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COMMISSION ON EDUCATION IN AGRICULTURE AND NATURAL RESOURCES
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Undergraduate Education in the Physical Sciences and Mathematics for Students in Agriculture and Natural Resources

PROCEEDINGS OF A CONFERENCE

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Preface

The Conference on Education in the Physical Sciences and Mathematics for Undergraduates in Agriculture and Natural Resources was held in Washington, D.C., February 12 and 13, 1968. It was sponsored by the Commission on Education in Agriculture and National Resources (CEANAR) and co-sponsored by the Advisory Council on College Chemistry, the Committee on the Undergraduate Program in Mathematics, and the Commission on College Physics.

ANALYSIS OF COMMITTEE REPORTS

The purpose of the conference was to analyze preliminary reports by three committees that CEANAR formed in 1967: the Committee on Chemistry, the Committee on Mathematics, and the Committee on Physics. As requested by CEANAR, these committees recommended future course requirements in chemistry, mathematics, and physics for undergraduate curricula in agriculture and natural resources.

Conferees were divided into five working groups to analyze the preliminary reports. After the conference, the committees prepared their final reports.

USING THIS PUBLICATION

This publication consists of four parts. The first part is concerned with the CEANAR conference. It consists of an orientation paper by Franklin E. Eldridge and reports by the working groups. The remaining three parts consist of the final committee reports.

Before studying the working-group and committee reports, readers would do well to reflect on the main points of Dr. Eldridge's paper. They would also find it helpful to consider the following questions, which were suggested by Dr. Eldridge in correspondence subsequent to the conference, and relate them to their own campuses.

1. How are students in agriculture and natural resources different from other university students? How are they similar?
2. What is the undergraduate enrollment and what are the trends?
3. What percentage of the undergraduates continue into graduate study, and what occupations are entered by those with bachelor's degrees and those with advanced degrees?

4. What subject matter is taught in courses in agriculture and natural resources?

5. What is the background of professors in agriculture and natural resources? Are they competent to teach chemistry, mathematics, and physics?

ACKNOWLEDGMENTS

The Commission wishes to express appreciation to Dr. Eldridge and to Arnold A. Strassenburg, who presented thoughtful, informative papers at the conference, and to George A. Gries, a member of the Commission, who planned the conference and served as chairman.

Russell E. Larson, Chairman
Commission on Education in
Agriculture and Natural Resources

Summaries

THE CONFERENCE

In the opening plenary session of the conference, Franklin E. Eldridge presented an orientation paper entitled "Trends and Goals in Undergraduate Curricula in Agriculture and Natural Resources."

Next, the three committee chairmen—C. Edmund Marshall (Chemistry), H. L. Lucas (Mathematics), and Otto H. Schmitt (Physics)—commented on the highlights of their committees' reports and discussed trends in undergraduate teaching in their fields.

Arnold A. Strassenburg concluded the opening session with a paper on "Integrated Physical Science Courses for Science Majors and Nonmajors," in which he discussed courses that may supplement or supplant introductory courses in chemistry, mathematics, and physics.

The conferees were then divided into five working groups for discussions on the topics named below.

Group	Topic
1	Chemistry
2	Mathematics
3	Physics
4	Physical Science and Mathematics
5	Integrated Physical Science Courses

Groups 1, 2, and 3 were asked to analyze the three committee reports by applying to them a set of discussion questions prepared by CEANAR (see page 13). Group 4 was asked to consider the overall needs of the physical sciences (chemistry, physics, and others) and mathematics in the curriculum. Group 5 was asked to consider the suitability of courses in the physical sciences and mathematics for students in agriculture and natural resources. After the discussions, each group prepared a report.

WORKING GROUP REPORTS

The working groups generally endorsed the recommendations of the CEANAR committees on chemistry, mathematics, and physics.

The chemistry and physics groups emphatically endorsed committee recommendations that source materials be developed that would help instructors in chemistry and physics to illustrate how principles learned in these courses can be applied to agriculture, natural resources, and biology. Even better, said the physics group, would be a course in physics structured especially for students in the life sciences.

