oakley. *Principles of Mathematics.* 448 p. McGraw-Hill Book Company, New York, 1955.

Kemeny, J. G. *Introduction to Finite Mathematics.* 372 p. Prentice Hall, New York, 1957.

Griffin, F. L. *Introduction to Mathematical Analysis.* Revised edition. 546 p. Houghton-Mifflin, Boston, 1936.

We believe that a basic mathematical training should be required for all biology students.

1. The composition of the ideal college course in basic mathematics should be different from most present offerings in that there should be less manipulation of figures and more extensive treatment of broad mathematical concepts and their applications.

2. The training should include sufficient experience with manipulation to develop an understanding of basic mathematical concepts, including the rudiments of the calculus.
3. Basic mathematical training should be essentially the same for all college students: that is, no special courses for biology students are envisioned. However, this does not preclude the use of illustrations drawn from the biological sciences in mathematics courses.
4. Additional experience with statistical methods should be available at the advanced undergraduate level.

Chemistry Group: Roe (consultant), Anderson, Chadwick, Gunsalus, Humm, Irvin, Painter, Raper, Went

Three questions were addressed to the group:

1. What chemical background is essential to the study of the biological sciences?
2. How, under present circumstances, may this be attained?
3. Would a request for divergence from present programs be desirable and in order?

1. It was generally agreed that chemistry through organic is essential to the understanding of biology, that the biologist must have a body of biochemical and physical chemical concepts for advanced work in the dynamic aspects of biology, and that at the major level for a bachelor's degree this represents an essential minimum. Not all of those present favored the inclusion of quantitative analysis in the list of indispensable work in chemistry.

2. Dr. Roe stated that the recommended training in chemistry can generally be obtained in existing courses and in most institutions can be fulfilled in two years. He reported that there are good one-semester courses in organic chemistry; a similar course could be established by many chemistry departments as a 6-hour course in the sophomore year, with an 8-hour freshman course in general chemistry and qualitative analysis as the only prerequisite. In the second term of the sophomore year a two-hour lecture course on the organic and natural-product chemistry of proteins, carbohydrates and lipids could follow the organic chemistry course. If the student wishes, a course in quantitative analysis could be taken in the same term. Dr. Roe also noted that courses now given in some institutions are based on this background and cover biochemistry and those aspects of physical chemistry essential to biology.

3. By formal motion, the group recommended that chemistry departments be asked to consider the development of a general chemistry course based upon organic chemistry and qualitative analysis (equilibria, etc.) as a new approach at a rigorous level. Such a course would be of enormous value to biology in permitting effective teaching of dynamic biology in the freshman year; at the same time it might well be of greater value to the liberal arts student who takes only one course in chemistry than is the conventional general chemistry course. Dr. Roe indicated that such a course is entirely feasible; the main requisites are the preparation of suitable texts and laboratory manuals, arrangements for interchangeability of credits among colleges during the transition to the new type of course, adjustments in courses which follow the first, and changes in entrance requirements of professional and graduate schools. It is also feasible to follow such a general (freshman) course with quantitative analysis, additional organic chemistry and, where desirable, a one-term inorganic course.

A less desirable alternative is to request that chemistry departments consider a second-year course, based on the present general chemistry, which would provide training in organic chemistry, biochemistry, and physical chemistry. This course would not include quantitative analysis. What is visualized is a one-term course of 3-5 hours in organic chemistry followed by a semester course on principles of biochemistry and physical chemistry.

Possible sources of funds to support such experimentation (general chemistry based on organic compounds) in the reorganization of general chemistry teaching were discussed. A number of institutions (among them, California Institute of Technology, Brown University, and Pomona College) are currently experimenting with first courses in chemistry using the organic materials approach. The fact that these courses were not designed primarily for biology students, but were initiated by chemistry departments to improve introductory teaching in chemistry, reinforces the suggestion that this kind of course would be useful both to prospective biologists and to liberal arts students in general.

Physics Group: Palmatier (consultant), Bailey, Behnke, Griffin, Greulach, Sizer

The physics group unanimously recommended that all biology majors be required to take one year of physics.

Course Content: Physicists must determine the content of the introductory physics course, which, however, may be expected to emphasize basic principles and to include modern physics. A group of physicists considered the problem of content for the introductory physics course at a conference at Carleton College in September, 1956. In the resulting statement, "The American Association of Physics Teachers Report on Improving the Quality and Effectiveness of Introductory Physics Courses," they advocated an emphasis on basic principles and listed the following (section 7 of the report cited):

1. Conservation of energy and mass
2. Conservation of momentum
3. Conservation of charge
4. Structure of the atom
5. Molecular structure of matter
6. Waves
7. Fields

A physics course organized to emphasize these principles will be heartily welcomed by biologists.

Physics Laboratory: Applications might well be illustrated in the laboratory, through a careful selection of experiments to be performed. Thus, experiments could be chosen that would be especially appropriate for the biology major. To implement this suggestion, Dr. Palmatier agreed to suggest to the American Association of Physics Teachers that a biologist familiar with the applications of physics to biology be invited to participate in projected conferences on the introductory physics laboratory.

The Biology Program in Relation to The Total College Program

The conferees believe that the primary function of the undergraduate college is to foster the development of literate, broadly informed, and responsible citizens. What every educated person should learn about the life sciences is therefore one of our concerns; another is the general literacy of prospective biologists. It was the consensus of the Conference that no more than half of the total undergraduate program for those majoring in biological fields should be devoted to biological and supporting science courses, the remainder being alloted to courses in the humanities, including English and foreign languages, and the social sciences. Conferees emphasized the importance of encouraging students to develop, as early in their careers as possible, skill in reading, writing and speaking their own language, and competence in reading one or more other languages. Among foreign languages, German is considered most valuable for the biologist and French ranks next, but there is also definite need for substantial numbers of American biologists to be familiar with other languages, including Russian, Spanish, Portuguese, Italian, the Scandinavian languages, East European languages, Japanese, and others.

DIALOGUES ON THE CORE PROGRAM FOR PROSPECTIVE BIOLOGISTS

I.

Group B at the December meeting, part of a discussion on what further experience above the introductory program all biologists should have.

Comroe: There's one I'd like to put on the list. I don't know whether the term is a common one but it came into the medical schools only about two years ago: that's the "project system" for laboratory work. Many biological or medical science departments in medical school now have cut out almost entirely the regular kind of laboratory experiments and in their place require a research problem. Four or five students will be given a research problem and that's their job for at least a month. This involves all the experience that goes into making a scientist. They've got to read the literature; they've got to know the background; they've got to get apparatus assembled; they've got to see if the apparatus works, is calibrated, is suitable for the measurements they are going to make; they've got to make the measurements, add them up, assemble them, evaluate them; and they've got to write a paper on it. That to me is what is a common experience that is absolutely essential for every biologist, one that ought to come in the college curriculum somewhere.

Romer: Of course, many students do get this.

Comroe: I don't mean for a master's or a doctorate, but as part of their essential undergraduate work.

Romer: Yes, I agree they should get it as undergraduates. Sometimes it's called a senior thesis, which may sometimes be literary but would much better be done as a laboratory problem. And I think a good college will require it, at least of a major for honors. This is, in a sense, an elaboration of what we said for the elementary course, that as far as can be done the laboratory ought to be one in which the students act like scientists. The topic on which the undergraduate research is done might be anything. I think this idea ought to be generally agreeable to everyone here. Is that true? That is, that any biologist as an undergraduate should do a piece of original research, no matter what his field—ecology, systematic botany, biochemistry, or what.

Oosting: I would tend to put that under the heading of desirable rather than essential.

Lawson: I wouldn't; it is really essential.

Oosting: Because of the practicality of it again.

Comroe: But it is practical now. At least at some levels you can ask for a foundation grant so that students can be paid during the summer months to do their research problems.

Oosting: When do I do my research?

Comroe: Well, they will probably be working on some aspects of the thing you are interested in.

Romer: What about East Lansing? You have how many thousand students in your elementary course? How many majors do you get? Would it be in the hundreds? If so, and if they all did a research problem, could it be done?

Lawson: Oh, yes, it could be done.

Romer: In a lot of schools they have to apply for honors to do this; otherwise they get a pass degree.

Oosting: You think this could be done with the numbers of people you have?

Lawson: We couldn't do it with our 5,000 in the first natural science course, but our students scatter into a number of different departments. Immediately above us there are departments of zoology, botany, bacteriology, anatomy, physiology, entomology, horticulture, geology and so on. These departments are relatively small in comparison to ours, and they're adequately staffed so the classes are not very large—the individual professor is in charge of classes of 10 to 20. They could certainly do this.

Comroe: There are two ways in which it can be done. One is a real honors project in which the person puts in an awful lot of time and where the results might even be worthy of publication. The other is an experiment which is not headed for publication and in some cases, even an experiment already reported in the literature or a modification of such an experiment. The essential thing is that the student follow the whole process through by himself.

Lawson: There's one thing about this that I'd especially like to support. It puts the student in a situation which he is not used to in most of our college courses in biology today. You take a course, memorize, regurgitate, and give it back, and that's it. In many of our courses in biology the students don't get a chance to get their teeth into anything, to find out what it means to solve a problem. I think that's again one of the major weaknesses of biology teaching. Here we would give them an experience that we would hope would have at least the potentiality of making thinkers out of them, and change the whole point of view in relation to learning. I think this is exactly what we have to do.

Romer: And particularly for the boys who go to medical school. A couple of years ago a lad stopped in to see me. When he was a senior in college he wanted to do a piece of research work, so I gave him a little bit of the normal development of the perilymph, which is very poorly known; he had a lovely time at it and published a little paper. It was a number of years later that he stopped by. He had then been through medical school, had interned, was on a team doing some research job he wasn't very much interested in. That senior project was the one time in his whole career that he had been able to do something by himself that he was interested in, when he had been able to do a little something on his own. What he did as a senior was an event he had never as a medicine man had any subsequent opportunity to repeat.

Comroe: Well, I suppose about a quarter of the medical schools throughout the country let students do some research; a very few require it.

Romer: (It has always struck me as a pitiful thing that medical schools should operate like trade schools, without giving students any opportunity for research.) Does everyone now agree to the undergraduate research idea?

Oosting: I go back to practicality. We have a rather odd system. We could do it, I guess, but in our system we put so much time into our basic courses and still have a research department—each of us has from four to twelve graduate students and all the energy we're talking about here goes to them.

Comroe: I recognize all that. What I'm trying to do is to say to college presidents or trustees or deans that this group feels this is the way a biologist is made; that biology departments can't do it if they are not properly supported; that they need more money, more men, more space in order to train biologists properly. That is the purpose of this recommendation, to press them to provide the means.

Romer: Should we phrase this, then, to say that every undergraduate major should have this experience?

Comroe: You can't do it if you can't do it, but you can use the recommendation as a lever.

Hall: Would the following be considered enough? Within a course, perhaps in only one of the several courses one would take as an undergraduate, there would be projects which call for at least some originality, original projects for each student or small teams of students.

Romer: Yes, that's agreeable. We hadn't mentioned the teams but as long as there is originality and they're really doing a piece of research, that's it.

Comroe: I think that's fine. All we were trying to do was to get away from the cookbook kind of experiments and to get them to go through the whole process of seeing a problem, collecting, evaluating, interpreting data and reporting their findings.

Romer: Now would we like to go back to the subject of areas? Are there any areas for which you would like to recommend further work as being essential? We talked about one without coming to any conclusions—ecology. Are there any others that we talked about as areas for the introductory course that would be essential, desirable or useful to elaborate upon at this second level?

Lawson: I'd like to propose the possibility that there aren't any areas that we should point our finger at as specifically necessary.

Romer: I was in that position. I said earlier that I was going to vote "no" on every field that came up.

Lawson: So I've just made it unnecessary for you to go through all the various areas.

Oosting: One thing I'd like to have kicked around is that you're turning out biologists of various kinds, of which a very high proportion know no organisms except the one they are working on. I think it is very unfortunate that this is true, and I think that a certain amount of systematics ought to be included in a biologist's training. Here I'm pointing the finger more at zoologists than at botanists. I think it's pretty routine for botanists to be required to know plants, but zoologists may get along very happily with one or two animals.

Comroe: What you want, then, is a course in comparative anatomy and physiology.

Oosting: No, on organisms and procedures for classification of organisms, taxonomy.

Romer: I thought you were arguing strongly against that for the introductory course.

Lawson: I am right now.

Oosting: No, I want them to know plants, I want them to know animals, and the system by which they were named. I don't care about phylogeny—I just want them to know about the system, why organisms were separated into groups, why the names make sense, and so on.

Comroe: Couldn't you give them mimeographed sheets that would cover this?

Oosting: No, you want the experience of living with organisms, handling them, sorting them out, so that when you see that plant or bug again you can put a name on it, put it in perspective with others.

Comroe: You wouldn't get that in the first-year course?

Oosting: I should say not.

Romer: By the way, is what you are proposing an elaboration of something in the first-level course or what kind of experience is it?

Oosting: This is an added concept, I would say.

Hall: It's a little reminiscent of something we suggested as belonging in the elementary courses.

Oosting: Though perhaps a little difficult to do with 5,000 students!

Hall: I'm going to state a position which I'm just stating for the first time to myself; I'm not sure whether even I believe it. If it is true that there should be one synthetic course in the first year and if we admit that we fill it out with both botany and zoology, this means that we will probably treat all of the subjects in it less intensively and extensively than the fewer subjects we used to teach in one course. Then, would you think there should be a second-year course in general biology that would elaborate most of the aspects? Here are examples of areas that it seems to me go across-the-board: I would say that in the field of genetics and in the field of cellular physiology there is a great deal of material that is much more advanced and sophisticated than you would hope to cram into the first-year course but which would be extremely useful, if not necessary, for practically all biologists.

