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BIOLOGY IN A LIBERAL EDUCATION.
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REPORTED ARE THE PROCEEDINGS OF A COLLOQUIUM HELD AT STANFORD UNIVERSITY WHICH DEALT WITH THE REASSESSMENT OF THE DESIGN OF INTRODUCTORY COLLEGE BIOLOGY COURSES. THE REPORT INCLUDES A DIVERSITY OF IDEAS AND CONVICTIONS, AGREEMENTS AND DISAGREEMENTS, AS EXPRESSED IN INVITED PAPERS AND IN DISCUSSIONS OF PARTICIPANTS. SOME OF THE TOPICS CONSIDERED ARE (1) HIGH SCHOOL BIOLOGY AND ITS RELATIONSHIP TO COLLEGE INTRODUCTORY BIOLOGY, (2) COURSE CONTENT, (3) ORGANIZING PRINCIPLES AROUND WHICH A COURSE MIGHT BE DEVELOPED, (4) A TWO-YEAR INTEGRATED PROGRAM, (5) A DOUBLE-TRACK PROGRAM INVOLVING THE HISTORY AND PHILOSOPHY OF SCIENCE, (6) THE ROLE OF THE LABORATORY, (7) THE SOCIAL RESPONSIBILITY OF THE BIOLOGY PROFESSOR, AND (8) THE QUESTION OF SEPARATE COURSES FOR MAJORS AND NON-MAJORS. COPIES OF THIS REPORT ARE AVAILABLE FREE OF CHARGE FROM CUEBS, 1717 MASSACHUSETTS AVENUE, N.W., WASHINGTON, D.C. 20036. (DS)

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REPORTS OF THE COLLOQUIUM ON BIOLOGY IN A LIBERAL EDUCATION, STANFORD UNIVERSITY, AUGUST 2-13, 1965 / Edited by Jeffrey J. W. Baker

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FOREWORD

I should like to express my gratitude to Dr. Peter Buri, who has checked over this material as I have prepared it. Dr. Buri and I spent considerable time going over each paper and selecting passages which we thought reflected well either the individual author's opinion or an opinion held by all or most of the group. Thanks also go to Dr. Earl Hanson, Chairman of the Commission on Undergraduate Education in the Biological Sciences (CUEBS), who independently read copies of the material produced at Stanford and noted for me passages he felt were significant.

Every paper prepared by a Stanford participant who attended the full 12 days has been directly or indirectly quoted, save one (my own). The extensiveness to which certain papers are quoted over others is not meant to indicate that these were considered more valuable contributions; rather, they seemed to represent more accurately areas in which there was a general consensus.

Many participants spent considerable time outlining either the introductory courses they teach in their respective institutions or ones which they considered desirable. It was decided to publish none of these outlines: to publish one might have been construed as an endorsement of the course; to publish all was clearly impossible.

I know I speak for all the Stanford Colloquium participants in expressing appreciation to Drs. Paul B. Sears and Paul Weiss, Yale University; Dr. Paul Schmidt, University of New Mexico; Dr. Walter V. Brown, University of Texas; Dr. Joseph Schwab, University of Chicago; Dr. Robert Platt, Emory University; and Dr. Johns Hopkins III Harvard University, for providing us at the outset with challenging and provocative thoughts concerning the role of biology in a liberal education.

I have tried to capture the essence of the Stanford Colloquium by focusing on the major areas of agreement or disagreement; only my colleagues can judge the extent of my success or failure. I am sure that I speak for all of us, however, in saying that far more was gained by each participant than was given, and in expressing heartfelt thanks to Dr. Buri for his role in establishing a truly exciting atmosphere in which to work.

Jeffrey J. W. Baker

Wesleyan University
Middletown, Connecticut
June 1, 1966

CONTENTS

THE CHARGE TO THE GROUP

Two weeks before the opening of the Colloquium, each participant received a memo from Dr. Buri, Colloquium Director and Chairman of the Panel on Biology in a Liberal Education.* The charge to the group was expressed as follows:

> The Colloquium has as its primary aim a reassessment of the design of introductory biology courses. It will provide you an opportunity to develop and express your own ideas in the company of others, all of whom are vitally interested in this matter. No attempt will be made to reach a consensus of opinion during these meetings; however, considerable agreement on many matters will, no doubt, come to light. It is felt that the problem is a complex one, and will admit of several, perhaps many, solutions.
>
> It would seem that the goals of any course are most fully

* Other members of the Panel: Garland E. Allen, Richard V. Bovbjerg, Harriet B. Creighton, Thomas S. Hall, Earl D. Hanson, Charles Heimsch and Gairdner B. Moment.

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and unambiguously expressed in terms of detailed course design itself. For this reason, and in recognition of the likelihood that diverse approaches may have equal validity, participants will be asked to work out their recommendations as individuals. This will allow each the fullest possible freedom of expression in attempting to arrive at a recommendation that has a sound and coherent rationale. We wish only to direct the attention of participants to the issues that ought to be faced by anyone who undertakes curricular development of this sort. A great deal has already been said regarding what the introductory course should achieve. We hope the Colloquium will shed some light on ways in which this may best be done.

The Colloquium meetings opened on August 2, 1965, with talks by Walter V. Brown, The University of Texas; Johns Hopkins III, Harvard University; Robert B. Platt, Emory University; and Joseph J. Schwab, The University of Chicago. Each of these biologists have long been concerned with introductory courses that are liberal in intent.

On the evening of August 3, Paul Weiss, of the Yale University Department of Philosophy, gave a critical resumé of the four talks and the discussions which followed them. Later, Dr. Paul Sears, of Yale University, visited the Colloquium and presented a paper.

The succeeding days were devoted to work periods. Participants were asked to develop course designs of their own, as well as the rationale behind them. The papers prepared varied in length from two to over thirty single-spaced pages. Each paper, when completed, was made available to other members of the Colloquium. In order to provide continuing opportunity for discussions of the major issues surrounding the design of introductory biology courses, Colloquium participants met in seminars of five or six persons during the morning before turning to work on their own papers in the afternoon.

The final three days of the conference were devoted to presentation of the course proposals and rationales of individual participants. Discussions of these followed each presentation.

In summary, the assembled participants gave attention to both the theoretical aspects of biology in a liberal education and the practical problems of implementation through outlines to introductory courses based on these ideas.

AN OVERALL VIEW

As the reflections on the role of biology in a liberal arts education were begun, the general feelings of dissatisfaction seemed similar. One participant expressed it this way:

> In the past dozen years of teaching I have become increasingly distressed by the disparity between my teaching approach to biology and my research approach. Although I would not pretend consequential significance to my research work, it has provided a rather sound basis for judging the "mystique of research," and for recognizing fully and with chagrin that my own teaching, as well as much with which I am familiar, is pedantic and largely descriptive of only the terminal product of research. All too frequently this is to the exclusion of the processes of ferreting out the information presented. This may not be entirely inadequate for some purposes, but I submit that it poorly reflects the nature of science as an inquiry into the nature of things. While I believe I have made some progress in my teaching

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with this objective, I have not been able to see it through, either in the abstract or in practice.