The chemistry and mathematics groups called for greater emphasis on professional development for faculty members, stressing that individual colleges and universities are primarily responsible for such development.

The physical science and mathematics group, although endorsing the three reports, recommended that the proportion of required courses in physical science and mathematics not be increased for students in agriculture and natural resources.

The group discussing integrated physical science courses believed that existing courses describable as integrated physical science courses meet the needs of few students in agriculture and natural resources.

COMMITTEE REPORTS

Chemistry

The Committee on Chemistry recommended that all students in agriculture and natural resources take a year-long course in chemistry that includes a good introduction to the chemistry of living systems; that many of these students take a second course consisting of systematic organic chemistry, analytical organic chemistry, and biochemistry; and that source materials be prepared that would enable teachers of introductory chemistry to correlate principles of chemistry with phenomena in agriculture and natural resources.

Mathematics

Looking 10 to 15 years into the future, the Committee on Mathematics

- Recommended mathematics requirements for three optional areas in agriculture and natural resources: education, technology, and science.
- Recommended that entrance requirements in mathematics be gradually strengthened until the desired level is reached in about 5 years.

Physics

The Committee on Physics stated that almost all students in agriculture and natural resources should take a year-long physics course. The course should not be the one that is standard for majors in engineering and physics; it should be oriented to the needs, interests, and mathematical background of students in agriculture, biology, and related fields. Supplementary materials that relate principles of physics to biology should be prepared for use by instructors in physics.

Contents

THE CONFERENCE

Trends and Goals in Undergraduate Curricula in Agriculture and Natural Resources

FRANKLIN E. ELDRIDGE

The Land-Grant College Act was passed a little over 100 years ago. The act brought a great change in higher education, a change that accompanied the recognition that education and knowledge were highly applicable in fields other than law, medicine, and theology. Education for education's sake, although important and still highly regarded, was seen in better perspective. The application, through education, of newly discovered scientific principles laid the groundwork for the tremendous advances that have occurred in our modern world.

MEETING INDIVIDUAL NEEDS

With this change in philosophy came the recognition that, for most students, education is most effective when it is shaped to meet the needs and desires of individuals. Under this concept, educational programs are directed to students, not to the subject matter being taught.

Sweeping changes are again being made in educational technology. As before, they center on means by which knowledge can be made more meaningful to students.

This attitude is apparent in the reports of the CEANAR committees on chemistry, mathematics, and physics. The committees were not thinking just of the ways in which subject matter can be divided and subdivided. They were trying to determine how chemistry, mathematics, and physics should be taught in order to meet the needs of agriculture students, recognizing that these students have needs that others do not have. One requirement, they said, is that instructors whose chief interest is in the subject matter be able to communicate freely with students whose chief interest is in applying the subject matter.

Before looking at the way in which physical sciences and mathematics should be woven into undergraduate curricula in agriculture and natural resources, we should take an overview of curriculum building.

What premises should be considered in building baccalaureate programs or curricula? Let me present two of them as contrasts, as exaggerated statements of position.

One viewpoint starts from the premise that each human being has a goal different from that of any other human being. Therefore, ideally, each student should have a unique program of studies (or curriculum, or set of graduation requirements), which would be designed to help him progress toward his goal. As a concurrent premise, each professor should be permitted complete autonomy in preparing his courses and meeting with his students.

In opposition to the foregoing premise, one could say that the collective judgment of the wise faculty of the college of agriculture and natural resources should permit the formulation of one curriculum that would best prepare students, on the average, in the field of agriculture and natural resources. Such an approach would enable professors to use their time economically and would permit the development of highly sophisticated equipment and teaching techniques.

Obviously, a college must adopt a compromise between these two exaggerated positions. Some general patterns, with which you are familiar, have evolved as a result of efforts to reach such a compromise. Most of the components that must be included in graduation requirements for students in agriculture and natural resources are listed in Table 1. The percentages shown are the ones usually considered in curriculum conferences.

