PRESIDENTIAL ADDRESS

UNDERGRADUATE CURRICULA IN BIOLOGY

Willis H. Johnson, Wabash College

During the past year it was my privilege to participate in a Conference on Undergraduate Curricula in Biology, sponsored by the Committee on Educational Policies of the Division of Biology and Agriculture of the National Research Council. Since I am convinced that the problems considered in this conference should be of interest, not only to biologists, but to all involved in undergraduate education, I want to present to you a summary of the work of this conference.

First I would like to say a few words about the background of the Conference, about the objectives and organization and about the participants.

In 1953 the Division of Biology and Agriculture held a Conference on Biological Education. At the conclusion this recommendation was made:

> "In view of the rapid development of the biological sciences, it is desirable that educational and instructional objectives and practices be subject to continuous and concerted study. Be it therefore resolved that a policy committee be established within the structure of the Division of Biology and Agriculture of the National Research Council, to confer with and advise those individuals and organizations that are most intimately concerned with biological education in its many facets as to the present and prospective demands upon, and needs of, the biological sciences."(1)

In 1954, Dr. Paul Weiss, Chairman of the Biology Council, appointed the Committee on Educational Policies with Dr. Howard Phillips as Chairman. Since that time the committee, through seven subcommittees, has been concerned with problems at all educational levels, from elementary and secondary to graduate and professional, and in all branches of biology, basic and applied.

The conference on undergraduate curricula was one of the results of the activities of the subcommittee on college education. Dr. Thomas Hall has served as chairman of this subcommittee. One of the first things which this subcommittee did was to write to some 500 biologists, asking them to indicate what they considered to be the most important problems in connection with college education in biology and what they would propose as solutions to the problems. A rather large number of problems were indicated and the subcommittee selected several of these for study and recommendations. As a result of this, a publication of the subcommittee "Improving College Biology Teaching"(2) will soon be ready for distribution.

In the list of suggested problems the need for a thorough, biology-wide appraisal of basic principles to guide selection of content and choice of organization for undergraduate courses and curricula stood very high. Many of those who replied stated that college programs often fail to keep pace with the evolution of the biological sciences and the changing needs of students and society. Many also emphasized the importance of coordinated consideration involving the whole range of biological disciplines, pointing out that past conferences and studies have generally dealt with separate fields, single institutions, or isolated aspects of a curricular problem.

The Subcommittee proposed to the parent committee that a conference be held on undergraduate curricula which would include representatives of all fields of biology. As a result the Committee on Educational Policies, supported by a grant from NSF, invited a broadly representative group of biologists to meet and consider curricular problems.

Those invited were:

Principal Participants

Willis H. Johnson, Chairman, Department of Biology, Wabash College, Crawfordsville, Indiana, *Chairman*

Marston Bates, Professor, Department of Zoology, University of Michigan, Ann Arbor, Michigan

Wendell H. Bragonier, Chairman, Department of Botany and Plant Pathology, Iowa State College, Ames, Iowa[2]

Julius H. Comroe, Jr., Professor, Department of Physiology and Pharmacology, Graduate School of Medicine, University of Pennsylvania, Philadelphia 4, Pennsylvania

Lincoln Constance, Dean, College of Letters and Science, University of California, Berkeley 4, California

Harriet B. Creighton, Professor, Department of Botany and Bacteriology, Wellesley College, Wellesly 81, Massachusetts

Donald R. Griffin, Professor of Zoology, Biological Laboratories, Harvard University, Cambridge 38, Massachusetts[2]

I. C. Gunsalus, Professor, Department of Biochemistry, University of Illinois, Urbana, Illinois

James H. Hilton, President, Iowa State College, Ames, Iowa[1]

George W. Kidder, Professor, Department of Biology, Amherst College, Amherst, Massachusetts

Chester A. Lawson, Head, Department of Natural Sciences, Michigan State University, East Lansing, Michigan

John A. Moore, Professor, Department of Zoology, Columbia University, New York 27, New York

Henry J. Oosting, Chairman, Department of Botany, Duke University, Durham, North Carolina

Robert B. Platt, Professor, Department of Biology, Emory University, Emory University, Georgia

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[1] Attended December meeting only.