Homer: This sounds a little like the early years of the Chicago course.

Oosting: Don't we have to assume that after the first year of biology all these biologists will certainly take other courses, and there may be an expansion of various of these areas, depending upon which ones they are most interested in? My suggestion with regard to ecology was that this is one that would be desirable for all of them, regardless of which others they chose. My suggestion with regard to systematic taxonomy was that I regard that as a definite weakness which many people finishing biology have in their program. I'm suggesting these two things in a slightly different way. I think ecology would be a desirable thing in terms of a general appreciation, but it's not necessary for anyone; but I also think that systematics, or knowing organisms, is a thing we are weak in all the way around.

Hall: I agree with you but I would add a third, something like cellular and molecular biology. But, Dr. Romer, you're a paleontologist interested in evolution; maybe you would say cellular and molecular biology would not be very important for your students.

Romer: No, I wouldn't say that. It depends upon how much they get. That is, a vertebrate paleontologist might like to go on from this point to take some vertebrate physiology, and so on, quite a lot of stuff, but just how much in just what fields I wouldn't say precisely.

Hall: At one phase in the Chicago experiment they had the general course, then the next thing you had if you went on in biology was something called "BZP," botany, zoology, physiology, in which you went into the same subjects but much more deeply.

Romer: With much more lab and much less lecture.

Lawson: The discussion here reminds me of something that was said at the opening session. The comment was that the curriculum we have developed the way it did for a great variety of reasons, and simply left us courses in comparative anatomy, histology, vertebrate embryology, etc., what we now think of as the standard courses through which all students should go. Are we now in the position of questioning their pertinence and suggesting alternatives for them?

Romer: This meeting is so arranged that we're not to consider courses like that until tomorrow, when we talk about how far the undergraduate programs should go toward specialization. All we have this evening is, what do all biologists need? Is there perhaps a major course beyond the first year which all biologists should have—something corresponding to the second year that used to be given at Chicago, which added to and elaborated very much upon what students had in the first year? Is there any feeling on that? In paleontology, I know, I want the boys to have a really good, stiff dose of genetics, not just a couple of lectures. Would that hold for all the kinds of biologists? I don't know whether they should have more cellular stuff, so far as the paleontologist goes. Is there an additional amount of these same areas?

Hall: Then the question is: Is there enough in any area to suggest a full year-course or a quarter- or semester-course? Or is there enough in several areas to suggest a second course in biology?

Romer: Let's take specific suggestions first. Ecology is a definite area in which some members of this group would like to have students get quite a lot more.

Lawson: Didn't you also mention taxonomy?

Oosting: I raised the question of whether there is some way to greater assurance that they will learn more organisms.

Hall: I want to speak in defense of this view. Supposing a person is interested in a biological problem and he is only conscious of one or two organisms. There's a very good chance that the solution of his problem lies in the use of another organism, so that even from the very practical viewpoint of research the broader acquaintance is needed. Also, there's something repulsive to me, as a biologist who was trained 25 years ago, in the fact that our graduate students are coming out without knowing organisms.

Lawson: May I say, though, that there is something equally repulsive to me about the way taxonomy courses are often taught?

Comroe: What's wrong with comparative physiology? Isn't that taxonomy? It tells you what the animals are, how they are different, why they are different. You can bring a lot of things into a course like that.

Hall: What we want is a deeper acquaintance with more living things. I shouldn't think we would basically care whether this were exclusively a descriptive, morphological type of thing versus a physiological type of thing. It should be both, shouldn't it?

Romer: It's part of my feeling, too, that one should learn something about animals some way, somewhere. The world doesn't solely consist of the rat and the mouse and the hamster. There are other animals and they really live full lives outside of laboratories.

Comroe: The most important one is the squid!

Romer: Well, that depends upon whether you are interested in the nervous system or not. Dr. Oosting, you said "systematics," but what you mean is a broader acquaintance with plants and animals?

Oosting: Yes, be able to name them at sight and be old friends with them.

Comroe: What do you want to know beside their names and their classification?

Hall: As much as possible.

Comroe: That's comparative biology of plants and animals.

Oosting: Perhaps, I don't see what you mean by comparative physiology.

Comroe: I mean, for instance, that the structure and function of the kidney are different in twenty different species, and this may be very important to the way animals live. I would also like to study the respiratory apparatus, and the gill system, and the way it is replaced by a lung. I would like to know about what Homer Smith knows about the physiology of the kidney and what Krogh knew about respiration. You would know a lot about animals by that time.

Romer: I don't think it makes much difference whether he attacks it from the standpoint of kidney physiology or I attack it from the standpoint of paleontology—you get acquainted with the animals in any case. If you start from the functional side, you have to move into structure; if you start from the paleontological or structural side, then you want to know the functions. You can tackle it either way and you go across the line if you are really interested. You could also start out with systematics.

Comroe: I think of biology as something dynamic. Biology means life, and life is dynamic.

Oosting: But I want to look at the slug or whatever it is outside, not in the laboratory.

Lawson: Outside, yes, but not where it belongs in some classification system.

Comroe: I think we all agree on the main idea. Every prospective biologist should get a broader acquaintance with animals and plants, and he should start digging in wherever he gets interested.

II.

Group D at the April meeting; part of a discussion on the content of the second-level program in biology. (cf. 42-43.)

Comroe: I think we should see first whether we agree on broad principles and general philosophy for this second program; if we do agree, then it seems to me that our report ought to be mainly one of philosophy, plus an outline of three or four ways in which this might be achieved. But I don't know if we agree on principles yet.

Bates: I suspect that if we have our general first course, giving the student a broad overall view of biological concepts, the second experience ought to allow him to go more in depth into things he finds particularly interesting. He should be able to go on working now on, say, insects or flowering plants. Or is it too early to let him do this as a sophomore?

Raper: If you are interested in personal preferences, I think I would prefer to require a definite program at the sophomore level and after that allow him even a rather high degree of specialization. But at the sophomore level I believe he is still too innocent to be asked to begin choosing his specialty.

Behnke: This is certainly the principle in engineering. There, even when students know the field they want to enter, they are not allowed to decide what courses they will take until they complete at least a two-year basic sequence.

Bates: [From the December meeting] we have the proposal that the second level should cover genetics, cell biology, physiology, and ecology.

Behnke: To accomplish this, what would you think ought to be in the second year? Another general course, or courses in these subjects?

Raper: No, these are basic things, things on which the specialties are going to be based. The table of contents may resemble the introductory course, but the approach is going to be vastly different. The elementary course is there and you can take off from it, and during the second year you can get across some of the more sophisticated of the modern developments in biology.

Phillips: Do you think there are at least two approaches which the group could adopt and still hold to the basic philosophy? One could require perhaps four areas—cytology, either general or cellular physiology, genetics, and environmental biology. These could be taken as an integrated course. They could also be taken as separate courses, one in each area. The latter would conform more closely to present patterns. I'm not suggesting that as a reason for choosing the second method, but only pointing out another possible way of providing the material we want.

Comroe: May I ask a rather detailed question here? What goes into a course in environmental biology? I know what it is, but what do you teach? In December I was in a session where ecology was emphasized a great deal but I am still not sure what distinguishes it from physiology.

Bates: I suspect that in your definition of physiology ecology wouldn't be set apart. For myself, I would like to remove the behavior of the organism as a whole, which is now covered in a great deal of physiology instruction, and the whole behavioral response, putting it in ecology. In giving a course I would start out with what you regard as pure physiology—the whole question of the nature of sense organs, perception, and response to sensory impressions.

Comroe: What do you mean? Light? Touch? That's physiology.

Bates: Well, my ecology takes in a lot of physiology. Then after considering the types of behavioral response, I would go a great deal into the perplexing question of innateness and modifiability. From this I would build up to questions of responses both to the physical environment and to other organisms. Now being in comparative psychology, I would move along to the Tinbergian kind of concepts—sign-stimuli and so on, the governing reactions among organisms. From this I would step along to the structure of populations.

Comroe: Society?

Bates: Society would certainly come in, and and population structure, birth rates, death rates, the concept of populations of single kinds of organisms and the interrelations of these populations with one another.

Phillips: Perhaps we may satisfy the question by saying that ecology is simply environmental physiology.

Comroe: Does this include all psychology—the conditioned reflexes, the United Nations, etc.?

Bates: I think one of the very unfortunate things in biology has been the separation of comparative psychology from physiology on the one hand and ecology on the other.

Comroe: If you were to ask a man in medical school what he means by environmental medicine, he would immediately say, "Environmental medicine means to me how man adapts in the tropics and how he adapts in the arctic." That's the end of it.

Raper: We have a third dimension now.

Comroe: Yes, space medicine comes into this, too. Well, all that, to me, is physiology. Environmental medicine is not really a discrete specialty.

Phillips: Yet this is a different thing from the physiology of an organism and its systems. Of course it's physiology, but now we are involved with the community—the interrelationships of organisms with one another and systems with one another.

Comroe: In your course in environmental biology, would you go into bees and ants and von Frisch's work?

Bates: Certainly von Frisch would have to come into the course. Is he a physiologist?

Comroe: Sure.

Bates: In your sense, then, in a way physiology is biology, with a study of functions as the core aspect of it.

Comroe: Well, I think your course in environmental biology would be a fascinating course and I would be willing to put this into the whole second year. How many think of ecology as being this?

Raper: I would like everybody to remember something we decided on yesterday. Man should not be the primary focus.

Comroe: I mentioned bees!

Bates: Certainly something should be said about symbiotic relationships between orchids and fungi, etc., and the whole field of autecology.

Phillips: May I be presumptuous enough to mention a little article summarizing the 1955 conference [sponsored by the National Association of Biology Teachers]? We had specialists representing ecology, physiology, and several other areas. Each man recommended that this second-level course and the first-level course be dominated by his own particular specialty. Not only that, each one got up and made a strong plea that every time you mention anything, it is physiology; everytime you mention anything, it is ecology; every time you mention anything, it is genetics. His field took in everything.

Comroe: Physiology to me is a very broad term. I use it in the sense of Ralph Gerard's physiological sciences.

Bates: Yes, but Haeckel in the original article where he proposed the term ecology, suggested that one could distinguish between an inner physiology and an outer physiology, and proposed to restrict physiology to inner physiology and apply the term ecology to outer physiology. This still seems to be a rather logical division.

Comroe: The only trouble is that sense receptors happen to run inside.

Bates: Yes, and whenever you analyze behavior, you rapidly get into inner physiology. Every division is arbitrary.

Bragonier: May I toss in the poor botanist's thought on what ought to be in your ecology or physiology or environmental biology? It seems to me that if we are going to do this on a broad scale, plants will have to be a part of it, too. I'll buy what you said; this would all be very interesting. I would toss into it also the reaction of the plant to its environment; the soil; the development of the plant and its associations; its associates in given environments, how they react as societies. Then I would get into something in the way of physical measurements of environmental factors (wind velocity, soil temperature, etc.); east-west and north-south side comparisons; the time of year when different changes take place; temperature and moisture changes which result in reactions of plants of different types; the physiology of reproduction in plants, where photoperiodism, temperature reactions, moisture, humidity relationships are critical. I would get into a little physiology of seeds. You can show quite striking differences in lettuce—black-seeded and white-seeded lettuce—of the same genus; one has to have light to germinate and the other won't germinate in light. I would talk about blue grass, which needs 0.4% potassium nitrate and light to have maximum germination. To me all this is a phase of environmental biology.

Paulson: Why not write a report without using any of these words like anatomy, physiology, ecology, general physiology, cytology, and so on?

Phillips: May I read just a little bit of this [report of the 1955 NABT conference]? "One of the most interesting and fascinating aspects of the reports and discussions of the scientists was the way in which a group of specialists quickly became generalists. There were some interesting arguments proposed to provide for the use of any one of the areas as *the one* around which an integrated course or curriculum could be developed. The effective manner in which these ideas were presented has probably resulted in 6-way split personalities among the conferees. Paradoxical situations were created, however, when each scientist, in an attempt to be fair, insisted that the individual subject could be integrated without any specific reference to the areas by name." Now, for instance, there was taxonomy (one area that we have ruled out here almost totally); we had a taxonomist in the group at Florida: "Taxonomy was described as 'the new dynamic science of systematics which has evolved during the past few years from the older, stereotyped Linnean taxonomy'." Again, "Morphology's primary place of importance was assigned to its role 'as a tool by which it forms the foundation, the superstructure or the protoplasmic bricks for the various topics'." (*American Biology Teacher* 17:26-28, 1955.)

Bates: Well, I'm not advocating environmental biology as a method of unifying biology.

Phillips: I'm not sure it wouldn't be a good one.

Bates: But one of my pet hobbies is to get comparative psychology, outer physiology, and ecology into a more systematic framework. Here you're talking about what's behind it. Some would call it physiology, some call it environmental biology. Is it important what label you apply to it? I think you jump out of a great deal of traditional hand-me-down routine if you talk about molecular biology or studies at the molecular level, the cellular level, the organ-system level, the organism level.

Paulson: It seems to me it's sometimes worthwhile to belabor the obvious and to emphasize that the biological system is a space-time continuum. If you take the time factor into account you are dealing with the dynamic aspect, whatever it is. It's part of the new systematics, in terms of an evolutionary process; of ecology, in the way in which bees communicate the location of food sources, or in the changing structure of a plant community with the advent of a new organism like man. But if you take a transect of any of these, be it the cell or organism or community, at any instant, you have this area you can teach separately as anatomy, but which makes sense only in being part of the continuum.

Behnke: I think the question about environmental biology points up that we have to be careful not to put into our report some terminology that won't mean anything specific to certain people.