The percentages in Column A of the table represent a widely accepted division of components for the major, or option, that is often called "general." For the student who wishes to be a scientist, emphasis on the components can be shifted as shown in Column B; more time is devoted to basic sciences and less to application courses in agriculture. And if a student wishes a business emphasis, it can be provided as shown in Column C; the emphasis is achieved at the expense of science, agriculture, and electives.

Ten years from now, the percentage for any of these components will be about as shown in the table; where differences occur, they will be limited to 2 or 3 percent. Tremendous changes may occur in the next 10 years, but they will be in the content of the courses within these components. If there is a marked percentage change, I would expect it to be in the humanities, which include communications; a percentage increase is probable in this component.

TABLE 1 Components for General, Science-Oriented, and Business-Oriented Curricula in Agriculture and Natural Resources

Components	(A) General (%)	(B) Science-Oriented (%)	(C) Business-Oriented (%)
Agriculture	30	24	24
Biological sciences	15	18	12
Business and economics	—	—	16
Humanities	10	10	10
Physical sciences and mathematics	15	24	12
Social sciences	10	10	10
Electives	18	12	14
Miscellaneous	2	2	2

QUEST FOR BALANCE

We want a complete, balanced education for students in agriculture and natural resources. We want it to be a solid foundation for a career. To meet this requirement, it must permit unpredictable adaptations in a changing world.

We are trying to build balanced education programs in which students obtain an understanding of the relationship between three groups of courses: the physical (science and mathematics); the social; and the cultural, or humanities. This does not necessarily require additional courses in these areas. More important is an attitude on the part of professors on agricultural faculties that knowledge in all three of these fields is essential.

Mathematics is an example. For many years, students in agriculture have avoided it. Their attitude has been: "Why take it? You never use it." Many students acquired this attitude from professors who thought of mathematics as needed for understanding chemistry or physics but not needed for understanding agriculture.

A few years ago, the College of Agriculture and Home Economics, University of Nebraska, instituted a requirement that all students in the college take additional mathematics. Some faculty members were concerned about students' reactions—would they object to the requirement? No objections were heard during the year that followed. Why? The answer became clear when we realized that the attitude of the staff had changed. Most of them favored the requirement, and this attitude generated student acceptance.

Today many faculty members are not quite sure about the need for the humanities and social sciences. Their uncertainty is reflected in student requests for waivers and substitutions. When a student is 1 hour short in the humanities area, he seldom meets the requirement with a 3-hour course; instead, he searches for a 1-hour course. By contrast, students often go beyond requirements in chemistry, biological sciences, or mathematics.

Ten years from now, faculty members representing a new generation will have achieved considerable numerical strength on our college faculties. Many of them will have had experience in international agriculture. Under the influence of this new generation of teachers, students will look more favorably on the humanities and social sciences.

Many high schools have stepped up their requirements in mathematics, biology, and chemistry. When graduates of these schools reach college in sufficiently large numbers, we can move into advanced courses in these fields more quickly than we do now, and we can build early courses in agriculture in the expectation that students will grasp application of basic principles more quickly than do students of today. Persons who resist change in these circumstances will be left behind.

VOCATIONAL ORIENTATION

Educational programs in agriculture and natural resources are strongly oriented toward vocational preparation at both the graduate and undergraduate levels. Candidates for MS and PhD degrees are preparing for specific types of work. Although they include certain basic areas, such as biochemistry, genetics, or economics, in their programs, most of them are preparing for specific vocations and therefore tend to emphasize more directly applied courses.

This vocational orientation is supported by students, parents of students, and faculty members. It is true that some faculty members are keenly interested in pure research and that others profess to believe in education for education's sake. Even these, however, support vocational orientation in conferences with students. The reason most commonly given by a student requesting a course substitution is: "This course would be more valuable to me in the work I plan to do than the other course would be." If the faculty adviser agrees with the student's evaluation of the courses, he is almost certain to approve the request.