Another, speaking of apprehensions familiar to many Colloquium participants, wrote:

> In the day-to-day routine of teaching, research, and committee meetings, we are slave to the immediate goals and tasks confronting us. They seem endless and repetitive. All of us welcome the opportunity to back off a bit, ask a few questions of ourselves, and try to gain a larger perspective. This Colloquium offers us a chance to examine the position of biology as a part of the liberal arts curriculum. We should start, perhaps, by asking ourselves a few questions. What should every educated person know about biology? Is this the same material the potential major should master? How can biology best be taught as a liberal arts subject? Can meaningful biology be taught without a basic understanding of chemistry? What areas need to be included in the elementary course? How do you take care of the diversity of student background? If you believe it is important to have breadth as well as depth, how is this accomplished? How does one maintain a reasonably close association between faculty and student in these days of mounting enrollments?

Each of us had specific areas which we felt most warranted the Colloquium's consideration. One professor maintained that the success or failure of a course was comparable to the degree to which it reflected the nature of its subject. He felt, therefore, that the group's primary task was to establish "the fundamental nature of the discipline of science."

Most of the Stanford Colloquium participants were involved in teaching introductory biology to college undergraduates; few were completely satisfied with what they were doing. Since the majority of our students would study no more science, the main concerns were whether all the biological facts we had been teaching these students were essential and whether our teaching methods were designed to reflect biology as the investigative science it is.

This latter point received considerable attention from the Stanford Colloquium participants. One felt that, except for "cursory allusions to a few classical experimentations or investigations," students were not given an appreciation of the investigative methods of biology. Another made the following observations:

> Perhaps the two main emphases that biologists hope to present to majors and nonmajors alike are the basic concepts of biology, i.e., adaptation and evolution, molecular aspects of living material, the dynamics of the physics, chemistry and biology of the organism, the interrelationships of organisms and environments, etc.; the discipline of biology as a science including methods of questioning, investigating, interpreting, and relating biological phenomena. Both of these emphases require subject matter. The balance of emphases and choice of subject matter depend to some degree upon the limitation of a specific situation.

Probably all of us agreed with Jerome Bruner's statement, quoted by one participant:

> Perhaps the most basic thing that can be said about human memory after a century of intensive research, is that unless detail is placed into a structural pattern, it is rapidly forgotten.

In essence, then, the majority felt that the teaching of certain facts was essential in any biology course; agreement on *which* facts were essential was another matter! All seemed to agree that a unifying plan or plans, such as a "theme", was necessary for every course if the facts presented were to be meaningful; again, the precise *kind* of theme or pattern found far less agreement.

A few of us attempted to define a liberal education. A member of the "Schultzian" school of philosophy provided one particularly apt description:

> I assume that a "liberal" education is one that liberates the mind—not only from the bondage of ignorance and superstition but also from the props, foundations, and frames of reference which sustain the unliberated minds of that particular historic age and culture. Linus is only aware of his blanket when it is taken away from him. Then he is deeply disturbed. Linus, liberally educated, can take it or leave it. It is now his matter of understanding and free choice. Does this meaning of liberal have any consequence for the design or execution of an introductory biology course? Obviously.

No matter how the definitions of a liberal education varied, every participant felt strongly that biology was a necessary part. As one participant put it, "an understanding of living matter, its origin, its properties, its qualities, its organization, its behavior, its continuity, its capacities and its limitations is all-pervasive in its influence upon society and the mind."

Most felt an obligation to view critically present undergraduate courses and to make no part of a course—however sacred—immune to this critical look. Many also saw a need to extend the inquiry beyond a debate on the amount of time that should be allotted for a particular area of biology:

> There is a very great danger of blindly accepting a corpus of unexamined meaning, in which case the concern of the project immediately switches to interminable arguments about such problems as: how to divide up 30 lab exercises so that 15 utilize plants and 15 use animals, or how to achieve a neat balance and do justice to animal behavior, biochemistry, bacteriology, animal genetics, plant genetics, comparative anatomy, ecology, embryology, biometrics, general physiology, phylogenetics, cytology, and the life cycle of *Plasmodium vivax* other than all within the purview of a 26-week introductory course. On the other hand, there may be some justice to the thoughts of those who point out that considerations at levels more general than topical subject matter tend to degenerate into critical restatements of the threadbare arguments that have so long cloaked educational practices. While we argue at their ramparts, there is, in fact, a revolution going on, albeit somewhat willy-nilly. Burgeoning populations and advances in education gadgetry must force us to reconsider our endeavor at *all* levels. . . .
>
> . . . We must be prepared to face the hardest questions first . . . I would hope to be able to develop the soundest possible justification for every act of commission and every act of omission in our educational endeavor. I would hope to reject "harmlessness" as a justification for any action. We need to face such questions as. What's it all about? What am I doing here? Why bother? We must also be prepared to face the distasteful. If, for example, it turns out that the only viable function of a lecture as a teaching method is to satisfy important ego needs of the professor, let us admit it, accept it, and act in a reasoned fashion on it. If, on the other hand, the function of the lecture proves to be giving the "word" to those incapable of reading, let us admit that and again act in a reasoned fashion. If it is, in fact, possible to structure meaningful answers to the truly fundamental questions, to arrive at reasonable mean-

> ings for our basic terms; then, much of the incessant argument about methods and subject matter will fall into sensible order. It is true that our society forces some aspects of the meanings of such words as college, teacher, etc., upon us; but we must agree on what *we* mean if our activity is to have meaning. I refuse to buy such clichés as: there is no best way, or, it makes no difference whether . . . , etc.

Finally, the Stanford Colloquium participants faced the fact that biology is a changed and changing discipline—that most of us were taught introductory biology courses that would no longer be fully acceptable in terms of subject matter and/or approach. In the words of one professor:

> Whatever problems contemporary biological education faces, they are primarily the result of the success and expansion of the field as an academic discipline. New methods, new information, and new problems, all have eroded away the centr: elements which characterize the earlier systems of thought, and our teaching of biology must mirror these changes.

ERIC

HIGH SCHOOL BIOLOGY

Among the Stanford Colloquium participants was a secondary school teacher and author of one of the Biological Sciences Curriculum Study (BSCS) group lab blocks. Also present as confronters or observers were several BSCS officials and advisors, one of whom addressed an opening session.

Despite this fact, it seemed to me that surprisingly little attention was paid to the effect of secondary school biology on the college introductory course. Participants cited several probable reasons for this. All readily admitted that certain secondary course were equal or superior to the introductory college courses offered at some institutions. Yet, the number of such courses and teachers capable of teaching them was thought to be still very limited.

It was pointed out that the impact of BSCS materials had not yet been felt at the college level. However, some individuals had taught students who had taken BSCS biology and said they found little difference between them and students who had taken other courses. Two persons stated that their BSCS students recalled certain key terms or phrases of modern biology (such as DNA or RNA), but demonstrated either superficial or incorrect information concerning them. These persons would have preferred the students not to have had such biology, feeling that "there is nothing harder to teach a student than something he thinks he already knows."