[2] Attended April meeting only.

Alfred S. Romer, Director, Museum of Comparative Zoology, Harvard University, Cambridge 38, Massachusetts

I. W. Sizer, Head, Department of Biology, Massachusetts Institute of Technology, Cambridge 39, Massachusetts

Frits W. Went, Professor, Department of Biology, California Institute of Technology, Pasadena, California

Other Participants

Division of Biology and Agriculture, National Academy of Sciences—National Research Council

L. A. Maynard, Professor of Nutrition and Biochemistry Emeritus, Cornell University, *Chairman*[1]

Frank L. Campbell, *Executive Secretary*[1]

Paul Weiss, Head, Laboratory of Developmental Biology, Rockefeller Institute for Medical Research, 66th Street and York Avenue, New York 21, New York. Past Chairman of the Division of Biology and Agriculture; Chairman of the Biology Council 1954-57

Russell B. Stevens, Professor and Executive Officer, Department of Botany, George Washington University, Washington, D. C.; Executive Secretary of the Biology Council, 1954-57.

Committee on Educational Policies

Howard M. Phillips, Dean, The Graduate School, Emory University, Emory University, Georgia, *Chairman*

Clyde E. Bailey, Dean Emeritus, Institute of Agriculture, University of Minnesota, St. Paul 1, Minnesota

John A. Behnke, Vice President and Science Editor, The Ronald Press Company, 15 East 26th Street, New York 19, New York

Claude S. Chadwick, Head, Department of Biology, George Peabody College for Teachers, Nashville 5, Tennessee

Thomas S. Hall, Dean, College of Liberal Arts, Washington University, St. Louis 5, Missouri

Milton O. Lee, Federation Secretary, Federation of American Societies for Experimental Biology, 9650 Wisconsin Avenue, Washington 14, D. C.

Theophilus S. Painter, Professor, Department of Zoology, University of Texas, Austin 12, Texas

Richard E. Paulson, *Executive Secretary*

Subcommittee on College Education of the Committee on Educational Policies

Thomas S. Hall, *Chairman*

Benson E. Ginsburg, Associate Dean of the College, University of Chicago, Chicago 37, Illinois (during 1957-8, Center for Advanced Study in the Behavioral Sciences, 202 Junipero Serra Boulevard, Stanford, California)

Victor A. Greulach, Professor, Department of Botany, University of North Carolina, Chapel Hill, North Carolina

Willis H. Johnson, Chairman, Department of Biology, Wabash College, Crawfordsville, Indiana

John R. Raper, Professor of Botany, Biological Laboratories, Harvard University, Cambridge 38, Massachusetts[2]

National Science Foundation

Donald B. Anderson, Dean, Graduate School, North Carolina State College, Raleigh, North Carolina; Program Director for Education in the Sciences, National Science Foundation, 1956-57.

The Conference held two sessions, the first in Washington, December 8 and 9 and the second at Chapel Hill, April 1-4.

The Conference dealt with two interrelated problems: biology in the college, and the college in the training of biologists. Before it could attempt to deal with these problems the Conference had first to reach agreement on the general objectives of college education. The Conference took the stand that the primary purpose of the undergraduate college is to develop literate, broadly informed, and responsible citizens. In this they were concerned with what every educated person should learn about the life sciences and with the general literacy of prospective biologists. The conference further agreed that the college has a second purpose: to help the student acquire a firm grounding in the broad field of learning which includes his ultimate occupational goal. It was the concensus of the conference that no more than half of the total undergraduate program, for a major in biology, should be devoted to biological and supporting science courses, with the remainder alloted to courses in the humanities and social sciences.

Discussions at both meetings were focussed upon three main questions related to the three principal levels with which undergraduate education is concerned.

First: Should an acquaintance with biological sciences be expected of all college graduates? What objectives, characteristics, and content are recommended for introductory college 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 field of specialization?