Vocational orientation has advantages. One of these can be associated with the general absence of student unrest (the ugly kind) among students in agriculture. We have this stability, at least in part, because students see the relevance of vocationally oriented courses to their goals. Inability to see the relevance of required courses is often cited as a factor contributing to student unrest of the socially objectionable type.

Students in agriculture are motivated by relevance, and relevance is tied to vocational preparation. Therefore, we should plan curricula around students' interests and goals. Programs and courses must be kept flexible, and the curricular base must be kept broad. Other departments in the universities must be encouraged to update courses in which our students are enrolled. We cannot be satisfied with modernizing the courses directly related to agriculture and natural resources. We need up-to-date courses in English and in foreign languages. We need food technology courses—instead of the butter-making courses we had a few years ago.

Persons affiliated with colleges of agriculture, being close to rural America and emotionally attuned to the rural situation, do not fully accept the fact that the U.S. population is predominantly urban. Yet we know that more than half of the students in colleges of agriculture come from nonfarm homes.

Being part of an urban society, we are obliged to put more emphasis on the humanities and social sciences in our curricula. We have a definite trend in that direction. But before we can proceed at full speed, we must have a change of attitude on the part of our faculties—acceptance of the shift that has taken place in the population and appreciation of the need for better understanding of urban society.

Course content and teaching quality are more important to education than mechanical reorganization of courses within curricula. If we are able to design more useful curricula, we must give close attention to these factors. In doing so, we must be concerned not only with our own courses—those taught in colleges of agriculture and natural resources—but also with the courses that we list as prerequisites.

SOME BROAD TRENDS

By looking at broad trends, we can make the following predictions concerning the courses that we will have in our curricula 10 years from now:

1. Advanced courses in natural sciences and mathematics, including statistics, will be offered earlier in our programs.
2. Courses in the humanities and social sciences will gain wider acceptance in professional colleges.
3. Professional, or applied, courses will continue to change extensively in content as knowledge increases, but the percentage of credit hours represented by such courses will change little.
4. The effort to make the baccalaureate program available to a reasonable number of students within a 4-year period will be continued.
5. There will be a continuing battle to keep free electives at 15 to 20 percent of the curriculum, for the sake of flexibility.
6. Technical agriculture programs above the high school level will rapidly gain in acceptance.
7. Colleges of agriculture and natural resources will make greater use of individualized study booths, audio-tutorial systems, information-retrieval systems, and other forms of modern educational technology.
8. Quality of teaching will be more widely subjected to evaluation techniques.
9. Enrollments in agriculture and natural resources will increase steadily but slowly, and the demand for graduates will continue to exceed the supply.

In summary, we will have continuing growth and adaptation to needs in undergraduate programs rather than revolutionary changes. The major changes will be in course content and in teaching methods.

It will be the responsibility of those in higher education, both in the colleges of agriculture and natural resources and in the basic-science areas, to see that our courses are in step with knowledge and with educational methods.

Working Group Reports

The following questions were furnished by CEANAR for guidance of discussions by the first three working groups (chemistry, mathematics, and physics):

1. How much and what kind of (chemistry, mathematics, or physics) should undergraduates in agriculture and natural resources have? How should this vary by option and major field?
2. How can these recommendations be implemented on individual campuses?
3. Are sourcebooks needed to improve instruction in (chemistry, mathematics, or physics) for students in agriculture and natural resources?
4. Are special summer institutes or other in-service training programs needed for faculty members in agriculture and natural resources and in (chemistry, mathematics, or physics)?

CHEMISTRY*

Despite a conscientious effort to develop a diversity of opinion in the working group, almost every view expressed in this report represents a consensus. Two members of the CEANAR Committee on Chemistry were in the working group; five of the eight members present represented departments of chemistry in schools of arts and sciences; one of the others is a biochemist. A much wider spectrum of views from biological and agricultural fields should be sought.