The fact that many high school biology teachers are poorly trained in their discipline was also cited by a participant as a possible reason for the lack of impact of secondary school biology on biology at his institution. Therefore, no matter how good the available materials, the high school teacher's background limits his effectiveness. That very few high school biology teachers participate in research was also noted, for it was the strong conviction of many at Stanford (but by no means all) that excellent teaching was possible only if the teacher himself was engaged in research. Thus, to this person, the difference between even an excellent secondary school biology course and a college course would seem to be multidimensional and unlikely to be appreciatively changed. Another individual expressed some aspects of this opinion in the following passages:

> Having established biology, arbitrarily, as an essential ingredient of the academic spirit as embodied in the college and further assuming it to be desirable for all students, the next question concerns how to bring the intellectual essence of biology to the surface. I use the term intellectual because the material essence of biology may be brought out in innumerable ways without touching the academic spirit. Though perhaps trite, I like the thought that whereas the high school course brings biology to the student, the college course brings the student to biology . . .
>
> . . . It is interesting to me to compare the attitudes of high school and college teachers toward textbooks. In general, high school teachers are searching for good texts, often highly pragmatic about texts, often complimentary about texts. In contrast, college professors are highly critical of practically all elementary texts and indeed, rebellious. There are reasons for this difference in attitudes, and they are not simply that college professors are hopeless, intellectual

snobs. The best college professors represent strong, resourceful, authoritative, but egocentric units, and insofar as their knowledge and spirit dominate the scene, any textbook is merely an inferior instrument.

COURSE CONTENT

The Stanford Colloquium participants directed considerable attention to subject matter essential to any introductory biology course in a liberal arts institution.

One participant expressed the need to select topics "so fundamental that they should appear in any introductory biology course." Attaining full agreement among those present as to which topics were so fundamental that they *must* be included, however, proved an impossible task. During a dinner conversation involving three Colloquium participants, one noted that there are certain "basic topics" which *any* biologist would agree should be in an introductory course, and mentioned such a topic specifically. Immediately, his two companions disagreed that the topic was "basic" at all!

Nevertheless, a comparison of course outlines submitted at the Colloquium shows considerable agreement. Virtually all

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contain units on the nature of science, anatomy and physiology, metabolism, photosynthesis, genetics, developmental biology, evolution and ecology.

A problem to which many of us directed our attention was "coverage" of the major plant and animal phyla. The majority were either actively engaged in teaching such material or had courses which included it. With one or two notable exceptions, few professors were satisfied with this portion of their courses and expressed their dissatisfaction in various ways.

For some, the solution to the problem was simple—eliminate the survey of the phyla. These persons felt that similar material was thoroughly covered in pre-college schooling, and needed no repetition at the college introductory level. Some also felt that, since the majority of introductory biology students did not continue in advanced courses, they should be exposed to problems more pertinent to modern biology than purely descriptive anatomical and morphological differences between plant and animal species.

Other participants, however, while dissatisfied with the material on plant and animal phyla as their courses presented it, still felt that such material was pertinent and should be included. One suggestion was that each phylum might be discussed in terms of the use of some of the organisms within it to attack current research problems. Thus, for example, the squid (phylum Mollusca) might be discussed in terms of the use of its giant nerve fiber in neurophysiological research. The advantage seen in this approach was to de-emphasize the teaching of anatomical and morphological detail—of later importance only to biology majors—and to emphasize the experimental aspects of biology, using specific anatomical detail where relevant.

A few participants felt that to teach an introductory biology course excluding coverage of major plant and animal phyla and their representative forms would be a disservice to the subject and the student. At least one course outline devoted to a major amount of time to such coverage. One person in this group maintained (and many agreed) that textbook attempts to cover certain biological "principles" in both plant and animal forms simultaneously (e.g., treatment of the circulation of blood in animals and the translocation of water and nutrients in plants as if they were the same) was a great mistake. Rather, they felt it is essential that such processes, at least initially, be treated on the level of the whole organism.

It perhaps suffices to say that all Stanford participants felt the need to include subject matter in their introductory courses which could give the student an understanding of biology as an investigative science, while simultaneously covering enough fields to make him aware of the vast scope of biology. One of the difficult factors here is obviously that of time. One participant cited an hypothetical example of a student who reads of a scientific discovery in a daily newspaper. Noting the student's tendency to accept too readily the evidence cited, and referring to such an acceptance as a "first level" of comprehension, he wrote:

> The real problem . . . is how to carry the student as far as possible beyond the first level in the limited time available. I consider this problem to be far more important (difficult and intangible though it may be) than questions of specific mechanical devices or the details of how many principles exist or whether botany is getting its fair share of attention.

All of the Stanford Colloquium participants were well aware of the changes in their discipline and that many of these changes had come about on the molecular level of investigation. Some seemed to view this fact as posing a threat to the older disciplines included under the biological sciences (i.e., morphological taxonomy, phylogeny, etc.). Others, however, welcomed the newer material, viewing it as contributing to a beneficial selective filtration of course material:

> There is one thing that especially impresses me about the teaching of biology today. This is in the rapidity in which the molecular revolution in biology has forced us to cull out the dead wood of biology. Perhaps biologists should be grateful for this, not resentful, for rarely has any field progressed as rapidly. Yet, suddenly we are faced with an heretical idea—that we cannot retain even a survey of the representatives of the great animal and plant phyla (Harvard sends its students to the museum during Christmas vacation), or that we cannot describe the organization and

> functional attributes of the vertebrate or the angiosperm, because all new contributions to molecular biology must be inserted automatically as they occur. There is a fallacy present, I believe, in that biologists are thought to line up with one or another group—to be with us or against us. Many of us are quite sympathetic to both points of view, respectful of each sphere of knowledge, and admittedly temporarily perplexed as to what the optimal blend of the two elements should be in a formal course. I suspect that there is room for flexibility and freedom in this matter. There is not, however, freedom in the sense of license for boorish and dogmatic downgrading of legitimate elements of the discipline of biology. Of course, if perchance we have made some gross errors in delimiting the discipline, then doubtless the offending portion of the domain should be honorably dischaged.

All of the colloquium participants seemed wholeheartedly committed to presenting the most modern-up-to-date introductory course possible to their undergraduate students, regardless of the amount of "weeding out" and teaching difficulties which might follow such a commitment. As one participant expressed it:

> Although it may seem to be paradoxical, and may be an incorrect assumption in any event, I think that the poor teaching of classical biology by molecular biologists is worse than the poor teaching of molecular biology by classically oriented biologists.

COURSE ORGANIZATION

It is interesting, perhaps, to present some participants' proposals for organizing a liberal arts introductory biology course. For several, the selection of content based on adherence to a theme was of primary concern. For others, mode of presentation of the material was more important.

Briefly, some organizing principles were as follows:

1) **The "inquiry" approach.** Several Colloquium participants saw value in the inquiry approach to biology, while others considered it more an atmosphere within the course. One professor uses it as the organizing principle for his entire course. For example, he has the students read the research literature available on a cell organelle and then present their own oral and written summaries, with citations, to the class. It was felt that this approach gave the student a clear conception of how scientific information is gathered, as well as an insight into the way

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scientists communicate with each other through research literature.