Bates: If we said "environmental biology," the person reading it might immediately think only about biocoenoses and geotomes!

Behnke: That's what I mean. Maybe we ought to go back to the specific question.

Bates: Well, can we agree on the areas proposed to be included in this second-level course? "All biology majors should have, in addition to the first course, genetics, ecology, cell biology and physiology."

Raper: There is one rather glaring omission in that list to me. That's something about development.

Phillips: I think the reason development was ignored was that in our group in December there was denunication, to the extent of eliminating it, of the traditional type of embryology course, in which you got embryology instead of developmental biology. In fact, there was almost unanimous agreement to vote that sort of thing out.

Behnke: That doesn't rule out the developmental approach.

Comroe: I was about to ask you, what is the difference between embryology and development?

Bates: Embryology is a rather curious subject in that it takes whatever organism and studies it only up to the moment when it is born or hatches. What comes after is something else. In developmental biology you have much less trouble with this curious separation.

Behnke: "Development" emphasizes all the processes of growth and differentiation, the functional processes rather than merely the morphological results.

Comroe: Development includes changes from conception to death.

Bates: What happened to embryology in botany?

Raper: There isn't too much. Embryology in a botanical system is a rather simple sort of thing compared with what it is in animals, but the distinction that the hatching point is anything critical in a plant has never been recognized. Growth, and the results of growth, are emphasized.

Phillips: One description of embryology is "from germ cell to germ cell."

[The group agreed that a study of developmental processes should be included in the core program.]

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Comroe: [Referring to list of basic areas to be included] We almost have a pattern here. First our students will have genetics, which has to do with processes that determine what an organism is like. Then comes cellular biology, the functional organization of cells. Next, under development, growth and regulatory processes, students study the whole organism. Finally, they go to environmental biology, studying how everything outside affects the organism as a whole. There you have a very good second year.

Bates: We should emphasize that what we are thinking of is definitely not just a rehash of the first-year course.

Comroe: We haven't said yet whether this applies to plants or animals or microorganisms, or all of them.

Bates: Apparently we are agreed that at the second-year level we can't make the plant-animal-protista separation.

Comroe: Suppose you got this recommendation at your university. What would you do? Would you perhaps get together with the professor of zoology and say, "Let's whip up some courses in which we cooperate on this?"

Raper: If we got this, I think we would still do what some of us are trying to do right now. I don't know how far we shall get. We are thinking about developing a second-year course that would do what we have been talking about.

Comroe: Would you perhaps in the same lecture talk about plants and animals?

Raper: Yes. Of course, we already have a single biological sciences department, and this would be a terrific advantage.

Phillips: At Emory we also have a biology department, which would eliminate some problems in introducing such a course. Our elementary biology is given at the sophomore level, after students have had chemistry. Then we do what we have been talking about in courses given at the junior level that are required of all biology majors. In the senior year they may go into botany or zoology specialization. Of course, they don't come out with much specialization, but, so far as we are concerned, this is fine at the undergraduate level. We are in favor of what Dr. Comroe said earlier: that specialization should take place mainly at the master's and doctor's level.

Bragonier: That's essentially what we do. We don't look upon the student who has a major in botany or zoology as anything more than a graduate in science. They are not yet botanists or zoologists.

Phillips: To structure this, could we agree to recommend that this further core of studies be given as a second-year course? Where that is not possible, we can recommend that the topics or areas mentioned be covered in courses provided by the various departments.

Raper: I don't really see why you could not have these areas covered in separate courses. Moreover, in an adequate, integrated course of this kind both zoologists and botanists would have to be involved.

Comroe: I would prefer merely to say that we think the material could in some cases best be given in a single course.

Bates: And this should be a coordinated sequence, not a hash of uncoordinated lectures given by different people.

Raper: I should think that four or five people could share in giving such a course, if the administrative setup facilitates this. Cooperative effort by the people in different disciplines would provide the proper coverage of plants, animals and protista.

III.

Group A at the April meeting. After agreeing that all prospective biologists should take further work in genetics, growth and development, and cell biology, the group took up the question of common need for a broader knowledge of organisms, physiology, ecology, and certain other elements. (cf. p. 41.)

Gunsalus: Yesterday we decided to leave systematics out of the general course. Now do we say that all biologists need an exhaustive survey of the plant and animal kingdom?

Constance: Not exhaustive, but a broad acquaintance.

Griffin: As part of a common core or as part of our third level?

Humm: I think that every biologist should be able to recognize that what he is working on is an animal and to describe that animal in sufficient detail so that other people can recognize it. Let me give an example of what some may be tending toward. A pharmacologist I know has his own classification of animals: there are humans, rabbits, mice; all the other animals are "bugs." So far as he is concerned, since I work on fish, I am beyond the limbo of anything that is conceivable!

Griffin: What you really mean, then, is a common course?

Humm: As far as the first course is concerned, I don't think systematics warrants a place. Basically, the first course is a selling job. One thing that kills off our prospects for zoology faster than anything else is to face them with 21 or 22 phyla, the names of which, the suborders of which, they have to memorize. If you have ever had to memorize the names of the hemimetabolous insects, you'll know what I mean.

Hall: I think the question would be this. If we deemphasize a kind of survey of the living world in the elementary course, should it or should it not be brought back in? In other words, should the microbiologist, for example, know the phyla of animals and their chief differentia?

Constance: I'm somewhat sympathetic with the statement [by one group in December] that "students should be informed more broadly concerning the variety of plants and animals than what they learned in the elementary course, but that this should not be called systematics." It seems to me that some of your biochemical people, for instance, are so prone to think that the particular organism they work on is an absolutely isolated thing with no connections.

Hall: Perhaps we are working our way toward a really basic principle, one that also comes into our earlier talk about ecology. That is the basic question: Should all biologists be to some extent sophisticated general biologists?

Constance: I would buy that.

Hall: If so, then instead of saying that we believe in systematics, which sounds like a thorough and detailed survey, we could say that all biology students should be more broadly educated concerning the variety of plants and animals than they are likely to be after coming out of the first course.

Humm: This should be done for all groups of students. I remember a man who was working in a chemistry department on steroids, obtaining steroids wherever he could get them—sponges, anything. Coming to the zoology department to give a seminar, he said he had the most exciting piece of information: he had discovered, on the basis of his steroids, that the king crab was very closely related to the spiders! He couldn't understand why the whole zoology department burst into laughter.

Anderson: You can think of other horrible examples: the biochemist teaching plant physiology who holds up Elodea and refers to it as an alga. This sort of thing can happen, and it's important to realize that species variations can have very different, distinct biochemical correlates.

Constance: Somehow I would like to hook ecology into this. Could we say, "more broadly informed on the variety of plants and animals in their ecological, or environmental, settings"?

Hall: You might say "more broadly educated in general biology."

Gunsalus: That means different things to different people.

Stevens: Another aspect of this knowledge of variety is the greater diversity of research materials opened up. The fellow interested in a very specific biochemical problem, for instance, may be using the wrong animal.

Gunsalus: At least, whatever he has seen, he has not seen enough. This is a thing that is really beginning to make sense in our division. The boys can all see you must do two things: you must know some biological system or systems very well, in order to know how to control them to get at the new, interesting problems. In addition, you must know the spectrum of biological materials with which you can ask questions.

Hall: I think there are other reasons we want the biologist to be broadly educated in this sense than to know the diversity of research materials. This is but one of many important reasons why the biologist should know more than his own little corner.

Griffin: If we have agreed to leave organ physiology to the third level, we seem to end up with three common-core entities: genetics, cell biology, and this one.

Constance: Isn't physiology in the same bin as ecology? That is, in addition to cell biology, all biologists should have some work above the elementary course in organ physiology and such areas.

Griffin: But they need not have the same work. Botanists may get one course, zoologists another.

Constance: But isn't this true also of the diversity and environmental relations? I'm not sure that the diversity and ecology could be taught in any common core course that would serve everyone.

Hall: I was thinking of it as belonging at this level.

Griffin: And really being something common.

Humm: I can't see any possible harm in having such a common course.

Gunsalus: But I can't see any source of a teacher. Because of numbers you're likely to compartmentalize. Then wouldn't it be better to have a good man here and a good man there, even if each did not quite cover the whole spectrum, than to mess across the fields?

Griffin: In so far as there are common cores, in a big university they run into all the size problems of the first course. I feel just as strongly about this at one level as at another [having small classes confers strong advantages].

Hall: But in some sense we do believe in a sort of pool of common studies, without getting too specific about how it is done.

Griffin: Another point that appeals to me at the moment is combining genetics, growth and development. Do we really need at this level a whole unit of genetics? We have said we want to stress this above the usual present level of intensity in the introductory course. I would hate to see growth and development left out of this common core and perhaps the place to include it is not as a fourth item on the list—which may be already too long —but to do something we have been vaguely talking about, to work up a course combining genetical and embryological principles at the second level. Admittedly, our particular idea may not be generally useful in all kinds of colleges. We were trying to think of something that would really be useful to premedical students, yet would give substantial biology for nonmedical biologists. I admit the botany was left out of this particular consideration. But what do you think about broadening the course to include control of differentiation, etc.?

Humm: Are we thinking about semester courses or what? You will have trouble getting all the genetics you want into one semester.

Gunsalus: Our microbiology students go to the botany or the zoology department for a course in genetics, then they take our course in microbial genetics, which is really biochemical genetics with statistical methods and chemistry included; students in other departments are likely to go to a course in cytogenetics. In other words, perhaps you can't expand genetics beyond one term because divergence then comes in.

Hall: I'm very much attracted to the suggestion. It's related to what we said about genetics for the elementary course. In a way, genetics by itself, statistical genetics, is not really interesting. It becomes interesting when it tells us something about the organism. For a long time we talked about hereditary units and their phenotypical expression. An enormously interesting world of interconnections is now emerging, and I think the basic question is whether some of this material ought to go into the core course. How can genes affect differentiation?

Griffin: It will of course mean leaving something else out, will mean doing a less thorough job of traditional genetics.

Gunsalus: My argument would be that that can be done somewhere else.

Griffin: Then we would ask for further work in genetics, growth and development, and their interrelationships.

Humm: Do you feel this would take the place of classical embryology?

Griffin: In the common core, yes. That doesn't mean that there wouldn't be a specialized course in embryology at the third level.

Humm: But the genetics we have has so little to do with our embryology. At least, I don't think you can do what you propose. The genetics of most of the embryologically interesting forms is not known. True, you can go into a few things like hidden lethals in the embryo of Drosophila, but they aren't many.

Griffin: I would have this course include some traditional experimental embryology, for instance, what is known about mechanisms between gene effects and adult phenotypes, the effects of transplanting nuclei, etc. But it would not use as text the standard chick or pig books.

Gunsalus: Well, I think we're agreed on this area. Now, what about evolution?

Constance: I think we covered that in the elementary course, plus the additional work that now will be included in genetics and ecology in the additional studies.

Hall: I think what was meant here was a high-level course on the modern theories of evolution, to follow the second-level course in genetics.

Gunsalus: I think that would be optional.

Hall: But are we sure that as many biologists as should would know what Sewall Wright, for example, has to say?

Constance: Would this tie to the recommendation of a group for a senior course?

Gunsalus: I don't mean optional in that it shouldn't be included, but rather in the way it is included. We consider Sewall Wright's work in a seminar. For microbiology, it is something that impinges on your work, therefore you should know about it; there is important thought in this area which should be part of your working equipment. But to say there should be a course at the common-core level is to ask too much.

Hall: I am inclined to hold out for a high-level course.

Humm: How far along would a student need to be before he could handle this?

Constance: I'd say this is graduate work. I may be wrong, but that's where we put it.

Hall: Perhaps you're right, if we are to include all the kinds of biologists—perhaps the practical agronomist doesn't need it.

Gunsalus: What about theoretical and philosophical biology, statistical methods, evaluation of scientific writing?

Constance: You might want to say that every biology student before he gets his degree should have some experience along these lines. This might be the common denominator.

Gunsalus: To me they are methods and logic. That means you do not include them in your common core but hire intelligent people who will indoctrinate the students in this way as they go along.

Anderson: I think this an area where a great contribution can be made. I'm distressed at the lack on the part of our students, even at the advanced graduate level, of a knowledge of the history of biological thought, how the mind of man has slowly evolved these concepts, how the parts have been put together. I think perhaps there is a lack of appreciation of just how much has been done in many areas. The very concepts of science, the philosophical foundations of science, are not understood: the necessity for assumptions, the basis for making assumptions, etc. I'm not sure, though, that this is an undergraduate course. Perhaps it should come at graduate level.

Hall: Except insofar as it can be worked into other courses. In my freshman biology we do spend six weeks in the spring reading a series of papers by major students of evolution, beginning with Buffon and ending with Sewall Wright. The whole idea of the unit is to do exactly what you say: to show how we've had to struggle to get and reject and revise ideas, and how this process is still going on.

Anderson: There would be much better appreciation, I think, of the amount of effort involved in the development of the concepts we have, how the mind has worked, and how man today shouldn't be too certain that ideas that seem to have come to the forefront are actually an expression of reality. It would give a perspective, a depth, which I think is very useful to students. Most of them get very little of this anywhere.

Constance: At our institution there is a lot of thought that in his senior year a student in almost any department ought to be encouraged by senior theses, comprehensive exams or some sort of synthesizing courses to try to put the pieces of his undergraduate education together. We feel that departmental majors tend to go out with nothing but a series of courses without ever really relating them. There should be some kind of effort to relate them.

Griffin: The devices you mention may go in the opposite direction. The senior thesis may be the most specialized of all undergraduate work.

Anderson: I rather interpreted what we want as the history of biological thought, a summing-up.