This working group wishes to express its general approval of the preliminary report of the Committee on Chemistry. We suggest, however, (1) that additional emphasis be given to the recommendation that the chemistry offered to students in agriculture and natural resources be a terminal course, and (2) that the report be reworded to eliminate any implication that the chemistry courses described therein should be aimed primarily at students in agriculture, natural resources, and biology. We believe that these students should study the same chemistry that chemistry majors do and that the courses outlined in the report are desirable for <u>any</u> student of chemistry. We believe that chemistry courses and agriculture curricula are moving in these directions and that CEANAR should do what it can to hasten such changes.

We call attention to the recommendation that the standard material for the first 2 years of college chemistry should not be greatly changed. The material should be reorganized to allow introduction of the fundamental concepts of organic chemistry (not nomenclatural traditions) early in the course, so that organic materials can be referred to throughout the freshman year. Group members condemned the practice of concentrating whatever organic chemistry is included in the freshman year in a short period near the end.

There was some disagreement on the extent to which geochemistry should be reintroduced into freshman chemistry courses. Some members believed that it should be a substantial part of the course. Others asserted that geochemistry could be referred to in citing examples of more fundamental concepts but should not be part of the course.

The group gave general approval to the recommendation that the second year of chemistry should resemble the new "biorganalytical chemistry" that is being offered at the University of California, Los Angeles, but did not examine the proposal in detail.

The report recommended that chemistry faculties be encouraged to include a much wider array of biological, organic, and agricultural examples in both the freshman and sophomore years.

Because of differences in student preparation and ability, the group believes that, where economically justifiable, it may be wise to offer separate routes through chemistry. The separation should be based on students' ability rather than on their prospective majors. Where two routes are provided, the usual procedure is to separate an accelerated (or honors) group from a slower (or

*Working group: Dana L. Abell (chairman), D. N. Marquardt (recorder), Donald F. Crossan, Adrian H. Daane, Roy A. Keller, A. R. Kemmerer, C. N. McCarty, C. Edmund Marshall, and Elizabeth Rogers.

regular) group. This second group should not be given a watered-down version of chemistry. Special treatment should be limited to (1) allowing more time for studying material that is essentially the same as that studied by the first group and (2) making a special effort, where warranted, to include examples that are pertinent to students' backgrounds and objectives.

At Michigan State University, students enrolling in chemistry are given tests to determine which of two routes they will follow. The routes cover essentially the same material—a course in introductory chemistry that includes laboratory work—but at different speeds. On one route, for regular students, the material is covered in a two-quarter sequence; on the other, for accelerated students, it is covered in one quarter. In their first quarter, the regular students are assigned to laboratories of the TV-lecture type; in the second quarter, their laboratory work is the same as that performed by the accelated students. Subsequent chemistry courses are arranged in five combinations, and a student from either of the introductory routes may choose any of them. One of the five combinations includes a two-quarter course in organic chemistry that is designed especially for students in the agricultural and biological sciences. This course can be used as a prerequisite for biochemistry. This is one situation in which students in agriculture and biology could justifiably be separated from others.

The working group believes that chemistry is an experimental science and agrees with the statement in the committee report that the laboratory must be retained. However, the laboratory must not be allowed to become a series of routine cookbook exercises. Every institution is encouraged to look seriously at the investigational, or problem-type, laboratory, which is receiving considerable attention, particularly in physics and biology. In a laboratory of this type, a student becomes familiar with a number of techniques and receives instruction concerning a general problem area. He is then given responsibility for developing his own program of investigation, which may extend over weeks or months. But an institution should not adopt laboratory procedure of this type without carefully considering the space that it requires and the demands that it makes on faculty and student time. More important, this approach should not be undertaken if enthusiasm for it is lacking.

A sourcebook showing how a knowledge of chemistry can be applied to solving problems in agriculture and biology would contribute greatly to making chemistry more interesting and relevant for freshmen and sophomores. Examples of questions that would be appropriate for treatment are "How does a herbicide work?" and "What does a nerve gas (e.g., parathion) do to living organisms?"