In support of this idea, one participant wrote:

> I agree with Conant and others that the best way to display the nature of science is to drop the novice into an intimate position in the activity itself—to apprentice the novice to a scientist—the "you can't learn to swim without getting wet" school. There is no need here to go into the considerations that would render this ideal very nearly impossible. There is, however, one point in the actual biological enterprise with which the students can be realistically related. This point is the literature of science. I refer here to the real literature, not the stuff of textbooks, although on rare occasions real literature has been written in the textbook form. Textbooks, in fact, appear to me to be written from a position of total misunderstanding or lack of comprehension of the meanings and proper goals of the educational endeavor.

2) The "scientific method" theme. Interrelated with the inquiry approach was that of a course theme based on the student's early and sustained exposure to the logical basis of scientific methodology. A shortage of text materials utilizing this technique was mentioned by one participant in this report. Critics of this approach noted the danger of giving the student an overly rigid view of scientific methodology; they stressed the necessity of the student's awareness that much of the logical scientific framework applied to experiments fits far more nicely after the work is done than before. Directing his comments to this last point, a participant wrote:

> All we know is that by following the method we arrive at an image. To say that we know the image first and somehow construct the method afterwards seems to be a position often taken by those who would design curricula in biology. This fallacious position leads to a rationale for an introductory course whose first goal is to present the image as it happens to appear at that time. I would characterize this approach as "the revealing of the mudpies." If this is the goal, I would maintain that there may be some question as to whether it is, in fact, science, or in any sense mirrors science.

Proponents of the "scientific method" approach acknowledged

ERIC

these drawbacks. However, it was strongly felt that they could be circumvented through continued emphasis on the deductive nature of scientific experimentation and avoidance of the false pretence that the research scientist's original reasoning processes were being created.

3) The "evolution" approach. Another participant selected evolution as a course theme. He wrote:

> If there is any one major idea or concept of biology which serves to unify the field, it is most probably that of organic evolution as presently understood. Accordingly, it would seem proper that any introductory course in biology should not only include this concept as part of its body of material, but also make every attempt to interweave it throughout the course as the unifying thread.

4) The "whole organism" theme. A few participants felt very strongly that the living organism in its entirety should be the central focal point in a biology course. One wrote:

> The course would concern itself mainly with the broad generalizations of biology but would include as illustrations a consideration of additional concepts strictly plant or animal. It would be oriented toward the living organism with excursions to the molecular and the biosphere level as these are needed for knowledge and understanding.

Supporting this, another maintained that "studies of isolated systems are in the spirit of biology only if related to the integrated organism."

5) The "organismal-environment" complex. Another colloquium participant thought an introductory biology course should "acquaint the student with our present level of understanding of biotic phenomena, and introduce him to the processes of method and logic through which this current level of comprehension has been attained." This person stressed "adaptation" in an extensive paper which supported the organismal-environment complex as a course-unifying theme:

> . . . Adaptation . . . may be effectively employed as the basic frame of reference within which nearly all biotic activities or attributes may be meaningfully interpreted. Adaptation may in fact represent the *most unique and universal attribute of life.* Hence the concept of adaptation may well be the central phenomenal principle of biology.

. . . Adaptation is more than "skin deep," and that in fact *every level of organization* from that of the ecosphere to that of subcellular molecular complexes represents a manifestation of the adaptive potential of life.

The concept of evolution has been employed as an integrating theme for biological curricula, yet evolution itself is subject to interpretation as merely demonstrating the process of adaptation viewed in the perspective of time.

Although evolution may be seen as operating at the level of the interbreeding population or panmictic unit (in the case of sexually-reproducing organisms), it actually reflects the ceaseless process of adaptative adjustment of the molecular genetic mechanisms of living systems. The concept of the *gene* has itself been utilized as the unifying idea of biology, primary emphasis thereby being placed upon the molecular organization of replication of the genetic code and its translation in terms of the metabolic machinery of the cell. These topics are indeed of cardinal significance for they concern the universal mechanisms whereby adaptation is achieved. However, genes do not develop or evolve *in vacuo,* but under the influence of genic and nongenic selective forces. Biology curricula oriented primarily to the concept of the gene may tend to emphasize the molecular and cellular levels of biotic organization at the expense of organismic and supra-organismic considerations. Seldom is the liberal arts student oriented to the biotic world as an interactive complex operating simultaneously on molecular, cellular, organismic, and supraorganismic levels, subject on every level of organization to natural selection toward adaptedness and co-adaptedness. Employing a curricular construct based on the concept of adaptation rather than that of the gene *per se* should promote a multi-level approach which would encourage appropriate consideration of the organismic and supra-organismic aspects of biotic integration as well as the sub-organismic one.

6) The "themeless" course. Some participants felt that a "theme," as such, was unnecessary in introductory biology. They believed that any unification such themes provided was far more obvious to the instructor than to the student. One such professor observed:

> Insofar as biology represents a discipline it should be approached as a unified subject. Yet, I am not convinced that a course must be built around a theme or even a set of so-called principles. Evolution is often regarded as a suitable

> thematic umbrella. After evolution, themes are hard to come by. Is it not possible to put across evolution concepts at various levels centripetally without subverting other major topics or rather without making the topic incidental to evolution? The main intellectual force of morphogenesis is the experimental methodology of developmental biology applied to the emerging concept of the gene and forces affecting its expression. This is integrative but not particularly theme-directed or dependent upon evolution.

Echoing this sentiment, another wrote:

> From our discussions here I am not convinced that a single pattern for teaching biology should be hoped for or expected. What *can* be hoped for and expected is a course which offers the students a coherent picture of biology, indicating the major problems, the major levels of integration, where the problems exist, and a tentative position for himself in relation to the world in which he lives.

Another person felt that a course stressing only one theme (e.g., molecular biology, evolution, or human anatomy and physiology) fails to develop a true understanding of the scope and importance of modern biology. Indeed, several participants saw nothing wrong in presenting a biology course as a series of problems, with little or no attempt being made to establish an underlying theme. One group even distributed an independent paper outlining their proposal. These quotes give some insight into its basic ideas:

1. The term "problem" is important, not concept, principle, or attribute, but problem. We hope its use will stimulate inquiry; that method as well as content will be seen. This approach points out the unknown as well as the known. It is probably good pedagogical technique in engaging student interest.
2. It is difficult to find central problems which, when broadly conceived, are absolutely unique to biology. It probably isn't fruitful to pursue this search. Although no single problem may be unique to biology, the entire array of such problems certainly will be.
3. Certain general concepts—e.g., relation of structure to function, adaptation, homeostasis, etc.—will be applicable in studying many problems raised in this way, but concepts seem less powerful as organizing guidelines than do these problems.

It should be noted that several who proposed certain "themes" also agreed with this last-quoted viewpoint. For example, those in favor of the scientific method or inquiry approach felt this technique highly appropriate for presenting the individual units of the problem-solving approach course. In other words, if genetics and development were among the problem areas tackled, the theme suggested by the scientific method approach should apply just as well as in a more unified course.

7) The "paperback" course. Perhaps not so much a theme as a technique, a textbookless course based completely on carefully selected paperbacks was presented by one professor. He emphasized that his course is given to both majors and nonmajors, that it does *not* presuppose a chemistry background (this being supplied by one of the paperbacks), and that individual research participation is used as a teaching device for the more talented students.