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

At the Washington session the participants were divided into 4 groups of 7 or 8 persons each for the consideration of questions 1 and 2 with a variety of interests represented in each group. For question 3 they met as botanists, zoologists, medical biologists, agricultural biologists, and biologists interested in teacher training. Each group had a recorder who presented the results of the group discussion to the conference as a whole.

Following the Washington meeting the subcommittee met and prepared a digest of that meeting. This digest showed the areas of agreement and also indicated the recommendations that were made by one,

or two, or three of the groups on both questions 1 and 2. This, then, served as a guide for the discussions at Chapel Hill.

In this interim between the two sessions the conferees had an opportunity to confer with their colleagues on the questions which had been raised at the Washington session.

At Chapel Hill the conferees met again in 4 small groups to consider questions 1 and 2 with the digest of the Washington meeting as a guide. The groups were mixed; i.e., the participants found themselves with persons they had not met with in small group in Washington. For question 3 the participants met in two different ways at Chapel Hill. They met first as botanists, zoologists, etc., as in Washington, and then they met in groups according to Areas of Inquiry according to the system developed in the Division of Biology and Agriculture which is familiar to many biologists as it is used in a modified form by the National Science Foundation.

These groups were:

Molecular and Cellular Biology
Regulatory Biology
Developmental Biology
Group and Environmental Biology
Genetic Biology
Systematic and Evolutionary Biology

The recorder in each small group (there were four for No. 1, four for No. 2, and eleven for No. 3) presented his report to the Conference as a whole for discussion. Following the discussion each report was adopted by the conference as a whole. These reports with only minor editorial changes will make up a large part of the Conference Report which will soon be ready for distribution as a National Academy—National Research Council Publication.(3) I am sure that most of you will say, after reading the document, that there was an amazing degree of agreement in the different reports on a given question.

The Committee on Educational Policies, in setting up the Conference stated this as the objective "to develop guiding principles and useful model programs for organizing undergraduate instruction in biology." The Committee further stated "No single conference can resolve all questions, nor can any small group, however, distinguished, speak for all biologists. The Committee believes, however, that the Conference can significantly promote what must be a continuing process of study, review and modification of programs, helping to insure that biological education evolves at a pace commensurate with the advancement of the science it serves." In other words it was the hope that the recommendations of the Conference may prove of value to departments and institutions which are in the process, or may in the future undertake, curricular revisions.

Question I

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

At the concluding session on April 4, 1957, the Conference unanimously adopted the following resolution:

> "We believe that all educated persons should obtain a knowledge and appreciation of the biological sciences. This may be attained through good precollege courses, the kind of introductory college courses in biology outlined in the report of the Conference, or self study. Biologists should make every effort to maximize opportunities and motivation for young people to acquire at least this much understanding of biology."
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> All but four of the participants further recommended:
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> "This basic knowledge of biology should be obtained through formal courses in high school or college."

The Conference considered and voted on this resolution as a way of formally affirming the view that the biological sciences, being an important component of our culture, deserve to be appropriately represented in the background of every well-educated person. Colleges and universities share responsibility for supplying this understanding with the secondary schools.

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 application and implication are essential aspects of a liberal education and necessary foundations for other curricular areas. Such knowledge can only be obtained through a study of biology. Once mastered it has essential interconnection with many aspects of the social sciences, philosophy, medicine and agriculture, esthetics, and other humanistic desciplines. 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 an example of scientific achievement for which a non-biological science can provide equivalent knowledge. Both the physical and biological sciences should, therefore, be included in the student's curriculum. If possible the introduction to the physical sciences, together with mathematics, should precede biology. However, general college courses in biology should not be postponed on this account. Adequate high school preparation in mathematics, physics, and chemistry can meet the needs as regards the college general biology course.

The sense in which an introductory program in biology was recommended as liberal education for everyone looks toward a course (or 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 organize. Such a program should have equal value to the potential biology major and the nonbiologists alike. It should be challenging in intellectual content and good enough in substance to serve as prerequisite for more specialized courses for the major.