If a sourcebook is to fulfill its purpose, the examples must be understandable and interesting to the students for whom it is intended. Thus, there is an editorial problem, and solving it requires money, professional time, and editorial talent. The last-named requirement is the most difficult to meet. The editor should have a proper appreciation of the opportunity represented by the sourcebook and the ability to bring interest and attractiveness to the material.

It would be unwise to attempt to direct the book to the biologist rather than the chemist. In fact, the extreme significance of chemistry to the biological sciences (including agriculture) has already been thoroughly impressed upon instructors in these fields. The value of using biological examples in teaching chemistry has been less readily grasped.

We recommend:

1. That an advisory panel be appointed immediately (a) to seek out persons qualified to collect and edit material for a chemistry sourcebook that would be suitable for first- and second-year students in agriculture and natural resources, and (b) to identify sources of funds.

2. That the panel include some members of the CEANAR Committee on Chemistry.

The group discussed the problem of continuing professional development with particular reference to instructors in chemistry and in the biological sciences who are obliged to teach aspects of both subject areas in order to explain relations between the areas. The value of in-service training for instructors who have this task was readily recognized, and ways in which it can be obtained were explored. These include seminars, local and regional institutes, and exchange of instructors between departments and between institutions. The group was firm in its belief that the home campus is the best place for in-service training to be given.

All institutions need to develop programs for encouraging interchange of instructors among departments in which chemistry and biology are taught. Some institutions have found that sharing assistants across departmental lines is an especially effective stimulus. With this arrangement, assistants may be used in clustering student discussion groups around interest areas. This is another of the few situations in which segregation by intended major may be of value.

We recommend:

1. That CEANAR take the initiative in developing plans for a conference on continuing professional development through in-service programs in the disciplinary areas.

2. That CEANAR consult with the American Chemical Society on the feasibility of the Society's developing, as part of its continuing-education program, a series of short courses designed to bring biology to chemistry instructors.

MATHEMATICS*

The working group compliments the Committee on Mathematics for a thorough and thoughtful analysis of the role of mathematics in curricula in agriculture

*Working group: Lester V. Manderscheid (chairman), J. Wayland Bennett (recorder), F. Yates Borden, Jerome L. Clutter, J. C. Eaves, E. S. Lindstrom, H. L. Lucas, Robert H. McDowell, H. M. Nahikian, and Douglas S. Robson.

and natural resources. In response to the discussion questions, the group reached the general conclusions stated below.

1. How much and what kind of mathematics should undergraduates in agriculture and natural resources have? How should this vary by option and major field?

The group discussed the curricula recommended by the Committee. Some concern was expressed relative to listing three major curricular areas: science, education, and technology. The group understands that "technology" refers to a 4-year degree program, which should not be confused with a 2-year terminal technician program.

We recognize the desirability of increasing the level of mathematics competence of all degree programs, but we have some reservations about achieving 4 years of mathematics in the high school curriculum and increasing college-level requirements; curricula at both levels are already crowded.

We recognize the value of mathematics as a tool of logic and as the one universal language of science, but we question the need for the high level of mathematics recommended for the terminal baccalaureate degrees.

Our general conclusions with respect to the first question are:

- Mathematics requirements, though increasing, should vary by option and major fields.
- New developments in science, in computer technology, and in management of renewable natural resources make it imperative for schools of agriculture to examine their curricula periodically.

2. How can these recommendations be implemented on individual campuses?

This question will be resolved on the individual campuses. How it is resolved will depend on the training and education needs of the graduates of each institution and on the nature of student input. We suggest that each institution study the committees' recommendations and adopt the proposed programs to the extent that resources permit. Coordination among all disciplines will be essential if these objectives are to be achieved.

3. Are sourcebooks needed to improve instruction in mathematics for students in agriculture and natural resources?

Sourcebooks can be useful teaching aids if they contain problems that have valid subject-matter content in both mathematics and the area of application. We doubt that many such problems could be devised that bear on basic calculus and the life sciences. A few problems involving economics and biology could be identified, but not enough to constitute a sourcebook. Perhaps in linear algebra and probability courses a wider variety of examples or problems could be found that possess valid biological and mathematical context.