THE TWO-YEAR INTEGRATED PROGRAM

In his paper, one Stanford participant suggested:

> One approach might require two years, enrollment from both the sciences and the humanities, and most certainly include a lab. It might begin with mathematics, move into physics, then chemistry, and finally biology, providing a truly integrated approach.

As if responding to this idea, another participant submitted *A Plan for an Integrated Physical and Biological Sciences Course for Liberal Arts Students*, prefacing it with points made by the Colloquium's "resident philosopher" Dr. Paul Schmidt, of the University of New Mexico:

1) Biologists are afraid of the "new biology."

2) The teaching of a course must mirror the nature of the subject.

ERIC

The plan envisioned a biology course for liberal arts students free of "all fear of new biology" and reflecting "the logical nature of biology" in its present form as a combination of "traditional" and "new biology." As this participant expressed it:

> The integration of the new biology into traditional biology seems to result in a subject with a logical sequence beginning with considerations of energy, leading through molecules and macromolecules to cell organelles, cells and tissues, and then to organisms and populations. It is noted that traditional biology deals largely with the latter of these while the new biology is concerned more with the former. Thus if we are to follow rule (2) of Professor Schmidt we must teach the new biology first and then lead into the traditional areas. This, apparently, is the reverse of the usual procedure. Using genetics as an example, we observe that students are usually taught Mendel's Laws first, chromosome or cytological genetics as an example, and finally, are told about DNA and RNA and shown how the linear arrangement of information in nucleotide sequences and the various gyrations of the DNA and RNA molecules can "explain" observed genetic phenomena. According to the plan being investigated here, the molecules would come first, their gyrations and chromosomes second, and then, probably with some historic flavor, the observable genetic consequences of the molecular aspects.
>
> Similarly, anatomy would, according to this idea, be taught in the order of macromolecular structure, physical chemistry of micelles and other stable polymolecular configurations, subcellular and cellular structure, tissues and gross anatomy; again approximately in the reverse of the traditional order. Two years will probably be required to present the entire integrated program. This agrees with Professor Sears' statement that one year of science is no longer enough for liberal science students.

ERIC

THE HISTORY AND PHILOSOPHY OF SCIENCE: A DOUBLE-TRACK PROGRAM

One Stanford Colloquium participant noted in his paper that special effort should be made to include at least some elements from the history, philosophy, and sociology of science in our courses. Another addressed himself even more specifically:

> The problem now becomes one of determining what the straight and narrow path is, if, indeed, it is straight and narrow, and its starting point. What is biology's very own methodology? Is it merely an accidental hodge-podge of methods borrowed elsewhere? We are, I agree, hampered here by the current lack of good historical analysis that would be capable of pinpointing the truer evolutions and the central conceptual cores that would allow us to delineate the biological methods, the path.

Still another observed:

> . . . biology as a science is evolving, and has continuity, with its present rooted in the past. Great theories and great

insights arose from complex events, and the future can be speculated upon best with these insights. Therefore, an historical perspective is desirable.

Since these ideas evolved independently from the thoughts of at least three individuals, it was particularly appropriate that one of the Colloquium participants was from the field of history and philosophy of science. He wrote:

> To meet this demand, it is proposed that the student take two courses simultaneously: one in a science (in the case discussed here, biology), and one in the general history of science. The course in introductory biology would be rigorously organized and taught by a biologist. It is hoped that the biologist and the historian of science would review and discuss each other's course outline as much as possible. It should be emphasized, however, that the overriding concern of the biology course should be the teaching of biology.

A paper was presented by this participant outlining the approach such a double-track course might take. Certain points, perhaps, deserve excerpting here. For example:

> No specific facts of biology or any science are absolutely requisite. What is most important for the general education of students in science is the nature of scientific statements and the way in which information is gained. Of course, the study of how information is obtained cannot be taught *in vacuo*. Information . . . the content of science . . . must be taught in a rigorous way. But the organization of the course should reflect the more important goals: the introduction of students to what scientists do by the practice of science itself.

The author of this double-track course proposal went on to discuss the "case history" approach designed to meet the requirements of a general education course. This approach, employed in a number of universities and colleges in the past 20 years, is so well known as to preclude description here *

In reference to the case history approach, this pa[illegible]icipant wrote:

> A number of problems arose from this method. First, [illegible] is difficult to prove that they really teach students t[illegible]

* See *General Education in a Free Society*, Harvard University Press, 1944, an[illegible] *Harvard Case Histori[illegible]s in Experimental Science*, edited by James Bryant Conant, [illegible]arvard University Press, Vol. 2. A more complete discussion of this Colloquium partici[illegible]'s proposed program appears in the December, 1966 issue of *CUEBS NEWS*.

nature of scientific investigation. The case history approach teaches about science but does not teach science itself. A student is asked to learn how science operates by reading how other scientists work, but is not given the opportunity to study a laboratory problem itself at first-hand. Second, such courses tend to be hybrids. They are not good science because they do not teach aspects of modern theory (in biology, chemistry, or physics as the case may be). They are also not valid courses in the history of science, since the cases are generally written to trace a single theme to a number of workers. Although this may be extremely interesting, beginning students do not have a framework in which to place historical studies. In addition to being bad science, such a course is also in danger of becoming bad history, by treating issues out of context. Because it failed to accomplish the goal set for it, the case history method has now been abandoned by Harvard. In all but one course (and that will be discontinued this year) introductory natural science courses have returned to teaching "straight science."

Despite the fact that the case history approach has not proved satisfactory, it is still agreed that the goals of such a course are valid and worth pursuing. Yet how is it possible to meet the demands of the scientific discipline itself, while at the same time treating problems in the history of science? The biologist willingly expresses his desire to teach the broader relations of his discipline to philosophical and sociological problems. At the same time, however, he admits that when it comes to a choice of biological information *vs.* philosophical or historical (in terms of lecture time), he will generally choose the former. This is a perfectly reasonable choice. It is difficult to expect a practicing scientist to school himself thoroughly in these interesting but nevertheless peripheral areas of his subject-field. How then can the wider aspects of the relation between science and society be included in the students' general education course in science?

The double-track program proposed by this participant seemed specifically designed to tackle this question.

THE ROLE OF THE LABORATORY

There was virtually unanimous agreement among the Stanford Colloquium participants that laboratory experience was the most important part of any introductory biology course. As one person put it, the laboratory is "essential in the design of the course to reflect biology as a science." Some persons from larger institutions, while in agreement with this idea, found it ironic that, for the most part, the laboratory was that portion of their course that they found most convenient to turn over to graduate students.

One person's laboratory procedure outline showed a strong preference for students performing open-ended laboratory investigations. These were seen as being on-going through the academic year and were designed to show students "the necessarily incomplete nature of biological investigation."