Hall: Perhaps all we should say is that this is part of the training of every biology major, that he should get it somehow, either as a really explicit part of some courses or as a separate course.

Griffin: I keep thinking how wonderful your course must be at the elementary level.

Hall: About 46% of our students enter into it; the rest pretty strongly resist anything with an historical context.

Constance: The argument at my place is whether every student should take philosophy as a freshman or sophomore or whether something of the sort should come in his senior year.

Anderson: I think there is something to be said for having this separate from a fragmented approach in separate and varied courses. There is a synthesis here which should come as a unit. If you take a segment in one course, a segment in another, this might defeat the purposes.

Stevens: You're thinking of a fourth-year "Advanced Biology" for everybody.

Anderson: That's right; I'm thinking about bringing these things together.

Hall: I also give a course of the same kind at the senior level. It's very different from what is in the freshman courses, because it assumes a fairly substantial knowledge of biology. I think it does some good at both levels.

Gunsalus: What about evaluation of scientific writing, statistical methods, design of experiments?

Anderson: That is something apart from what I've been urging.

Gunsalus: I'm not saying it is the same thing, but that it might come out at the same level, perhaps at the senior level.

Humm: Is it possible to have a course on experimental design, on methodolgies, on a very general level—for all biology students?

Gunsalus: By referring to core areas, we mean things to be included, but not necessarily common courses. I would agree that you can't accommodate all students in the same class for a course on experimental design, but I would say that all students should be trained in this.

Constance: If you take a very small department, couldn't you, in fact, by the time your half-dozen biology majors reach senior level, through a seminar or some such device, get across to some extent such things as evaluation of scientific writing, design of experiments, criticism, etc.? Obviously you couldn't do this in one course at a large university.

Humm: There is one other question that, as the devil's advocate, I'd like to raise. Should we consider our common core in the light of how it serves to sell zoology or biology to the prospective majors? The program we have set up so far, I think, sells biology magnificently to a pre-physiologist, or to a pre-geneticist. Does it sell it to a pre-comparative anatomist? Or to a pre-embryologist? All of them are necessary in eventual teaching. Does the pre-comparative anatomist get a great deal out of these courses that are required as musts? It isn't a matter of what he needs. What I'm saying is, does he effectively make up his mind that he wants to become a comparative anatomist while taking these courses? We have already created a terrific shortage of comparative anatomists in just this way. In biology there are many needs. Not all of them are fulfilled by a person with a tremendous background in genetics, biochemistry and physiology. How do you get into the field you're in? By studying under a stimulating man in the field. What will our core program produce? Biochemists in our image?

Gunsalus: No. We are trying to provide a stage from which students can move, a background which we haven't had, or perhaps don't even conceive.

Stevens: But your point is simply that students may be non-stimulated to go into the things that we are downgrading here.

Hall: I think this will come into the third level, where we'll provide morphology, systematics, etc.

Platt: This comes at an early stage, where most of them don't know what they want to do. We're not bending the twig but trying to get a sturdy trunk, from which the twig can grow.

Griffin: We seem to have come to the conclusion that there are four things that should be included: 1) genetics, growth and development; 2) cell biology; 3) broader education in terms of the variety of organisms in their environmental settings than the elementary course provides; 4) philosophy, history, and analysis of evidence. If we mean four separate courses, I'm afraid this may be more than would be realistic. In addition, more physiology would be included in the third level. All biologists would have some, but botanists would probably have something different from zoologists, etc.

Hall: The question of whether this is too much in addition to the introductory course would depend upon how much specialization you are going to allow at the undergraduate level at all. This might depend somewhat on what the proposed specialization is. If it is nursing or forestry, you might have to finish your job in the four years. If it's one of the basic biological sciences, there might be relatively little specialization.

Griffin: This would make a good premedical curriculum.

Constance: I'm worried about dropping physiology at this level.

Griffin: I thought we agreed that we couldn't visualize it as a common element. Our cell biology includes physiology at that level. Beyond that we were thinking of different courses for different kinds of biologists. The line between second and third levels becomes fuzzy.

Gunsalus: Only if you reduce it to courses. If you say that everyone should have certain areas, but are willing to have these presented in several ways in several departments, then you eliminate the difficulty. Then you have to put physiology in.

Constance: Is this it? 1) Genetics-growth-development, and 2) cell biology (by which we meant both structural and physiological aspects, including molecular biology) might perhaps be given in common courses. In addition we think students should have three common areas of experience: 3) supercellular physiology, 4) something about the variety and ecology of organisms, 5) something about philosophy and the evaluation of evidence; the last three might be based on different materials and presented in a variety of ways.

Anderson: There is one other thread we might consider. I believe firmly that through all our teaching in biology we must develop in students a feeling of responsibility for self-instruction; that we should never, in talking about areas or courses, focus too strongly on the idea that guided, supervised study is the only way these young people are going to learn. Somehow in our report we should emphasize that we feel that anyone at the college level is old enough to accept responsibility for self-instruction, and that much of what we regard as somewhat peripheral, or even rather central, should be learned in this way.

Hall: Would you go so far as to say that we should examine people on material we can expect them to have learned even when we do not offer formal instruction on it?

Anderson: Yes, definitely. We are going to have to reduce the number of formal courses. This means that the student is going to have to accept responsibility for self-instruction. I'm just as convinced as I can be that you should not offer a multiplicity of courses but should get fundamental things taught in an efficient manner, then give the student responsibility. This is a principle that should go through all we are thinking about.

Gunsalus: There is also a tremendous impact upon a student when he finds that he can take a problem and get some sort of answer by his own effort.

Anderson: Yet even at the graduate level we get so many who can't see how to learn without guided, supervised instruction, who can't accept responsibility for self-instruction.

Griffin: This is of the essence. We're all agreed on its enormous importance.

THIRD PROBLEM: SPECIALIZING IN THE BIOLOGICAL DISCIPLINES

SPECIALIZING IN THE BIOLOGICAL DISCIPLINES

INTRODUCTION

The conferees agreed that the college should give the student both a liberal education and an opportunity to move into the general field which includes his occupational goal. In this context we may distinguish six groups of students: (1) students who take biology as a cultural major, without planning a professional career in any branch of the science; (2) students preparing to teach biology in elementary and secondary schools, or in adult education programs for laymen; (3) students interested in careers in fundamental research and college and university teaching; (4) students interested in becoming practitioners in the applied fields, ranging from medicine to agriculture; (5) students interested in research and development in the applied fields, including health and medical areas, agriculture, management of natural resources, and industry; (6) students who plan to become technicians.

At the December meeting one discussion group emphasized the view that liberal arts majors, premedical and other preprofessional students, prospective high school teachers and future graduate students in biology do not need to specialize in particular biological areas at the undergraduate level, while students who expect to be ready for certain kinds of technical employment by the time they graduate need opportunity for some specialized training. Another group at that session recommended that students who select a biological specialty upon entering college be shown the importance of broad basic preparation and be discouraged from narrowing their programs too soon. The Conference as a whole agreed that some specialization is desirable during the undergraduate years in order to supply training in depth and to nurture special interests and abilities among students. Some discussants at both the December and April meetings urged that specialized work beyond the core program for all biologists should occupy no more than ten percent of the total undergraduate program.

The biological sciences have fragmented into a host of specialities defined by organisms studied, approaches used, methods of investigation, applications, areas of employment, and other criteria. Special colleges, schools and departments have grown up around most of these biological disciplines. The Conference did not believe that it could or should propose detailed curricula for all these specialties. This is a task for conferences concerned with special fields and for individual institutions. The conferees did believe, however, that they could delineate some guiding principles that might help those interested in the major areas of specialization in designing programs. To do so, the members first separated into groups based upon areas of professional employment: (1) botany; (2) zoology; (3) agricultural and conservation biology; (4) medical biology; (5) precollege teaching. After considering these areas, conferees then divided on the basis of areas of biological inquiry: (1) molecular and cellular biology; (2) regulatory biology; (3) developmental biology; (4) genetic biology; (5) systematic and evolutionary biology; (6) group and environmental biology. Reports from the two series of groups follow.

The conferees emphasized that the small college should attempt to offer only the core program plus a small selection of these specialties. The biology staff could thereby dedicate their time, energy and facilities to the development of a strong basic program. They would not fall into the situation of the two-man department that offers twenty-five different courses. The large university with many biologists and numerous departments, on the other hand, can offer specialized work in many or all of these areas.

REPORTS OF DISCUSSION GROUPS

Categories According to Areas of Professional Employment

Botany: Couch, Creighton, Oosting, Platt, Raper, Went

We recommend no specific courses which the student specializing in botany must take.

However, we recommend that the courses offered by any institution enable the student to obtain, during his undergraduate program, a comprehensive knowledge of the plant kingdom and of the structure and function of plants. This recommendation is based on the assumption that the introductory and core programs adequately cover the following recommended subject matter from the plant sciences.

Emphasis in the introductory program should be placed upon these aspects of biology: structure, physiology (including some appropriate material on molecular and biochemical phenomena) and reproduction, especially of higher plants and animals; growth and differentiation; regulation and control; genetics and cytology; classification and evolution of the plant and animal kingdoms; evolutionary processes and theories; ecology and conservation; involvements of plants and animals in human life. Certain of these subjects should be illustrated by both plant and animal examples, *e.g.*, genetics, cytology, evolution, and ecology. General principles applicable to all organisms should be demonstrated, but the unique aspects of plants, animals and microorganisms should also be recognized. Although living organisms are similar in many ways, there are basic differences among these groups which are of such importance as to require separate treatment. Among these are differences in structure, physiology, reproduction, growth and differentiation, regulation and control, classification and evolutionary history. In these areas separate attention should be given to plants, animals and microorganisms.

While we agree that a fundamental goal in the study of biology is the recognition and appreciation of certain basic principles, we believe that general biology programs should be organized on the basis of the study of plants and animals as functional wholes, objects which can be examined, handled and experimented upon, and that general biological principles should be derived from the study of discrete organisms. The study of individual plants and animals leads to more adequate understanding of the organism as a whole and of the interrelations of its parts and functions.

The study of plants belongs in the college work of every undergraduate for many reasons, including the dependence of nearly all organisms upon the process of photosynthesis, the role of plants in the carbon, oxygen, water and nitrogen cycles in nature, the action of plants in stabilizing and conditioning the soil, and the important role of plants in controlling climate.

Plant science topics which belong in the introductory biology program thus include:

1. Natural history, structure, physiology, and reproduction of flowering plants. Every effort should be made to keep anatomical and physiological details to a practical working minimum.

2. Study of the plant kingdom by means of carefully selected examples, with emphasis upon the importance and methods of classification and upon the evolution of plant groups. Many life-cycles treated elaborately in many courses could be eliminated; consideration of the algal phyla (except Chlorophyta), mosses, liverworts, hornworts, horsetails and club-mosses should be reduced and greater emphasis given to bacteria, fungi, ferns, and seed plants.

3. Mechanisms of evolution and inheritance in both plants and animals.

4. Ecology and biogeography of both plants and animals and their implications for conservation.

The history of botany should be woven into the study of topics listed above. Subjects which lend themselves to historical treatment include photosynthesis, plant hormones, mineral nutrition, evolutionary theory, genetics, photoperiodism, and antibiotics.

Zoology: Ginsburg, Griffin, Humm, Moore, Romer

In addition to the study of cell biology on the one hand, and of genetics, growth, and development on the other, which are recommended for all biologists, a major program in zoology should include substantial additional work on both the morphology and physiology of animals. While the content and structure of particular courses must be left to the discretion of individual departments and instructors, we suggest that this additional work in zoology could be accomplished by two one-semester courses at the junior or senior level, one primarily on physiology and the other chiefly on anatomy. Both, of course, should include laboratory work, and both should involve comparative study of invertebrate as well as vertebrate animals. A minority of the group suggest that it would be better to organize these two courses on an organ-system basis, essentially a year-course involving an integrated study of comparative physiology and morphology of animals.

Ecological relationships and the behavior of the whole animal should be kept in view throughout such courses and emphasized wherever appropriate, but these topics should not be required as separate courses. Similarly, the historical and philosophical aspects of biology should be considered, not in separate required courses, but as part of the subject matter of upper-level courses and of those constituting the common-core program.

While the principles of growth and development form part of the recommended common studies for all biologists, some of the group felt that for the zoologist these studies should emphasize animal embryology. As an alternative, embryology might take a prominent place in the upper-level course on animal morphology.

There should be further optional courses in special areas of zoology, and it is especially important that the more able and enterprising students be encouraged to undertake independent reading and/or research in the field or laboratory. Optional specialized courses should be available as electives only to the degree permitted by the staff and resources of the institution, without weakening the common studies recommended for all biologists and the basic upper-level work for zoology majors on the morphology and physiology of animals.

Agricultural and Conservation Biology: Anderson, Bailey, Bates, Bragonier, Smith, Stevens

We urge greater recognition by agricultural and conservation biologists of the values to be gained through studies in the basic sciences of the way agricultural information is developed, in place of devoting excessive student time to such matters as crop varieties and animal breeds. The speed with which this latter kind of information becomes outmoded indicates the wisdom of providing educational experiences more likely to be of enduring worth. Within the major area the best preparation emphasizes basic scientific disciplines and minimizes specialized, detailed courses.

A single orientation course for all agricultural fields, covering forestry as well as all agricultural specializations, is considered preferable to introductory courses in each curriculum (*i.e.,* replace Agronomy I, Horticulture I, Animal Husbandry I, Dairy Science I, Forestry I, etc., with Agricultural Sciences I).

We endorse, as highly desirable for students in agricultural and conservation biology, the proposal that departments of chemistry be encouraged to develop rigorous first-year sequences in general chemistry based on organic compounds to replace the year of inorganic chemistry traditionally offered.