OBJECTIVES

Despite differences in wording and emphasis, the statements of objectives produced by the four different groups were remarkably similar. The statement of one group is as follows:

1. To convey the nature of the scientific process and the 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, his material progress and 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 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 OF THE INTRODUCTORY BIOLOGY PROGRAMS

The discussion groups achieved generally similar conclusions on what the introductory program should include. In one form or another, all of them listed the following major topics:

1. Structure, living processes and development at the molecular, organelle, cellular, and organismal levels of organization (one group added the societal level).
2. Modern genetics.
3. Evolution, with emphasis on evolutionary processes (one group did not use the term but implied consideration of evolution in various topics in its list).
4. Reproduction (implied but not named by one group).

5. Relationships between organisms and their physical and biotic environments, as related to behavior (only one group used the label "ecology" but all obviously intended to cover basic concepts of interrelationships).
6. Philosophy and history of biology (implied but not listed as a separate topic by one group).

Certain groups attempted to spell out these topics in some detail. For instance the botanical group said:

"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, among them, the dependence of nearly all organisms upon the process of photosynthesis, the role plants play in the carbon, oxygen, water and nitrogen cycles in nature, the action of plants in stabilizing and conditioning the soil, and the important role plants play in controlling climate.

Plant science topics which belong in the introductory biology program 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 should be 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."

This is what the group meeting as geneticists had to say:

"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. The treatment here used need not go beyond simple cases."

One group, with one strong dissenter, recommended 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 more valuable items will not leave time for an adequate treatment. However, this group did recommend a thorough study of the structure, life processes, behavior, and environmental relations of a few judiciously selected organisms. The other three groups all proposed a brief survey of the plant and animal kingdoms to provide some idea of the range of diversity of organisms.

The introductory program which emerges is one which deals with the more modern and dynamic aspects of biology, with emphasis on such topics as physiology, development, genetics, evolutionary mechanisms, behavior, and interactions with the environment. Although there was general agreement about emphasis on modern concepts, a strong warning was sounded by several of the participants that we should not become so focussed upon analytical and biochemical procedures—upon what might be called the physiological dissection of the organism—that we forget the organism as a whole. This explains the strong insistence in some groups upon behavioral and ecological studies.

The Conferees also urged that the introductory program draws its examples from all the major groups of living things—microorganisms, plants and animals—and clearly show the unique role each group plays in the biological scheme. In this connection the conference considered the role of man in the introductory course or program and reached agreement that the course should not revolve about man. One group stated "Man may serve as a starting point for topics as a motivational device, but the entire course should not revolve about man."

The introductory 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. The course or courses should serve as an adequate preparation for any second level course. The way the course is organized would have to depend on each local situation. In this connection one group had this to say: "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." Another group said: "We reject 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."

Advanced college standing for superior high school preparation in biology was discussed; the consensus favored advanced placement on the basis of superior high school courses, provided standards are adequately safeguarded by examination.

Question II

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

A. Further Common Studies in Biology

The conferees agreed that, following the completion of the broad introductory program, all prospective biologists should have more intensive training in those areas that underlie the whole of modern biology than is possible in the initial program. 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 they are currently understood and a desirable background for future work in any aspect of biology. The student's future needs are unknown and indeterminable, both because his goals and ambitions may change and because 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 his expanding, often changing, interests.

An examination of the group reports reveals 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 included genetics, growth and development, cell biology, physiology, and ecology or environmental biology. In this connection it should be pointed out that one group considered this additional core training as involving the equivalent of a one-year course during the second year while the other three groups thought of it as involving the equivalent of at least two year-courses. There was general agreement that both plants and animals should be considered in at least part of this common core of study; some groups recommended that both plants and animals should be used throughout. Two groups thought that specialization might begin at some point in this phase of the undergraduate curriculum. One group, while stating that both plants and animals should be used in the work on genetics, ecology, cell physiology and cell morphology, indicated that the additional work in systematics, growth and development, physiology, and morphology might be taken in courses based on either plants or animals. It was felt that no single method of organizing and presenting the materials of the additional common studies could be recommended. In some institutions it may be possible to do this in one or more integrated courses; in other institutions it may be necessary to provide one or more separate courses for each area.