The importance of an introductory biology course laboratory in Harvard University's "Nat Sci 5" was emphasized by a course instructor:

> We put enormous energy into finding the best possible teaching fellows for the labs. These men form the only close contact the students will have with biologists. We recruit in many departments other than biology . . . history of science, physics, biochemistry, medical school, etc. . . . and use not only graduate students but also postdoctoral, advanced and undergraduates (with whom we have great success) and even a couple of faculty members from other colleges who have wanted to see what we are doing. These teaching fellows are paired up to complement and support each other . . . one with a molecular approach with one from classical biology. Each pair of teaching fellows handle 30 to 35 students. We demand that teaching fellows attend lectures. . . . A course such as this is educating not only to undergraduates but also to its teaching fellows, the next generation of college professors.

While there was considerable agreement of the desirability of "inquiry oriented" laboratory exercises, one participant pointed out that biology is not *always* purely experimental in nature and a course should avoid making it appear so:

> I think that it is particularly difficult to demonstrate ways in which the school of critical inquiry should permeate all aspects of the course. The laboratory, of course, presents the best opportunity for presenting the student with practical experience in scientific methods. I would like to point out that this need not necessarily be an actual "experiment" done in the laboratory. As Claude Bernard points out so clearly, observational sciences are also based on experimental reasoning. I had hoped to plan, in a general and preliminary way, a sort of "26 Afternoons at Ideal College," but there has not been sufficient time for this. I will merely point out that I visualize three types of laboratories: 1) critical observations and reasoning, 2) presentation of a problem and suggestions on the procedure by the instructor, and 3) small research problems originating in the minds of the students.

While there were many observations and suggestions concerning laboratories and laboratory procedures, only a few of the more pertinent are mentioned here:

1) Familiarity (with varying degrees of sophistication) with many of the tools of biology—the microscope, micro-

tome, respirometers and/or manometers, stimulators, physiograph or kymograph, isotopes (via X-ray film or detectors), anaesthesia, scalpels, titrations, pH meters, spectrometers, growth chambers, analytic balances, centrifuges, etc.

The importance of familiarizing students with the tools and techniques of biology received considerable support:

> It is here that revolutionary changes have taken place over the last decade or two. Until very recently, the microscope was very symbolic of biological equipment, perhaps *the* basic tool. It is still a basic tool, along with slides and dissecting equipment. Now, however, all the tools and instrumentation of chemistry and physics are also included. Everyone knows the role of the ultracentrifuge, gas chromatography, and the electron microscope, but now we also have elaborate controlled and other proved means of acquiring and analyzing data. The accelerated molecular biology owes its achievements to technical advances in large measure. Instrumentation and methodology are more important than ever because the sources of data are more removed and indirect than they ever have been and the observer observes vicariously, and we also have to exercise great responsibility in their uses.

2) Maximum use of live materials. Thus, fertilization and cleavage should be observed using live sea urchins, e.g., not prepared slides, although such slides may be made available for comparison and for observing later stages.

(One course called for *only* living materials in the laboratory. To some participants this seemed a rather excessive reaction to the prevalence of musty, formaldehyde-soaked specimens to which many of us were exposed.)

3) Completion of experiments. Experiments should work to a reasonable degree so that students can get some results and begin to learn some skills.

4) Prompt presentation to students of an exciting, open-ended situation during the first or second meeting, preferably. A live plant or animal which can react to various stimuli in a measureable way would be the most ideal experience.

5) Inclusion of certain concepts of measurement using biological materials.

6) Coordination of laboratory sessions with the lectures.

(Some felt this vital; others voiced strongly the opposite view.)

7) Use of small reading room with books and reprints. From the materials found here, the reading assignments are given. While the college libraries also do this, its more valuable role would be to provide a way for the student to be casually exposed to a much wider range of books. The shelves would contain popular introductory biology texts, a few good introductory books in chemistry, physics, mathematics, and sociology, fiction about biology (including science fiction), biological classics which instructors never have a chance to assign, back copies of *Scientific American*, molecular models, books related to social concern in areas of biology, and, where feasible, duplicated copies of pertinent research literature.

8) Avoidance of over-emphasis on lab reports and drawings. Students should use a drawing as a personal thing to make his own recall easier. There are courses for drafting and lettering . . . this is not one of them.

THE SOCIAL RESPONSIBILITY OF THE BIOLOGY PROFESSOR

The responsibility—or lack of it—of the professor to make students aware of biology's social implications proved to be a point on which virtually everyone had strong opinions. It was suggested, for example, that the study of genetics include discussions of race, or the study of ecology include discussions of man's need to control his birthrate.

One participant wrote strongly in favor of the professor's responsibility to emphasize the social implications of science in general, and biology in particular:

> The purpose of our schools is the development of free, capable, and responsible individuals aware of something beyond their desks or benches . . . within themselves, within their homes, within their society, and ultimately, within the nature of the universe. At the heart of our system of higher education is the liberal arts college. It is here that we expect our future leaders to acquire the perspective, the

ERIC

> insight, and the ability to communicate that will enable them to become the catalyzers and the binders of an open society. The teacher of undergraduates must therefore be more than a specialized scholar; he must himself possess the general skills and exemplify the values he is responsible for transmitting. There will always be those who will not acquire a wider view and sense of responsibility commensurate with their achievement in specialized tasks, and there will be those who do not have the ability or the will to achieve mastery in some endeavor, but an increasingly high proportion of the educated must possess both breadth and depth if we are to avoid being ruled by technicians and demagogues.

Later in his paper, he stated:

> The massive involvement of science in our lives has forced upon the scientist a new responsibility, both as an expert and as a citizen. The scientist can no longer feel that the essential amorality of science absolves him from responsibility for the uses of technological power. He has become a new keeper of mysteries. Rather than act merely as an oracle, he must learn to communicate to the non-scientist the essential implications of his methods and findings; at the same time he must not assume that his technical competence makes him infallible on questions beyond the realm of science.

Another participant, also in favor of a strong "responsibility" stand, noted our "capacity to release more energy and cause more change in nature per unit time than man has ever known." He felt that such power must carry with it full recognition of man's responsibility to himself and his land "for the management of the changes he chooses to introduce."

Human values, felt by some to be inherent in a biology course, were also of concern. One person felt that biology, as well as the humanities, must give the student the "basis for rational decision-making in his future life" and the realization that "his life is shaped by decisions which are rooted both in concepts of science and religion, law, art, etc." Another participant stated this idea another way:

> I also think that a liberal education course in biology should recognize that man has a rightful interest in himself as a biological organism. I do not propose that this become a "human centered" course; on the other hand, I feel there

> is an obligation of biology teachers to see that the student obtains a concept of himself as a biological organism and a part of the living world. There is also an obligation to point out ways in which biological facts and concepts are involved in medicine and in social and political problems.

Conversely, many felt that a biology professor should *not* concern himself with the social implications of his subject. Outspoken in this matter was Dr. Paul Weiss, of the Yale University Department of Philosophy. He felt emphatically that the biology instructor's only responsibility was to teach good, up-to-date biology, and that the constant attempt to show utilitarian justification for a particular area of biology was, in a very real sense, an attempt to justify its existence—to "apologize" for it, so to speak. Other participants, echoing this view, believed that such an approach worked against a primary educational need of the non-science major, i.e., the imparting of an appreciation for pure or basic research, with no eye to the ultimate usefulness of the knowledge such research might bring:

> An introductory biology course can serve the general student in another area of human endeavor where topics in biology impinge on problems in man's society. Ever since the explosion of the first atomic bomb 20 years ago, the question of the social implications of science and the role of scientists as professionals should play in the solution of social problems has been discussed and debated. As responsible biologists, it is incumbent upon biology teachers to present to the students in an unbiased manner the facts and their scientific bases, pointing out their inadequacies and incompleteness where they exist. Problems that appear imminent should be indicated whenever they are relevant to a particular topic under consideration. But presentation of personal opinions and decisions for social action are outside the scope of biological education.