In line with recommendations on the introductory and core programs, we feel that the most desirable arrangement for undergraduate students in agricultural and conservation biology would allocate no more than one-half of their program to biological and supporting science courses.

Not more than one-fifth of the training in the biological and supporting sciences (10% of the total undergraduate program) should be devoted to studies in the student's specialized agricultural or conservation field. However, we do not wish to attempt to specify the courses or areas to be included in this fraction, for we believe that such decisions must be determined by the student's vocational objectives and by local situations.

Medical Biology: Comroe, Gunsalus, Hall, Irvin, Kidder

Students who plan to make a career of medicine or medical sciences should include in thier curriculum the material suggested for all biologists under the introductory and core programs. Their program might also include additional experience in depth in areas of *dynamic* biology.

Even more important is that the future medical scientist or physician have experience in the design and execution of experiments. At present many medical school curricula provide little opportunity for this kind of experience. This type of activity should therefore be encouraged during the undergraduate years.

The group recognizes that there is unnecessarily wide divergence among American medical schools in their admission requirements. Moreover, there is little relationship between the printed philosophy, as it appears in medical school catalogs, and the actual demands of medical faculties. This results in confusion in counseling students. The rigidity of the printed requirements has also tended to have a constraining effect on undergraduate biology teaching.

In recent years there has been a notable effort, through conferences and special studies, to emphasize the importance of a broad liberal education as preparation for the study of medicine. This we also consider to be sound philosophy and a healthy reaction against the excessively narrow requirements of past decades. The pendulum may have swung too far, however. We believe that the curriculum recommended in this report, for example, would meet both the desire to give premedical students a liberal education and their need for substantial basic work in the biological sciences, chemistry, physics and mathematics.

We therefore recommend that a conference be called to bring college and medical educators together for an exchange of views that might lead to a more nearly uniform philosophy of premedical education. This, we believe, would benefit both biology and medical education.

Teachers for Secondary Schools: Behnke, Chadwick, Constance, Greulach, Lawson, Sizer

The group dealing with special work for biology majors planning to become teachers of high school biology recommends only two additional elements of preparation beyond the introductory and core programs specified in preceding sections of the report:

1. Further study of field biology. The "natural history" approach (identification, ecology) has frequently proven effective in stimulating interest in biology at the high school level, and the teacher is usually regarded as the local expert in such matters.
2. Further studies in methods, such as the devising of interesting laboratory experiments. This course should be taught in a biological department as a thoroughly respectable scientific course but it should yield credit in the Education department, applicable to the education requirements for graduation and certification.

With the addition of these two items, the group believes that the competence in subject matter established in the core program for biologists is a thoroughly satisfactory preparation for high school teachers of biology, and should constitute the minimum requirement for their certification. We strongly recommend that the secondary-school teacher should major in the field in which he plans to teach. The biology teacher is also likely to be called upon to teach general science and often other science courses. The work in mathematics, chemistry and physics included in the core program will help prepare him for this; some study of earth science would also be a valuable adjunct to his training.

We strongly recommend that not less than one-half of the undergraduate training of the prospective biology teacher be in biological sciences and supporting physical sciences and mathematics.

With regard to experience in supervised teaching, we recommend that every potential biology teacher obtain experience as a supervised college laboratory teaching assistant, and that this be counted as an essential part of his practice teaching.

We believe it to be very important that biological departments do their utmost to give status to high school biology teaching, and that to this end they seek to establish and maintain close ties with their own graduates and with other teachers in their locality. Teachers should be encouraged to come to these departments for assistance on laboratory and teaching problems and for help and information on their continuing biological education.

We believe it highly desirable that the major part of in-service training for biology teachers be in biology and the supporting sciences, rather than in additional courses in Education, and we recommend the development of summer institutes such as those sponsored by the National Science Foundation, and similar programs. We think it very important that the teacher be encouraged and assisted in every way to keep up with advances in his field and to associate professionally with other biologists.

Groups According to Areas of Inquiry

We have used here a system for defining biological fields which avoids the problems of making a distinction between morphology and physiology on the one hand, and the problems of dividing biology according to the organism studied in the other. This system emerged from discussion in the Division of Biology and Agriculture of the Academy-Research Council and is familiar to most biologists because of its adoption in modified form by the National Science Foundation. The definition of the field which appears at the beginning of each group report is based largely upon definitions published by the National Science Foundation.

Molecular and Cellular Biology: Bailey, Gunsalus, Irvin, Kidder, Sizer

Molecular and cellular biology: Isolation, structural analysis, synthesis, and reactivity of biological substances; kinetics of biological reactions; diffusion; isolation, structure, and behavior of subcellular components and cells.

Molecular biology considers problems of biology open to definition and investigation by chemical and physical methodologies. This definition equates molecular biology with dynamic biochemistry, with particular emphasis on biological significances rather than physiochemical questions *per se*.

Cellular biology considers all problems of the cell and cell populations, including structure, function (processes), differentiation, and variability below the level of multicellular organization. In certain instances fungi, algae, protozoa, and mammalian cells in deep culture—though multicellular—may be considered in cellular biology in view of their study by the techniques of microbiology. The area of biology thus defined includes bacteriology, or microbiology, and those biological problems of cells, or organisms, among the fungi, algae, protozoa, and isolated mammalian cells, not all of which classically fall within the former disciplines.

For effective contribution as a major or for specialization at the baccalaureate level in the areas of cellular and molecular biology, training will be required beyond that defined in this report as:

Problem 1. A first program in general biology.

Problem 2. Second level, including (a) genetics, growth and development; (b) cell biology, including molecular and gross structure and physiology; (c) associated training in chemistry, physics and mathematics.

The amount and exact form of further study will depend on the extent and sophistication of the work provided in the "common core," the student's background and experience with the methods of science, and the level and nature of the future objective.

In all cases, further training in the following three areas is considered essential:

1. Physical chemistry, one year, based on calculus. Biological studies especially require knowledge of thermodynamics, reaction kinetics, open-end systems, particles, and properties of solutions. Consideration of the properties and behavior of large molecules (*e.g.*, sedimentation, electrophoretic mobility,

light scattering, x-ray and electron diffraction, nuclear magnetic resonance) would be beneficial but should not displace a sound introduction to physical chemistry.

2. Biochemistry. This should include dynamic and quantitative aspects of composition, structure, reactions, energetics, and hormone and other control. Relationship of the colligative properties of solutions to specific biological systems, relationship of the gas laws to respiration, reaction kinetics and possible reaction mechanisms, and elaboration of other principles of biophysical chemistry would be useful.

3. Microbiology. Modern concepts of molecular structure, physiology of growth, the development of the cell and the culture (population), metabolism, variability (genetic and chemical alteration and control), the molecular basis of specificity (including the rudiments of immunochemistry), levels of cellular and subcellular organization, etc., should be included. The biology of viruses, virus-cell interactions, the transmission of genetic material and characteristics, and relationship of nucleic acids and nucleic acid metabolism to function (including biosynthesis) should also be considered. Consideration of the variety of organisms, based on sources of biological energy supply, biosynthetic potential, and survival value in the environmental setting should be related to large biological environments and the natural-selection potentialities of representative microorganismal types.

Regulatory Biology: Anderson, Bragonier, Comroe, Greulach

Regulatory biology: Regulation of functional activities, including metabolism, respiration, circulation, digestion, absorption and assimilation, nervous and muscular activity, special senses, immunological responses, respiration, translocation, transpiration, photosynthetic and metabolic plant processes, photoperiodism and phototropism, role and function of biocatalysts.

For students who plan graduate study in regulatory biology (physiology), we believe that, in addition to the common introductory and core program in biology and the work in mathematics, physics and chemistry required for all biology majors, introductory work in physical chemistry and statistics are essential. Those who are going into some phase of animal physiology should also have work in comparative animal physiology, while those planning graduate work in plant physiology should have introductory work in the phases of plant physiology not adequately covered in the core program.

While it is desirable that prospective physiologists take this additional work during their undergraduate years, it can readily be taken in graduate school, though this may prolong the student's graduate course. Undergraduates, even seniors, do not always know what particular biological field they will enter.

Any other time available in the undergraduate major should be used for biology electives.

Developmental Biology: Creighton, Chadwick, Hall, Humm

Developmental biology: Asexual and sexual reproduction; maturation of germ cells; fertilization; growth; reproduction of subcellular units; embryogenesis; histogenesis; organogenesis; general ontogengy; regeneration; adolescence; senescence.

In order to delimit the field of discussion, the group defined the development of an animal or plant as that period from the formation of the zygote to the advent of adulthood. It was further assumed by the group that the problems of aging in animals and plants would be considered in the first and second-level courses.

Assuming as a working basis that not more than 8-10 hours would be available under normal load conditions for undergraduate specialization, the group recommended the following general courses as essential for students entering plant or animal developmental biology:

1. It was felt that in addition to a broad comparative knowledge in the botanical or zoological field, a student in the area of

developmental biology must acquire a broad understanding of the adult phenotype of the animal or plant upon which he proposes to work. This might be accomplished by the following:

a. Plant Developmental Biology (assuming adequate coverage of plant structure and function in the first two levels). A course in plant morphogenesis, to include both descriptive and experimental material.

b. Animal Developmental Biology. A combined course embodying comparative anatomy, descriptive embryology and histogenesis, which would replace the standard comparative anatomy-embryology-histology sequence.

2. As optional and desirable at the undergraduate level (although the group expressed doubt that the ordinary student would be able to fit them into the schedule), the following courses should be taken as soon as possible: (a) a thorough course in biochemistry; (b) a full treatment of physiological genetics.

Group and Environmental Biology: Bates, Griffin, Oosting, Platt, Stevens, Went

Group and environmental biology: Gross effects of chemical, physical and biological factors on the activities, distribution, and survival of organisms; biocommunities; commensalism; symbiosis; physiological and psychological bases and correlates of the behavior of organisms at both human and subhuman levels.

Our discussion dealt mainly with basic requirements for further studies in environmental biology, which deals with interrelationships of organisms with their physical and biological environment. A number of peripheral fields might be included under the heading, but were not specifically considered in our discussion.

First, we reaffirm for the field of environmental biology the suitability of the program in physical and biological sciences required for all biology majors, as recommended by this Conference.

Second, specific prerequisites for specialization in environmental biology are: systematics, physiology, genetics (including population genetics), and general geology. The systematics requirement could be satisfied by substantial courses in taxonomy or field biology, both in zoology and botany. For future specialization in problems of animal behavior a strong background in animal physiology is also essential.

Genetic Biology: Ginsburg, Lawson, Raper

Genetic biology: Action and behavior of genes and chromosomes; nature and origin of inheritable characteristics and variations; effects of transformer substances; cytoplasmic inheritance; the "family history" of individuals and populations.

We recommend that the first-level introductory program include the following material on genetics:

1. Classical Mendelian genetics, including (a) multiple factors (quantitative inheritance), and relationship to the expansion of the binomial; (b) the relation of chromosomes to genetics, including mitosis, meiosis and chromosome-mapping; (c) sex-linkage.
2. Physiological genetics, using microbiological examples to show the relation of chemical entities to gene action.
3. Population genetics to relate genetics to evolution through the Hardy-Weinberg law and its relation to mutation and natural selection. At this level, instruction need not go beyond simple cases.

These topics can be compressed into a fairly short time by presenting traditional crosses and classical evidence within a treatment of the binomial expansion.

The second level, the common core program for all prospective biologists, should include an examination of the physical nature of the gene by way of the DNA model and relationships of RNA to protein synthesis. This may be correlated to first-level work through microbiological examples. The second-level program should also acquaint the student with such modern branches as viral and microbial genetics. The study of mitosis and meiosis begun in the first level can be carried further into problems of the detailed nature of chromosomes, crossingover, and other cytogenetic phenomena in relation to the nature of the gene. The relation of genetics to evolution introduced in the first-level program should be supplemented at the second level by a study of particular cases in which the student works with actual data.

The third-level program designed for potential geneticists, beyond the core program, should take the student into chemistry as far as biochemistry and into mathematics through a solid course in calculus and a post-calculus course in statistics. The third-level program should also include laboratory experience with a selection of the specific microorganisms, plants, and animals that have been of particular significance in the development of modern concepts of genetics. If the student has also had a physics course that includes modern radiation theory, he should then be well prepared to move into his graduate program.

Systematic and Evolutionary Biology: Behnke, Constance, Couch, Moore, Romer, Smith

Systematic biology: Description of physical and functional characteristics; classification; meaning and integrity of species; "family history" and biological relationships of species, genera, and higher categories; life cycles; evolution.

We believe that one or more courses on major groups of animals or plants should be among the special courses available when student interest and faculty capabilities recommend this. Such courses should be given in as broad a fashion as possible: systematics should be considered in the context of a comprehensive treatment of the general features of the group, including structure and functions peculiar to the group, behavior, relationships, ecology, distribution and evolution. It is hoped that there might be gained through such courses a knowledge of the theoretical basis of classification as well as the techniques of taxonomy.

Some work in geology is strongly recommended for students interested in evolution and systematics, and it is obvious that a knowledge of genetics (included in the core curriculum) is indispensable.

We also recommend that an undergraduate course in evolution, with emphasis on evolutionary mechanisms, be given, and that this be made available to students who are not biology majors.

SYNTHESIS AND SUMMARY

Participants in the Conference agreed that there is room for some specialization within the diverse areas of biology during the undergraduate years. A limited amount of specialized study is desirable because the field of biology is too vast for an individual to master more than a segment and because the college program should encourage individual development according to interests and abilities. Moreover, the curriculum must equip graduates either to work as agriculturists, technicians, precollege teachers, foresters, sanitarians, and junior biologists of other kinds, or to continue their studies in graduate and professional schools. It must also be remembered that many undergraduate students do not know what field they want to enter, nor what branch of the field; they need room to explore, and basic programs which permit a shift from one field to another.