The initial effort in this area should be concentrated on educating agricultural faculties concerning the current content of mathematics courses and on the appropriateness of a greater use of mathematics in agricultural courses.

4. Are special summer institutes or other in-service training programs needed for faculty members in agriculture and natural resources and in mathematics?

If mathematics is not being used in teaching advanced undergraduate agricultural courses, students will not be enthusiastic about taking the mathematics courses proposed by the committee. Thus, it is imperative that the faculties in agriculture and natural resources attend either summer institutes or in-service training programs to become more aware of current trends in teaching and using mathematics. Institutions often find that such programs are most economical if they are conducted on their own campuses.

The content and purpose of training programs would vary between institutions and between degree programs. The end to be achieved would be the best training possible for the greatest number of undergraduate students.

PHYSICS*

The group was in general agreement with the views of the CEANAR Committee on Physics concerning the need for a physics course with a biological emphasis. Traditional courses have little appeal for agriculture students, and they are inadequate to meet student needs in the next 15 years. It was agreed that an integrated course in the physical sciences would not be the most suitable approach at present. If such a course is to be taught, it should have the benefit of team teaching.

The report of the Committee on Physics provides the basis for two proposals from this working group. The proposals are intended to provide materials that would assist physics instructors in developing and implementing appropriate subject matter for students in agricultural, biological, and premedical programs of study.

To carry out the first of these proposals, a committee of seven members is recommended. The committee should consist of persons knowledgeable in physics and in the life sciences. Their function would be to solicit, assemble, and develop a sourcebook of illustrative materials and applications that could be incorporated into the present physics course offerings. Such materials would permit the physics instructor to demonstrate more quickly to the students the value of physics in their chosen vocations.

This committee should have funds for holding two or three meetings, the first for organizing and the others for evaluating materials collected. About $2,500 should be sufficient to produce the initial resource materials. The project could be completed in about 2 years.

A second proposal is for a longer effort, possibly extending 5 years, to permit a carefully planned study of physics courses for the life sciences. This study should involve a joint effort between physicists and life science professional personnel. One of its objectives should be the delineation of areas and applications in which students in the life sciences will find physics to be im-

*Working group: Randall J. Jones (chairman), Arlon G. Hazen (recorder), Newell S. Gingrich, Arnold Klute, S. J. Richards, and Otto H. Schmitt.

portant. The delineated areas could be a basis for developing and distributing resource materials that would be appropriate in future physics courses.

The first proposal is intended to help fill an urgent, immediate need. The second is intended to capitalize on the first by having available the kinds of materials that will be necessary in future physics course offerings. The short-term proposal can, if successful, help to ensure the success of the more deliberate long-range proposal. Both efforts would contribute to establishing strong, effective physics courses for students in the life sciences.

PHYSICAL SCIENCE AND MATHEMATICS*

The working group supports, in principle, the recommendations of the committees on mathematics, physics, and chemistry. The content of the proposed physics and chemistry courses should be stated in greater detail.

No special course should be added to the curriculum as a requirement for all agriculture students.

The place of such subjects as geology, meteorology, and oceanography in the agriculture curriculum was discussed at length. The group recommends that one semester of physical geology (based on one year of chemistry) be adopted as a prerequisite for a general soils course. Any meteorology elective offered to agriculture students should be based on mathematics through calculus and one year of physics. Such a course should concentrate on micrometeorology, microclimatology, and boundary-level processes in general.

After discussing the course on statistical inference recommended by the Committee on Mathematics, the group suggested that the course might best be taught by a statistician who is familiar with applications in biology and agriculture.

*Working group: Seth Baron Locke (chairman), Daniel O. Robinson (recorder), R. S. Dunbar, Jr., Robert T. Duquet, Franklin E. Eldridge, R. Saunders English, John M. Parker III, Melba Phillips, Richard M. Swenson, and Howard A. Tanner.