> Pragmatic matters such as natural resources, moral issues such as freedom, equality, regulation of the individual, high human virtues such as a sensitivity to beauty, and humility, are capable of deriving a part of their essence from an awareness of biological principles. I do not think that repetitious exhortations or charges to the audience are the means by which the implications of biology are brought to the student's awareness. I strongly believe that the role of the biologist in a liberal education is to give the student good biology.

An interesting sidelight of this discussion was the distribution of mimeographed copies of taped interviews between one biology professor and a few of his students. Part of the discussion concerned the students' opinions on the desirability of professors connecting the subject matter with its possible social significance. The opinion was fairly unanimous among these students that they did *not* want the two related for them. Of particular interest here was the fact that these students were from an institution noted for the student body's involvement in humanitarian and social-responsibility movements.

While there was sharp disagreement on this matter initially, I think that both sides saw and agreed with the concerns of the other. Those who believed in the biology professor's obligation to establish the social implications of his discipline seemed to reflect the concern for the bridge between the "two cultures." Those opposed did not lack this concern; rather, they feared that the professor's zeal to relate biology to contemporary problems of mankind might cause him to propagandize in favor of one particular political or sociological bias—to impart opinions which were less likely to have been scientifically derived. It was pointed out that while genetics might be used to help promote racial harmony, it was also used by Nazi Germany to promote just the opposite.

In conclusion, most seemed to agree that the manner in which the social implications of biology are introduced into the classroom is of considerable importance. Where it is appropriate to illustrate a biological principle, they concluded, certain sociological problems have a rightful place in the classroom. Twisted to fit an individual professor's bias, however, such problems have no place at all in a biology course.

MAJOR VS. NON-MAJOR

Should a separate course be offered to majors and non-majors? This question was discussed only briefly at Stanford. An earlier meeting of the CUEBS Commissioners in Washington had strongly recommended one course for both majors and non-majors. In general, this opinion was shared by the majority (though not all) of the Stanford Colloquium participants. It is worthwhile to point out, however, that most of this opinion was contingent on the belief that this one course should *not* be a "traditional" phylogenetic approach which stresses rote memorization of animal and plant groupings and parts.

Many persons felt the non-science major should receive, in his one year exposure to the subject, an appreciation of biology's scope, its history and philosophy, its current problems, and probable future. To some it almost seemed to come as a shocking afterthought that such insights are probably even more important to the biology major. Many felt that some of the specialized knowledge of biology now taught in introductory courses should come later in the education of a biology major. Thus, it was not thought that the non-science major should be exposed to the course traditionally given to the major, but rather both major and non-major should receive a newly designed course. Such a course would be designed to impart an overview of the field and its vast potential for intellectual growth and achievement, to the non-major for his continuing appreciation of the discipline, and to the major for the enrichment of his participation in it.

ERIC

THE DISSENTERS

It may already be evident that there were several areas of disagreement among the Stanford Colloquium participants. While many of these disagreements were minor, others were fundamental, keenly felt, and seemed essentially unresolvable.* For

* Such disagreement is hardly unique. Available to us during the Stanford Colloquium was a copy of "Biology in the University, Problems and Prospects," the proceedings of the University of California Special All-University Faculty Conference of Biology, June 8-10, 1963. A footnote on p. 8 of this report reads as follows:

[1] Our Committee could not agree on one question: the place of taxonomy in modern biology. The divergent points of view may be summarized as follows:

A. In the post-Darwinian period, taxonomy assumed a position of central importance in biology, because it became expressive of evolutionary schemata. It still holds a central position, as one of the main lines of biological research leading to a better understanding of the detailed course of evolution.

B. Taxonomy is simply the art of cataloguing living organisms on the basis of their degree of overall similarity, not different in principle from the humdrum but essential task of the librarian. Phylogenetic considerations are often irrelevant and misleading in taxonomy, which was consequently led into false paths by the Darwinian revolution.

It is exciting to contemplate the discussion that must have preceded the formulation of these two opinions!

example, while some professors presented a course based upon an evolutionary theme, one took exception, writing:

> I see no particular merit to teaching evolution in a liberal arts course. For one thing, the phenomenon of change with time, progressive or otherwise, is not unique to biology. For another, the mere idea of organic evolution is an ordinary part of the furniture of the mind of anyone who reads or goes to school.

Perhaps one of the sharpest areas of disagreement involved approaches to the liberal arts introductory course and what it should contain. A few felt that the approaches presented by many participants were too molecular, not giving enough attention to the whole organism and its environment. One person stressed the need for using "our individual imaginations and the tools of our discipline to give students as much contact as possible with the whole organism in nature, whenever it is possible, without slighting other important phases of the course."

One participant expressed the feeling, with considerable conviction, that our stress on "modern biology"—molecular biology in particular—was robbing the student of the beauty inherent to the living state as it exists in nature. Another felt that the "traditional" course to which the Colloquium members were addressing themselves no longer existed in significant measure: that they were "beating a dead horse." A strong majority, however, took exception to this idea.

In general, the dissenting thesis seemed to be that "change for the sake of change" was dangerous. It was pointed out by one person that teaching methods should change in line with biological innovations. Since this is frequently not the case, this person noted that "we need to guard against sacrificing valuable methods for the sake of novelty." While a majority agreed with this statement, as well as with the harmfulness of "change for the sake of change," disagreement as to what would be changed and what should be left alone still remained. One spokesman presented some other dissenting viewpoints in this area:

> A general biology course should serve to give insight into the nature of biology as a science, its spirit and methods of inquiry, its limitations, and the scope and content of its

subject matter and conclusions. In course design, care must be taken not to include too many topics which, by their number, may lead to superficial study of each. We must also guard against too limited a selection of topics which might give an incorrect or inadequate appreciation of the subject. Because of the complexity of biology, decisions on content and balance are especially difficult. We therefore have a wide variety of biology courses.

Further, in our attempt to study the diversity of life, plant and animal, the phylogenetic approach remains useful. It should not be rejected as a method because in the past it may have been used as a whole course framework and taught with a great excess of taxonomic and morphological detail. There are significant insights into evolution and comparative adaptation that may be gained by studying the diverse types of plants and animals within the framework of a phylogenetic sequence. It would seem unwise to lose these by studying organisms in other sequences or by other analytical arrangements merely to avoid the appearance of using an old established method.

During the conference, virtually all participants found points on which they became "dissenters"—some undoubtedly more than others. The presence of such dissent made the conference far more productive than it would otherwise have been. All of us were forced to defend—and thus re-examine—long cherished opinions and ideas. As a result, most of us either abandoned these ideas or approached them with renewed conviction and enthusiasm.