Specialized study should be built upon the kind of introductory program in biology and the kind of core program for all prospective biologists recommended in the first sections of this report. Discussion groups considering the needs of different kinds of specialists all emphasized the suitability and importance of these basic programs as preparation for their fields.

All groups also insisted that the specialized courses should occupy only a minor fraction of the undergraduate program. In general, they recommended that half of the student's pre-baccalaureate work should be in languages, English, the humanities and the social sciences, and half in the natural sciences and mathematics. Only about ten percent of the total program should be devoted to biological specialities. This means the equivalent, in most cases, of no more than three courses of four semester-hours each. Students who enter with advanced standing and those who take more courses than the minimum usually required for graduation will, of course, be able to spend more time as undergraduates on specialized work. Broadly speaking, however, training for a particular field can only begin in college; what is done there should be regarded as part of a sequence that will continue into on-the-job training or further study in graduate or professional schools.

The enthusiasms and interests of the local staff inevitably will and emphatically should determine what specialized courses an institution offers. This point was made repeatedly during the Conference. Both as biologists and as members of an intellectual community, the conferees were insistent upon the need for being aware at all times of the special importance, in any educational program, of the individual student and the individual teacher. Thus, while they urged that the instructor designing an introductory course very seriously consider the objectives and content discussed at the Conference, they recommended with equal vigor that the specific form and content of an introductory program should reflect the character of the college and the individuality of the instructor offering it. They believe that the best biology courses will aim at the objectives and include the content cited, but they also believe that this can be done in a great many ways, that the introductory program can take many forms. The same principle is equally valid for the second and third levels, the core program for all biologists and specialization.

The recommendation that the time spent on a biological specialty be limited has another important implication. If the student can take only a few courses, they must be of particular value to him. Biological departments should scrutinize their offerings with this goal in mind, and should especially consider what topics should be deferred to on-the-job training or to professional schools and which subjects most justly belong in the college or university.

Specific recommendations for different disciplines naturally emphasize only what the discussants deemed essential. Beyond this, many undergraduate courses in the biological sciences can and should be offered as electives for individual students. Naturally, the single biology department in a small college should restrict its electives in order to give adequate energy and time to the first- and second-level programs and a very few specializing courses, while the large university with many biological departments can offer a large number of these electives. Even in the smaller institution, however, the development of broad courses and the introduction of opportunities for individual study (project courses, senior theses, undergraduate research) will enable student and professor to follow topics which attract their interest.

Conferees looked at the specialties from two points of view, as occupational areas and as approaches to biological systems. The two intersect in all directions, and within each classification categories are by no means mutually exclusive. A prospective high school teacher, for instance, might be particularly attracted to the plant sciences and especially interested in physiological genetics, which involves a combination of developmental biology and genetic biology and bears close relationships to molecular and cellular biology. In the same way, the special "courses" recommended by different groups are not necessarily different courses. The same good course in general biochemistry will serve equally prospective concentrators in regulatory, molecular and cellular, developmental, and environmental biology. Similarly, the course in comparative animal morphology advocated by the Zoology Group might include the study of anatomy, development and histology advised for the zoologist interested in development. Other combinations of the recommended specialized courses can readily be conceived.

The main recommendations on third-level studies can be briefly summarized, it being understood that all groups advocate the first and second levels of basic work and a locally determined variety of further study:

Botany. No courses were recommended as essential for all botanists, provided the plant sciences are properly represented at the first and second levels. Choice of advanced courses will then be determined according to special interests within the plant sciences.

Zoology. Intensive study of comparative animal morphology and physiology, given as an integrated year-course or two one-semester courses, and a choice of further electives were recommended.

Medical Biology. For undergraduates preparing for medical study further study in depth in dynamic biology was advised, and experience in research was considered highly desirable. Efforts should be made to minimize differences in entrance requirements among medical schools and to bring the published requirements into line with the real requirements of medical faculties; a conference of college and medical educators should be organized to explore ways and means of accomplishing this.

Agricultural and Conservation Biology. Students in fields like agriculture, forestry, fisheries, and wildlife management should take stronger programs in the basic sciences, preferably a single common orientation course to this whole area of applied biology, and no more than ten percent of their program in specialized courses.

High-School Teaching. Prospective high-school teachers need the first- and second-level programs, a course in field biology, and a course given by the biology department but carrying education credit on methods of using biological objects in teaching. Teachers should obtain part of their experience in practice teaching as teaching assistants in college laboratories. Biological departments should strive to help give status to high-school teaching, to prepare competent students for this important role, to cooperate with teachers in the schools, and to encourage teachers in service to obtain most of their graduate education in biology and supporting sciences by making suitable courses available.

Molecular and Cellular Biology. Physical chemistry, biochemistry and microbiology are essential.

Regulatory Biology. Physical chemistry, biochemistry, statistics, and further study of comparative animal physiology or plant physiology are essential; microbiology is desirbable. However, part or all of this can readily be taken in graduate school.

Genetic Biology. Biochemistry, calculus and a subsequent course in statistics are essential, along with a thorough familiarity with the principal objects of genetical study; some or all of this can be deferred to the graduate years.

Developmental Biology. The botanist in this field needs a course in plant morphogenesis; the zoologist, a course sequence or, better, an integrated comparative course in anatomy-embryology-histogenesis; courses in biochemistry and physiological genetics are desirable, if time permits.

Group and Environmental Biology. Advanced undergraduate or graduate study should include geology, comparative physiology (including psychobiology for those interested in animal behavior); genetics; and systematics (plant, animal, or both).

Systematic and Evolutionary Biology. A knowledge of geology is desirable and genetics is indispensable. Courses on the broad biology of particular groups of organisms should be available. An undergraduate course in evolution would be useful both to biology majors and to non-majors.

DIALOGUES ON SPECIALIZING IN THE BIOLOGICAL DISCIPLINES

I.

Group on Agricultural and Conservation Biology at the April Meeting.

Bragonier: Here is a situation that seems to be not at all uncommon. In our agricultural curricula there are introductory courses to the point of nausea. There are introductory courses in horticulture, in landscape architecture, in agronomy, in animal husbandry. Presumably these are to orient the student to his major area. But to do this it is necessary to teach a little introductory botany or zoology. At the same time the student may be taking the introductory course in botany or zoology to get ready for advanced courses both in basic biology and in the applied areas. This giving of a little botany, for instance, often doesn't work very well; we have to spend a good deal of time straightening out misconceptions and it involves a tremendous lot of unnecessary duplication. We don't quite know what to do about this. Perhaps the basic biology course is what we need to give first.

Bates: This is one aspect of a very general educational problem—every subject seems to require its introductory course. That's all very well, but if you want a broad, general education, you may end up with four years of introductory courses. This can get very dull—they overlap, they don't carry the student into anything in depth. We need courses for giving information about the subject, not for "introducing" you to it.

Anderson: Isn't our problem here the degree of specialization? How much should the student be allowed to emphasize the applied specialities—agronomy, wildlife technology, forestry, entomology, plant pathology, etc.—at the undergraduate level in relation to broader basic areas? There is a very natural tendency for the faculty in a specific area to feel that if they don't get a student early, they won't get him at all. The result is a tendency to multiply special fields, to multiply courses in each field. I myself feel that such specialization is undesirable for several reasons. First of all, the student often does not know just what he wants to do or will eventually do; he may later find himself in a position where a restricted training is a considerable handicap. Second, what really is the best type of training? Even if a man continues in a special field, should he take many courses in that area or should he get broader work in the basic sciences? Should the student develop in the last two years any appreciable specialization in a specific field? If so, how much? This is a matter of active concern in some institutions. There is no unanimity of opinion on the question. Take a plant pathologist, for example; some feel that you can't train a pathologist in four years.

Bragonier: I think there would be 90% agreement on this.

Stevens: I think so. Plant pathologists were once polled on what courses a student should have as an undergraduate. Had a student undertaken the resulting curriculum, he would have graduated as an old man, and have had nothing but applied material.

Bates: What should the fellow who is going to be a plant pathologist do as an undergraduate?

Bragonier: Any of the good solid undergraduate curricula in agriculture or science.

Bailey: We have a curriculum in agricultural science specialization. All majors, whether in genetics or plant pathology or whatever, get good solid basic science; in their senior year they get some courses in their specialty.

Anderson: I believe this is a sounder approach, to get training in depth in the basic biological sciences rather than the applications.

Bates: What about entomology?

Smith: With just a slight modification, I'll go along 100%. I think we do have a place for an undergraduate major in entomology. It might even drop into a two-year type of curriculum. We have two outlets for students. One is pest control operators; there is big market for them, and they can make a good living. Here is a possibility for a terminal course. The other is the student who is going on in entomology through an advanced degree. His situation is quite different; I would prefer that he have practically no entomology at all as an undergraduate.

Stevens: Provided he has something solid in its place. It isn't the absence of entomology but the presence of other things that you want.

Smith: Yes. Often we get graduate students who have had all the entomology courses in the book, so they come for a doctorate. We have to send them to take fundamental courses, not entomology. It's a ridiculous situation. If we could get them to take the basic work as undergraduates, in the long run we would have much better entomologists.

Bragonier: I think you would find this point of view pretty well throughout entomological as well as phytopathological circles.

Bailey: I'd like to go back to the question of introductory courses. I used to think as Dr. Bates does, but began to change my mind a few years ago. My daughter took some of these courses and pointed out the following. When you look just at the introductory courses, they may look like a waste of time, as determined by the fact that everything you learn there is repeated later anyway. On the other hand, the survey course was full of empiricisms; at points it left students high and dry because they didn't have enough background to understand what they were talking about. But when they then encountered a course in pure science and were being taught the fundamentals, they began to see the answers. The science course became much more virile because they began to find answers to things that had been puzzling them.

Bragonier: That's very good. But there's this problem: agronomy students may take three survey courses—in agronomy, in horticulture, and in botany.

Anderson: You can deal with this in one course. We have an introductory course in the Problems of Agriculture. A 1-semester, 3-hour course, it gives each department two 2-hour periods to present its problems.

Bragonier: We have that, too. We call it "Orientation," and that makes four introductory courses for the agronomy major.

Anderson: The man who teaches ours tries to shock students into thinking. Then they go into the basic sciences. We have no departmental orientation courses.

Bailey: Don't you suppose these introductory courses arose over the years from problems of counseling and guiding students?

Anderson: Yes, and another factor is parental pressure. A student comes to study agriculture, goes right into basic sciences, doesn't see any agriculture until his junior or senior year. Parents can't understand it. Nor can students, particularly if they have to leave at the end of one or two years; they will have had nothing that brings them at all in contact with agriculture. We didn't have the orientation course in agriculture for a while but took students directly into basic science. There were numerous complaints. Mortality is heavy; many of the students are from rural schools where preparation is poor, but are put in basic chemistry, physics, biology, math. So the course served two purposes—to acquaint students with the problems of agriculture and to give early contact with the thing they are interested in.

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Stevens: Can't we have the terminal curricula not necessarily terminal, warp them a little bit in the direction of the pre-graduate curriculum, so that the student who gets interested and really wants to learn something will be able to shift from the terminal track to the other? But we might as well face the fact—or maybe I'm being unfair—that it will be more difficult to do the kind of thing we have talked about [at the first two levels] in agriculture than any place else—even premed.

Bates: I've gradually accumulated a rather acute feeling that agriculture is a rather depressed area in education. Many of our experiment-station projects are being relatively unproductive idea-wise as compared with, let's say, English stations like Rothamsted. This is something that seems to have crept up on us, perhaps as a result of all this specialization which tends to isolate people without giving thorough general background. From a general view, when they have concentrated on agriculture that has been remarkably successful in a particular area, for instance, when American experts come into a South American country, they're quite lost because they have a vocational training extremely well adapted to Wisconsin. All they can do is to try to move Wisconsin methods to the new place. I can't help but think that what we have to do is give a better background in botanical-ecological factors involved in what we are trying to do in cultivation, that we haven't given enough theoretical background for it, that our whole agricultural educational system has in a sense got caught in the same training trap as medicine.

Anderson: I think this is a very interesting and very important thing from the standpoint of educational policy. The tendency is to train people in the know-how prevailing at the moment, not realizing that you should be preparing people to meet new problems of 15 or 20 years in the future. In agricultural curricula people were first impressed with the utility of learning the particular varieties of corn or wheat that could be successfully used in a particular place. Now they realize that these are transitory things, that cultivation methods are transitory, that all of the practical aspects are going to be altered as research goes on. There has been a shift to recognition of the adaptability of basic knowledge in many directions. This is changing the training of the agriculture student very strongly away from the practical toward the basic sciences, in the hope that these men with a knowledge of the fundamentals will have a base with which to confront the problems of Colombia as well as those of North Carolina. The training of 20 years back—learning best varieties for this state, that sort of thing—is now disappearing, and should disappear. It's just like courses in methods in the graduate school. This always disturbs me. A new instrument comes out; everybody's got to learn how to use it, so let's have a course about it. But five years from now the method's superseded. What we need to worry about is training in the basic principles that underlie these developments. The techniques I learned as a graduate student in plant physiology are all gone—we don't use them at all. The strongest training a man can get in the basic areas is the best preparation. The university ought to provide this, even in the applied areas—agronomy, animal industry, etc.

Bates: But here we have a difficulty mentioned a bit ago. You are dealing with a student body sent to college by parents who want the students to have something they can see and use.

Stevens: That's a real problem. In my own teaching of plant pathology I refused to deal with spray schedules; I merely told them their fathers and county agents knew more about a spray schedule than I did. But this was not warmly received by the class. In these agricultural areas more effort by persons who feel as you do is needed to keep the pressure on, to keep this change moving along. The counterpressures to get back to varieties of barley and so on are very strong.