B. REQUIRED WORK IN RELATED FIELDS

The conferees agreed completely that adequate training in biology requires the attainment of a sound knowledge of chemistry, physics, and mathematics.

The following statement was made with reference to mathematics:

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 mathematical courses.
4. Additional experience with statistical methods should be available at the advanced undergraduate level.

Three questions were addressed to the group considering training in chemistry.

(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. General agreement was expressed that chemistry through organic is essential to the understanding of biology. It was agreed that the biologist requires a body of biochemical and physical chemical concepts for advance 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. It was agreed that the training in chemistry recommended for biologists can generally be obtained in existing courses in two years in many institutions. The consultant, Dr. Arthur Roe, Chairman of the Department of Chemistry at the University of North Carolina, reported that good one-semester courses in organic chemistry exist and that such a course could be initiated 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. The organic course could be followed in the second term of the sophomore year by a two-hour lecture course on the organic and natural-product chemistry of proteins, carbohydrates and lipids. The consultant 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 early in the program, and would also present a view of chemistry of greater value to the liberal arts student who takes only one course in chemistry than the conventional general chemistry course. The chemists present 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.

It was pointed out that a number of institutions (among them, California Institute of Technology, Brown University, and Pomona College) are currently experimenting with first courses in chemistry involving the organic materials approach. These courses were not designed primarily for biology students, but were initiated by the chemistry departments of these institutions for the improvement of introductory teaching in chemistry. This reinforces the suggestion above, that this kind of course would be useful both to the prospective biologist and to liberal arts students in general.

The physics group unanimously recommended that all biology majors be required to take one year of physics. Reference was made to the fact that physicists must determine the content of the basic course and it was pointed out that 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 seven:

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

The conferees subscribed to such a course for all biology students.

Question III

What is the role of the undergraduate program in preparing students for different biological specialties?

The conferees agreed that the college should give the student both a liberal education and an opportunity to get a good grasp on the general field which includes his occupational goal.

The biological sciences have fragmented into a host of specialties 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 of those concerned with special fields and for individual institutions. The conference 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.

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 of the college 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 which 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 these areas.

BOTANY

The botany group recommended no specific courses which the student specializing in botany must take. However, they recommended that the courses offered by any institution should 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 was based on the assumption that the introductory and core programs would adequately cover the subject matter from the plant sciences, already referred to.

ZOOLOGY

In addition to the introductory and core programs, a major program in zoology should include substantial additional work on both the morphology and the physiology of animals. While the content and structure of particular courses must be left to the discretion of individual departments and instructors, it was suggested 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 anatomical. Both should, of course, include laboratory work, and both should involve comparative study of invertebrate as well as vertebrate animals. A minority of the group suggested 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 mind 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

This group urged 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, was 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).

They endorsed, 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 Questions I and II, this group felt 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.

MEDICAL BIOLOGY

Students who plan to make a career of medicine or medical sciences should include in their program the material suggested for all biologists under Questions I and II. Their program might also include additional experience in depth in areas of *dynamic* biology.

Even more important, the future medical scientists or physician should 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 recognized 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 was considered to be sound philosophy and a healthy reaction against the excessively narrow requirements of past decades. The pendulum may have swung too far, however. They believe that the curriculum recommended by this conference, 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.

They recommended 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, they believe, would benefit both biology and medical education.

TEACHERS FOR SECONDARY SCHOOLS

The group dealing with special work for biology majors planning to become teachers of high school biology recommended only two additional elements of preparation beyond the core program specified in Questions I and II:

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 study 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. They strongly recommended 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.

They further recommended 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, they recommended 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.

They 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.

They 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 they recommend the further development of the summer institutes sponsored by the National Science Foundation and similar programs. They 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.

The reports of the groups meeting according to areas of inquiry are both interesting and instructive. However, this paper is already too long and I will simply ask you to read these when the full report is circulated.

In closing may I emphasize a statement made in the Conference report. "A report or a conference such as this one 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 professor, the individual department, the individual institution can determine what program will actually be offered to individual students." It was the hope of the conferees that the report on this conference would encourage more biologists to make their own critical assessments of undergraduate curricula.

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