EDITOR'S SYNTHESIS

The diversity of ideas and convictions expressed by the Stanford Colloquium participants might lead to the conclusion that virtually any kind of biology course could be justified for a liberal education. However, if this report seems to emphasize disagreement more than agreement, it is perhaps because I leaned over backwards in order to insure that minority viewpoints were not ignored. In truth, there *were* discernable concenses on many major points concerning what a biology course in a liberal education should and should not be. For example, the inquiry approach to science, stressing the "process" of science (i.e., the underlying logic of the scientific enterprise) received strong support, and the need was expressed for more of this in our lectures, laboratories, and course materials.

It was suggested by those who reviewed the initial draft that, in a final section of the Stanford Colloquium Report, I

ERIC

step out of my role as editor and into that of a participant-critic-observer. This role, of course, entails a subjective rather than objective analysis. The reader is here forewarned, therefore, that the opinions expressed in this section are strictly my own.

First, by focusing on disagreement as well as agreement, some sections of this report appear unduly negative. A prime example is the section on high school biology. As editor, I could only report on what had been written by the participants on the subject, and try to give the gist of the discussion. I am inclined to think, however, that the group should have devoted more time, both orally and in writing, to discussing the impact of BSCS biology on the high school course and its eventual effect on the college introductory course. Much fine work, for example, has been done by the BSCS, particularly in the line of opening channels of communication between high school and college teachers. These efforts, I felt, deserved far more attention from the group than they received. It may well be that, at the time of the Colloquium, the full impact of BSCS had not yet been felt at the college level. If the current trend toward BSCS and BSCS-type courses continues, however, it will be the college biology instructor who will have to meet the challenge of whether he can be as receptive to change and improvement as many of his high school counterparts have been.

The same aspects of negativism seem to predominate in reference to those who upheld the cause of the more conservative, phylogenetic approach to biology instruction on the college introductory level. Despite my efforts to obtain objectivity, by virtue of the content of the papers I was commissioned to edit, the report may often appear to be slanted. As editor, however, one is hampered by being able to pit the case of the "liberals" against the case of the "conservatives" on any one particular issue only in terms of what the representatives of each group actually committed to writing.* It so happened that the former presented in writing a more extensive and thorough defense of their positions than did the latter. For example, there are cer-

* The labels "liberal" and "conservative" are no more satisfying here than in politics, and I should not like to have to defend them. They seemed only a shade better than "modernists" and "traditionalists." It is essential to point out again that no clear dividing line into the two camps was possible at the Colloquium; on any one issue a participant might be found in either camp.

tainly intellectually valid reasons behind the plea for not losing sight of the whole organism in the rush to be modern and molecular. The "fair share of attention to botany" that one participant mentioned may be no more than a legitimate plea from botanists that plants not be considered as just simpler animals which happen to carry on photosynthesis. Most certainly, a strong case can be made for ensuring that a student complete his biology course with some concept of how a whole animal or whole plant is built and functions. Had this case been fully presented in writing by those who made it a central point in the discussions, the division of opinions on such points might not appear so wide. Even the most ardent of the "molecular biologists" present at the Colloquium would probably find little to criticize in the last mentioned point concerning student familiarity with the whole organism; rather their concern was directed towards introductory courses which include little else.

Second, I feel that the failure of the Stanford Colloquium to reach a clear-cut consensus concerning an introductory biology course in a liberal education is not necessarily a sign of weakness. The Colloquium participants were an extremely diverse group, and represented institutions equally so. For the purposes of the Colloquium, such diversity was both necessary and desirable. At the same time, this diversity posed a major obstacle to any unanimity of opinion, assuming such a unanimity to be a desirable goal (which it may well not be). Certainly there was no directive at the start of the Colloquium that any consensus or unanimity of opinion was to be considered a goal, nor should there have been.

Third, by not probing more deeply into the one course for majors and non-majors concept, I felt possibly that the Colloquium participants were somewhat limited in their approach to the problem of biology in a liberal education. One participant stated that he came prepared to debate the topic, but was told that a recommendation had already been made in favor of one course. Further, many participants came from liberal arts colleges where students do not declare their majors until after the first or second year. Since there was no possibility of a separate course for majors and non-majors in these years, any discussion of the point probably seemed to these persons to be irrelevant.

Thus, they may have felt compelled to include in their course outlines material which the "conventional wisdom" deemed essential for biology majors to know. That this was a restraining factor on the imaginations of some of the participants (as evidenced by their course designs) seemed to me obvious. It might possibly have been far better to not only debate the one-course concept (despite the impracticality of two courses at some of the institutions represented), but also to challenge the aforementioned conventional wisdom concerning what a major must "know" when he completes an introductory course.

Paradoxically, I suspect that the original one-course recommendation was based on the situation existing in some institutions where two similar biology courses, one for majors and one for non-majors, are offered side-by-side. In this situation, the one for non-majors almost inevitably becomes a watered-down version of the other. Further, it was recognized that some institutions, due to staff limitations, simply cannot offer two courses. The recommendation, however, was *not* intended to prohibit the creation of a course for non-majors differing markedly from the general course in both content and design; at the Stanford Colloquium, it may possibly have done so.

A fourth factor was the aforementioned diversity of participants and the institutions represented, as well as the kind of biology courses offered. The background of the instructor and the kind of student served by the institution were undoubtedly key determining factors here. Whatever the cause, however, it was certainly obvious from the course outlines submitted and/or the discussions that the kinds of courses offered often differed markedly. This is not to say, however, that the Stanford Colloquium participants should have been selected from more similar institutions. To have done so would have made any concrete conclusions emanating from the Colloquium that much less stimulating and useful to the thinking of biology instructors as they grapple with their local problems. Certainly there *is* a wide diversity among the colleges and universities of this country. Any failure to take this diversity into account would be fatal at the outset to a successful attack on the problem of biology in a liberal education.

What, then, did the Stanford Colloquium accomplish? By itself, possibly little. Viewed in broad perspective, however, its accomplishments are significant. Forced to explore many avenues of attack on the problem of biology in a liberal education, a few participants felt that the Colloquium had clearly identified those which were dead-ends. These persons also felt that existing avenues which showed promise had been marked, and new ones opened. The Colloquium also may have led the way to a fresh consideration of still unanswered questions. Is BSCS a college level approach in the high school and, if so, is this appropriate? Do college and high school students learn best in the same way? Presumably there is agreement on biology having a theoretical unity. Why, then, don't we have agreement on how to teach it? Is it because theoretical unity as a discipline has little to do with learning? Perhaps the main difference is merely the teacher's personality. If so, should we perhaps discuss the pertinent features here and not theoretical unity?

What about familiarity with modes of inquiry? Can we find a way to impart this outside of the laboratory? How do students learn best? Should we not determine this first, and then adopt our materials accordingly? These and other such questions must be answered if any meaningful attack on the problem of biology in a liberal education is to be made; at Stanford the groundwork for answering at least some of these questions was begun.

In short, the Stanford Colloquium, a study group of the Panel on Biology in a Liberal Education, provided a base from which further attacks on the problem of biology in a liberal education can be made. The fact that other groups are now in the process of doing so is evidence enough for this assertion.

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