Bates: You can make a similar case in medicine—pressure for specific know-how.

Bailey: I would like to point out another very practical problem. A very considerable percentage of our graduates in technical agriculture go into industry. In protecting those youth so they may qualify for a job, you've got to give them a chance to learn the varieties of hybrid corn and so on; otherwise they can't get a job.

Anderson: What I want to point out is that these are things that can be learned rather quickly, once the man has a good background of fundamentals. The same thing is true in engineering, where students also go into industry. As I understand it, the people in industry feel they can give the special training needed for the job in hand in a relatively brief time, provided the new graduates have the fundamentals.

Bailey: That may be, but the experience of the boys in interviews is that they don't leave a good impression when they have to say "I don't know" to the practical questions.

Stevens: I appreciate your point. But when you tell the student about varieties of corn so he can get a job, don't you think it essential that he be impressed with the fact that these are varieties for the particular area, that they don't necessarily work elsewhere, and are the varieties as of now, not a few years hence? Students should recognize the relative worth of this knowledge.

Smith: One other factor that enters in hasn't been brought out yet. It goes back to your point, Dr. Bates, about the research being done at experiment stations in this country. This goes back to political pressures; money was appropriated to solve a particular problem and you had to go out and get an answer to that problem. You didn't have time to get the reason why it worked; you had to bring the insect under control. That is changing. Just two years ago we were able to get money to put a man on strictly biological-ecological work in entomology, with no responsibility to any control problem. A few years ago that was unheard of.

Bates: The mere fact that all of us think like this is a reflection of the climate in which we are living. I hope we are a little ahead of it! But we are operating in a favorable climate of opinion for these changes.

Smith: Getting back to attitude of industry, too; just in the last few years I've seen a definite change in the attitude of the chemical companies, the insecticide companies, in the qualifications they want in a man. They seem to feel need for basic work in biology—ecology, taxonomy, etc.

Bailey: I'm not arguing against that in the least. Rather, I'm strongly for it. But I still insist that when these boys go out, they must have a thorough familiarity with the current techniques so they can start work with their own hands. That's what they will be called upon to do.

Bates: That's another question that always comes up—as in talking about medical school admissions. These industries talk so high—but what does the personnel manager actually do?

Anderson: There's also the problem raised a little while ago—one that I think is foremost in the minds of the people in these applied areas. How can they display the career opportunities in their fields to the entering student? The main reason for a curriculum in entomology or horticulture is not that they expect to train an entomologist, but that they want the student to realize that here is an area with opportunities. If he follows only the basic sciences from the beginning on, he may stay there, not realizing what the specialties have to offer. You don't want to kill off the fellow's interest—make him a chemist or biologist because he doesn't reach entomology until late. This is an important problem. We need entomologists and agronomists and plant pathologists. If the student could be made aware of career opportunities, I don't believe the applied people would worry at all about asking for much undergraduate specialization.

II.

Group on Teachers for Secondary Schools at the April meeting; following a discussion in which the group agreed to recommend two special courses beyond the core program, field biology and methods of teaching with biological material.

Lawson: I think we have to be very careful about recommending additional courses. Pretty soon it gets ridiculous—there isn't that much time.

Constance: The general impression I ended with after our general session on the core program for biologists was that the biology recommended plus the physical science prerequisites should be no more than half the student's program. Specialized work in biology would take only about 10% of the total, or 20% of the science. Our two courses could be two one-semester courses in the senior year.

Greulach: However, I would recommend that the methods course be counted as an education course (so that it comes into the time of the education department rather than biology), but that it be taught by a biologist.

Constance: And, we said, taught in the biology department. I'll go back and show it to the dean of education, who, incidentally, will agree in principle. I like this.

Sizer: Do you think that biology departments, by and large, would be willing to teach such a course?

Lawson: Well, I think the atmosphere is changing. Both the educationists and the biologists have awakened to the fact that we've got to get together.

Sizer: I think, though, that a lot of biology departments feel they don't want their departments "contaminated." It's perhaps a wrong view, but how can we persuade them?

Greulach: I think that in almost any fairly sizeable department you would find at least one staff member who would be willing and qualified to do this.

Lawson: We have a man this spring who is giving an off-campus extension course four hours one day a week. In this case the education department came over and asked us, saying they didn't have the right people. This is something new for us and it's making me hopeful that this may be a trend.

Chadwick: In our case our physicist teaches such a course, making it mostly physical sciences. I participate in about a fifth of the course.

Behnke: Perhaps students ought to get such a course in both physical and biological science.

Greulach: Maybe a semester of each.

Constance: Do we want to go any further in the direction Dr. Sizer suggested, on non-biological courses biology teachers should have? You mentioned educational psychology, sociology and anthropology. Do we want to say anything more about non-biological requirements for biology teachers?

Behnke: Before we leave biology, I hope we will be specific about the number of hours a teacher should have.

Constance: We talked about this yesterday. It seems to me the only way we can make a meaningful statement is to do it in percentages. We had this statement yesterday that seemed to cover pretty well all the reports, that somewhere between 25 and 50% would be what we would regard as about right.

Behnke: Would you say it should be, say, 25% in biology and a total of 50% in science, not including the methods course?

Sizer: This course should be included in the science. Once we start thinking of our own course not being a biology course, then we have lost it. We had better make it a biology course or not do it at all.

Constance: I don't think I agree. This is a course designed for people going into teaching; it should be part of their professional preparation. Education people are going to specify certain things for the training of the teacher. It would be desirable for them to specify something that's meaningful instead of—well, I don't know if this is fair, but I would say the history of elementary education, the history of secondary education, and so on—which may have some value, of course. If we could contribute what we regard as a meaningful chunk to what I regard as an overload of teacher preparation, I don't think you would be throwing the course away. I think you would be helping the student in a sense, in that you cut down the overload he has to carry.

Lawson: What Dr. Sizer and I want to do is make this course respectable in terms of science rather than making it another education course. Now it is going to be concerned primarily with teaching, but let's make it as respectable as any science course. If you include it in the science load, you show that you consider it respectable.

Constance: Then you may have to raise the load.

Behnke: I think that if you keep it in the biology department, you've accomplished what you want. But if you put it in the science requirement of 50%, then you still have the 18-22 hours of education added on.

Constance: That's right.

Sizer: Then who supervises it, who rides herd on it, if it has an education number?

Constance: Let's agree to leave it in the biology department, but give education credit. It would be very hard to keep control if it were listed an education course. I'm not sure how realistic this 50% is, anyway. My group talked about having mathematics to the level of calculus and a couple of years of chemistry as part of the core program.

Sizer: On your other question, probably we should leave psychology and so on to the people in those fields. My main point really is that it should be just as good psychology as the physics is good physics, for example.

Constance: Is there anything we want to say about practice teaching, the internship aspect?

Lawson: I wonder if we might not say this much, that students who are taking the special course in the biology department should have, as a part of it, some experience as laboratory assistants.

Chadwick: We believe so strongly in this at Peabody that we try to give every one of our majors a quarter of experience as a teaching assistant.

Constance: We try, too, but the education department will not recommend this as "practice teaching" of any kind. Do you have any recommendation on that? Is this in fact supervised teaching? Should it be considered as such?

Lawson: Within my experience this was the best training I had for teaching.

Constance: It was the only training I had ever had.

Behnke: It would be wonderful if, in their practice teaching, instead of having just an education supervisor they also had a biologist as supervisor.

Constance: You might not get that but I like Dr. Lawson's idea. Let them have two kinds of supervised teaching: in a high school, and as a laboratory assistant in college biology; and let the latter be regarded as at least equal to the other.

Chadwick: This is what we do at Peabody.

Constance: Is there anything we can do to encourage high-school teachers to keep up with literature and developments in their field? I would put on a little more pressure to make a substantial part of the continuing study they have to do be in biology.

Greulach: I've been going through several hundred applications from high-school biology teachers for our NSF Summer Institute. They are asked to indicate what journals they read. I have tabulated around 250 of them. Every last one of them reads at least two education journals, the *NEA Journal* and the state education association's journal; some read 3 or 4 other education journals. But somewhat less than 50% read any science publication at all. Of those who read any, most read only one. More read the *Scientific American* than any other journal. But only about a fourth of those teachers read enough journals to have any idea of developments. Only two read scientific research journals. *Science Newsletter* ranked after *Scientific American* in readership.

Behnke: What kind of technical scientific journal can they read?

Greulach: This gets right back to our interest in a special review journal for high-school and college teachers.

Behnke: I think, too, that getting them to read some general books in science might be better than getting them to read the technical journals.

Chadwick: May I mention a pet project? I resolved to get to know all the science teachers in my area—68 of them. I meet with them, invite them to come to the college with questions. I send them a newsletter containing announcements of meetings, conferences, study opportunities, but also with short items on research developments. The response has been magnificent. Many say they post the newsletters for their students. If 500 college and university biologists scattered all over the country did something like this, each adopted the science teachers in his area, took a personal interest in them, we could perform a tremendous service.

Sizer: I think this is not so far off our beam. If biology teachers are going to be teaching students who later come to us in the colleges, it seems to me we could very well recommend that there be a continuing relationship between the biology department and its graduates. This is precisely where we have failed. That's why they have turned to departments of education.

Behnke: We could offer two or three suggestions. A biological department might try to devise some way to help them keep up on recent developments. It might assist them with advice on laboratory and other problems they have in the schools. More and more of this is being done.

Greulach: In checking the Institute applications, I also found that practically none of the applicants belongs to his state academy of science or other groups where he would get a little contact with scientists.

Chadwick: About 5 to 10% of the science teachers are doing a mighty fine job; you would be hard put to improve them. About 20% are not at all equipped to do a good job. That leaves a big group in the middle whom we can help.

III.

Group on Botany at the April meeting; part of a discussion on botanical content of the introductory program, the core program for biologists, and further undergraduate work for plant-science specialists.

Went: I have something which I think is rather important. Students might have the idea that this is the whole of biology [when they see only a few forms] when there are untold thousands of other organisms about which they may never have heard. I think something you can perhaps do more readily with plants than with animals is to introduce the main kinds. When they go out, then, they at least have heard about mosses, about higher plants, about lichens, and so on, and will know about all they can expect to find. Plants they find won't be entirely foreign.

Oosting: That is, they will know that there are no other large groups. In my experience in teaching general botany, occasionally you meet up with some person who had your course 20 years ago, then became, say, a stock broker in New York. He comes back and tells you he "certainly remembers your course in botany." "What do you remember?" you ask him. "Well, we surveyed the plant kingdom, we went into photosynthesis, and genetics and so on; but especially I remember those field trips where you taught us the names of trees." I know that's very elementary but that's where you start folks, that's what they carry away with them.

Creighton: This is partly what people think botany is. If you don't teach it, they don't think they've had botany.

Couch: This is what I was talking about on this survey idea—letting people know that there are mosses and lichens and liverworts and so on.

Platt: I'm all for it.

Couch: The question is how are you going to get it all [cf. report pp. 61-62] in without the course being a rat race? Recently we had a new instructor come in. The first thing he had to say when he had to teach the general course was, "This is a rat race; it's impossible, I just can't do it!" But we have been doing it for four years. This is what bothers me about some outlines. Is it better to have a rat race or to have a sort of type course, like the old Sedgewick and Wilson general biology?

Creighton: This turns out to be a very practical matter. If you have a biology course, it's a bigger rat race than just a botany course. Now what happens is that unless you stand firm for what has to be done on plants, you'll get none of it because it will get dropped out. One of the first things to get dropped out is field trips. If it is, you lose all chance to teach the names of plants because you don't do that very well indoors. I think perhaps we should stress that we do think there should be field trips to observe and learn plants.

Couch: I'm sure, though, you don't want disorganized field trips—"Well, it's a pretty day; let's go for a walk"—they should be well-organized, well-conducted, and so on.

Creighton: It's the group's feeling that we should add to this survey of the plant kingdom the thought that you should teach the names of common plants of the vicinity?

Went: I would add one point: I can imagine a number of instructors would just not be good at this, would just reel off the names and let it go at that, without real study of plants in relation to their habitats.

Couch: Perhaps we need this recommendation to encourage the man in New York, let's say, places where you can't have field trips unless you go out and make a whole day of it.

Creighton: Actually, I don't think New York is the worst place. Our students who have been in New York high schools are likely to know more plants because they go to the New York Botantical Garden and the Brooklyn Botantic Garden. It's the students from the little high schools in the country or small towns or smaller cities who are never taken outdoors. Also, I'm not at all sure there's harm in saying this is desirable even though you know some people can't do it. Can we summarize with this? Study of the plant kingdom by means of carefully selected examples studied in field and laboratory, with emphasis upon the important criteria and methods of classification and on the evolution of structure and reproduction of plant groups, with the elimination of many life cycles, with reduced emphasis on algal phyla (except Chlorophyta), mosses, liverworts, hornworts, club mosses, with greater emphasis on bacteria, fungi, ferns and seed plants.

Went: You can get in this field study and study of some other plant groups when the lectures are on evolution, biogeography, conservation and so on—topics on which you can't give much laboratory work.

Oosting: However, to me the old Hofmeister series is still beautiful. It's out of fashion now because we've got all these laboratory artifacts where we think we're getting something very wonderful. Take a few examples. While you are talking about evolution to the land, show them some algae in a pond, show them some liverworts and mosses; let them find fern prothallia. If they could just see these things in the field as evolution: there are the great plant groups; you can see them growing. To me it's one of the best ways to get across evolutionary concepts. I know this is old-fashioned but I still like it.

Creighton: Our problem at the moment is to define what is the minimal botanical part of a general biology course. If a botanist is teaching it, he may go beyond this. Our hope is that a zoologist involved ought to feel that he is not doing a good job unless he does something with the things we list.

Platt: One problem is that it is so difficult to put all the botany and zoology you need in one book. Many colleges may find it desirable for the introductory course to have a botany and a zoology text rather than attempting to find one which will adequately cover both fields.

Creighton: You're faced then with the problem that this has to be done in a year, so it can't be a total botany, total zoology treatment.

Went: This doesn't matter. It's good to have a text where there is more than students really are expected to learn; they don't have to learn every page. In practice you will have a zoologist or a botanist to teach the course, and there is just no way to get away from it. There are practically no general biologists.

Creighton: This is perfectly clear to all of us but you find many who claim they are. Too many think botany is just learning the names of flowers. What we want to do is make an educational statement: there is all this that really belongs in the elementary program; this is what we think you ought to be able to teach in giving a biology course. Some argue that there should be a semester of zoology and a semester of botany, which facilitates an arrangement in which botany is taught by a botanist and the zoology by a zoologist. I'm not convinced of this. I teach a course all the way through and our notion is that if the students are supposed to learn this, both botany and zoology, it's a poor teacher who can't learn enough to teach it to them.

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Creighton: What about the second level?

Went: I feel that if the biology major has had the amount of botany we recommend in the introductory program, then he can get these other things [in the core program] in botany or zoology or microbiology.

Raper: I would like to think that all botanists are going to get more genetics, for example, than can be given in the elementary course.

Couch: I think the point Dr. Went is making is that if you have a really good course in general biology, which embraces botany and zoology, then we should not try to keep the student any longer in the general field. Let the zoology major get his genetics in zoology, the botany major his in botany, and so on.

Oosting: The statements from discussion groups say "additional work" without prescribing which way it is given.

Creighton: For the second level we can then say that if the beginning course has an adequate treatment of botany [as described in our report], we do not need to prescribe anything more for the student who is not majoring in botany.

Raper: Do you mean that you think the general course is sufficient in these general areas? I would like to raise an objection to this, having yesterday upheld very strongly that at least a second year of somewhat greater depth of training in general biology is necessary. This means a second course in which not necessarily many topics are looked at, but those few give sufficient background and whatnot to show what is going on.

Creighton: In how many institutions do you think there are people who can give this? I think it's going to be hard enough to get people to give the first course, let alone the second.

Raper: On the other hand, there are a lot of institutions which can do it.

Went: Don't you agree that this second level could be given either in botany or zoology? It has to be there but can be in either.

Raper: I think it's better if it's broader, and specialization is accordingly shortened at the other end. Another reason for this comes in talking about the small colleges. A good share of the people who major in biology will go out and teach in secondary schools or in small colleges. At the level of the BA or MA the chances are that they're going out to teach biology, whatever they specialize in.

Creighton: I still think this can be done better by botanists or zoologists. Let them have physiology, but give them animal physiology or plant physiology.

Raper: I think we agree on the main point. I don't care how they get it, but I think there should be a second layer in which the emphasis is largely biological, with as broad a perspective as possible, whatever the courses included may be. The four discussion groups reached a pretty general consensus on the areas that ought to be included in this second level, however it's done.

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Greulach: This refers to botany majors, people who are going on to graduate work and so on. What we should probably ask first is this: Would we be happy to get as graduate students in botany those who had nothing more than the core program? Or is that not enough?

Couch: Dr. Greulach's question is very practical. We get so many people who have had only introductory courses and want to come into graduate work in botany.

Greulach: And they have to take undergraduate courses before they can start their graduate work.

Creighton: This is where we should spell out that they should know more about plant structure, plant physiology and so on. We ask for applicants for graduate work who have had three courses in botany. In many institutions we can't find students who have had this. We try to assume that "genetics" includes a fraction of botany and so on but find when they come to us that it often doesn't.

Oosting: Let's not think in terms of courses but say that he should have had botanical study that covers certain specific things.

Greulach: And if it was covered adequately in the first two levels, then that will suffice.

Oosting: The departmental evaluating committee would have to study that and judge what the record really covers.

Went: Some might have physiology of agricultural plants, forest ecology, and similar courses.

Greulach: One thing they ought to get at the undergraduate level is old-fashioned taxonomy—learning the names of a few plants and how to identify plants.

Creighton: First-hand acquaintance with plant physiology is another. We sometimes forget that plant physiology includes some things that really are peculiar to plants, like tropisms.

Greulach: Yes, general physiology courses often really aren't *general* physiology. They may be general animal physiology, but I think they are more commonly general vertebrate physiology. They usually include a chapter or a part of a chapter on photosynthesis but that's often all on plant physiology, saying nothing about water relations and the other things more or less peculiar to plants. However, doesn't almost every botanist who goes to graduate school get plant physiology in his graduate program?

Creighton: Because they don't have it earlier. We used to be able to start with advanced plant physiology in graduate school. Ideally, it would be well if they had a general introduction at the undergraduate level.

Went: They should also have had a good course in plant anatomy.

FORMAL ACTIONS

FORMAL ACTIONS

On April 4, 1957, the Conference met to hear and discuss reports from the individual discussion groups. A number of formal actions were proposed and voted.

A. Group Reports

The Conference unanimously accepted the four reports on the introductory program in biology, the four reports on a core program for prospective biologists, the three reports on preparation in cognate sciences, and the eleven reports on specialization, as given in this report.

B. The Place of Biology in General Education

The Conference unanimously adopted the following statement:

> We believe that every educated person should obtain a sound knowledge and appreciation of the biological sciences. This may be attained through precollege courses, introductory college courses in biology of the kind outlined in this report, or by self-study. Biologists should make every effort to maximize opportunity and motivation for young people to acquire at least this level of understanding of biology.

With four abstentions, participants in the Conference also stated:

> This basic knowledge of biology can best be obtained through properly designed formal courses in high school or college.

C. Further Examination of Curricula in the Biological Sciences

The conference urged widespread, continuing and concerted effort by biologists to re-examine college programs and seek ways to improve them. By unanimous vote the Conference recommended serveral specific steps in this direction:

1. That sponsors of and participants in the Conference on Undergraduate Curricula in the Biological Sciences sponsor symposia and group discussions on biological education at meetings of major biological organizations.

In accord with this recommendation, a panel discussion was presented on August 26, 1957, at the Stanford meeting of the American Institute of Biological Sciences.

2. That a series of 30-35 regional conferences on undergraduate curricula in the biological sciences be organized, each conference preferably under the direction of a participant in the national conference, to include two or more biologists from each of 15-20 colleges and universities within a restricted geographical area, with the participants representing a wide range of special areas in biology, and to be so organized as to facilitate thorough consideration of the problems and issues discussed in the national conference.

3. That participants report the Conference to biological faculties of their own and other colleges and universities, professional biological societies, teaching sections and local units of professional societies, and state academies of science.

D. Support for Efforts to Improve College Teaching in the Biological Sciences

By unanimous vote:

> The Conference on Undergraduate Curricula in the Biological Sciences endorses in principle the recommendation that fund-granting agencies be urged to support worthy efforts to improve the teaching of college biology by supporting programs for internships, teaching experimentation, and curricular revision, including the kind of curricular reform advocated by the Conference.

E. EDUCATION OF BIOLOGY TEACHERS FOR SECONDARY SCHOOLS

The Conference emphasized the very great importance of high-quality biology teaching in secondary schools and their conviction that the key factor is the competence of the individual teacher. The Conference urged biologists and the community at large to make every effort to provide salaries, recognition, support and facilities that will attract competent people to careers in precollege science teaching. The Conference also unanimously adopted a resolution on minimum subject-matter standards for the preparation and certification of biology teachers for secondary schools and directed that a statement of its views on an acceptable curriculum be circulated to scientific organizations, educational organizations, colleges, universities and school systems. Although it necessarily repeats what was said elsewhere in the report, the statement is given below in full in the expectation that readers of the report may want to use it in discussions of teacher education in their own institutions and states.

At its final general session on April 4, 1957, the Conference unanimously approved the following resolution on *minimum* subject-matter standards for the preparation and certification of high school teachers of biology:

> The Conference on Undergraduate Curricula in the Biological Sciences recommends that studies in the sciences and mathematics should comprise *not less than one-half of the undergraduate program of prospective biology teachers for secondary schools.* Prospective biology teachers should take one-fourth of their total undergraduate work in the biological sciences, and one-fourth in mathematics, physical sciences and earth sciences.

The Conference recommends a core program for students planning to enter any area of the biological sciences, together with a restricted amount of work in the professional specialty elected by the student. The Conference recommends that specialized work should occupy no more than about 10% of the student's total undergraduate program, unless the student takes more than the usual number of undergraduate hours or is exempted from taking specific basic courses through examination or other advanced placement procedures.

The Conference recommends the following curriculum for prospective teachers (items 1-6 from a core program for all prospective biologists; 7 and 8 are special items for teachers):

1. ***Introductory program in biology.*** A one-year course or course-sequence.

> This program should provide the understanding of biology essential for every college student, irrespective of his ultimate goal. The program should convey the nature of scientific processes and investigative methods, including some history of biology; develop an understanding of and interest in living organisms through a comprehension of important biological concepts, as shown by a careful selection of factual detail; present biology as a growing field which uses techniques and ideas from many sources; provide substantial field and laboratory experience; and relate the biological sciences to man's other intellectual, cultural and practical activities. In addition, the program should encourage independent use of biological literature, foster skill in oral and written communication, and provide special opportunities for superior students. Intensive, searching study of a few judiciously selected topics is preferable to superficial study of many. Examples should be selected from all major groups—microorganisms, plants, animals—and should show their respective roles in the biological scheme. Essential topics include: structure, function and development at molecular, organelle, cellular and organismal levels; reproduction; modern genetics; evolutionary mechanisms; organism-environment relationships and behavior; philosophy and history of biology; and an at-most-brief survey of the

diversity of organisms. This kind of introductory program demands gifted instructors, opportunities for student-teacher interchange through small discussion and laboratory sections, and freedom for those who teach it to capitalize upon their special competences and enthusiasms within the boundaries of recommended objectives and content.

2. *Further basic study in biology.* Equivalent to one and more likely two year-courses.

These studies should provide more intensive training in those areas that underlie the whole of modern biology than is possible in the introductory program. Among these areas are molecular and cellular biology, physiology, growth and development, and ecology or environmental biology. Plants, animals and microorganisms should be included, often on a comparative basis. No single method for organizing and presenting material at this level can be recommended, but the core program should involve conjoint planning by all biological disciplines represented in an institution, and may make use of integrated courses as well as interrelated but separate courses in the major areas.

3. *Chemistry.* Two year-courses.

A year of general chemistry built in considerable part upon organic chemistry, including qualitative analysis, and emphasizing chemical principles; and a course in organic chemistry which stresses principles and covers some biochemistry. For many prospective biologists additional chemistry courses are indispensable, particularly physical chemistry and biochemistry, but secondary-school teachers may not be able to include them in their undergraduate programs.

4. *Physics.* One year.

The course should emphasize fundamental principles, including modern physics; laboratory work which gives some attention to biological problems and materials is desirable.

5. *Mathematics.* At least one year.

The minimum should be a year-course in basic mathematics which provides more extensive treatment of broad mathematical concepts and their applications and less manipulation of figures than do traditional courses. However, the training should provide sufficient experience with manipulation to develop an understanding of basic concepts, including the rudiments of calculus. For many biologists additional mathematics is very important, particularly statistical methods.

6. *The total college program.*

Believing that the primary function of undergraduate colleges is to foster development of literate, broadly informed and responsible citizens, the Conference recommends that no more than half of the total undergraduate program for a major in any biological field should be devoted to biological and supporting science courses, the remainder being alloted to courses in the humanities, including English and foreign languages, and the social sciences. For prospective teachers this would include a minimum of concentrated, high-quality courses in education.

7. *Further study in field biology.* Usually one quarter or semester.

The "natural-history" approach (identification, ecology) is frequently effective in stimulating interest in biology at the high-school level, and the teacher is usually looked upon as the local expert in such matters.

8. *Further study of methods of biology teaching.* One quarter or semester.

This should be a course in the use of biological materials and concepts in teaching, including the development of interesting laboratory experiments, informative field trips, and other aspects of high school instruction. The course should be taught by a biological department as a thoroughly respectable scientific course but should yield credit in the Education department as part of the requirements in Education for graduation and certification.

With the addition of items 7 and 8, the Conference believes that the competence in subject-matter provided in the core program for biologists is a thoroughly satisfactory preparation for high school teachers of biology, and should constitute the *minimum* requirement for their certification. The Conference strongly recommends that the secondary-school teacher should major in the field in which he plans to teach. The biology teacher is also likely to be called upon to teach general science and often other science courses. The work in mathematics, chemistry and physics included in the core program will help prepare him for this; some study of earth science (astronomy and geology) would also be a valuable adjunct to his training.

The Conference also recommends that every potential biology teacher obtain experience as a supervised teaching assistant in a college laboratory, and that this be counted as an essential part of his practice teaching. The practice teaching should also provide experience in secondary schools.

The Conference urges biological departments to do their utmost to give status to high-school biology teaching, and suggests that to this end they establish and maintain close ties with their own graduates and with other teachers in their own localities. Teachers should be encouraged to come to these departments for assistance on laboratory and teaching problems and for help and information on their continuing biological education.

The Conference considers it highly desirable that the major part of in-service training for biology teachers be in biology and the supporting sciences, rather than in additional courses in Education, and commended the development of the summer institutes sponsored by the National Science Foundation and similar programs. Teachers should be encouraged and assisted in every way to keep up with advances in their fields and to associate professionally with other biologists.