INTEGRATED PHYSICAL SCIENCE COURSES†

A variety of interdisciplinary science courses have been attempted at various institutions, the most common type being a terminal general-science course for nonscience majors. Most agriculture students are not involved here, however, because these courses are not specific enough. A high-level integrated course such as that offered at Bryn Mawr would serve as a prerequisite for more advanced science courses and would be of greater interest to the agriculture student.

Most of the group's discussion was in response to three questions. The questions and the conclusions that were reached regarding them follow.

†Working group: A. F. Isbell (chairman), Miles E. Anderson, Homer C. Folks, James E. Kuntz, B. D. Mayberry, William Reeves, and Arnold A. Strassenburg.

1. Are integrated physical science courses suitable for all undergraduates in agriculture and natural resources? For some of the undergraduates?

Integrated physical science courses as they now exist may be suitable for undergraduates in certain areas of agriculture, including agricultural economics and rural sociology, but they are not suitable for all undergraduates in agriculture and natural resources. Most such courses have failed, usually because of insufficient material or because of a lack of proper climate. If these deficiencies were cured, integrated physical science courses might be suitable for all undergraduates in agriculture and natural resources. The "proper climate" would be provided if congenial faculty members were involved in the courses and if a favorable attitude prevailed among students and receiving transfer institutions. It may be that the institutions in which these courses would be most suitable are the 2-year institutions, where the question of transfer to a higher institution does not arise.

2. What course(s), if any, would be replaced if one or more integrated physical science courses were introduced?

Courses replaced would include first-year chemistry, physics, biology, and mathematics. These courses would be joined in various combinations to form biochemistry, biomathematics, biophysics, and so on.

3. What should be the main objective of integrated courses?

The main objective should be to lay a foundation from which the student can move through advanced courses. Another objective is to save time, but it has not been achieved. If time were saved, integrated courses would be more useful.

If hopes for integrated courses could be realized, the courses would be distinguished by teaching of high quality, motivation would be provided by emphasizing relevance, and confusion would be reduced by interrelating subject matter.

How can relevance be ensured for students in agriculture and natural resources who are taking courses in the physical sciences? Departments in agriculture and natural resources could help by supplying examples from their disciplines to physical science teachers. Pertinent, interesting examples could also be found in cross-discipline meetings.

Other comments on integrated courses:

- Integrated courses, with the exception of descriptive ones, are frequently slanted toward future teachers in elementary schools.
- Integrated courses are experimental.
- We do not know of any integrated courses that have demonstrated an advantage for majors in the life sciences.
- Adaptation of existing course structures as recommended by other working groups seems to be a better solution for schools of agriculture.

We recommend:

1. That concepts and examples from the life sciences be prepared as source materials, that these materials be included in course textbooks, and that the textbooks be used both within a discipline (e.g., biochemistry in elementary chemistry) and across disciplines.

2. That the possibility of devising integrated science courses for majors in the life sciences be investigated and that attention be given to biochemistry, biophysics, and physics–chemistry.

3. That, as part of the investigation referred to above, courses be set up on an experimental basis, with objectives and controls that would make possible a detailed evaluation of the courses.

REPORT OF THE COMMITTEE ON CHEMISTRY

Comments on Two Proposed Courses

Students in agriculture, natural resources, and related fields have broad needs in chemistry, and these needs will probably be broader in the future. The minimum requirement for all students in these fields should be the course referred to below as the first college course in chemistry. Students with intermediate requirements should take the first and second courses. The higher requirements that would be necessary for students preparing for careers in chemistry-oriented research are not discussed here.

The modern trend in teaching chemistry is to integrate inorganic, physical, analytical, and organic chemistry at an early stage. Recommendation of the two courses discussed below is based on our belief that this trend will continue.

In the biological sciences, emphasis on molecular biology is increasing in introductory as well as in advanced courses. Although undergraduates 5 to 10 years from now will probably have fair to excellent backgrounds in the basic principles of chemistry, it is not likely that they will be prepared for courses in molecular biology: they will be handicapped by inadequate knowledge of organic chemistry and biochemistry. Hence, the first college course in chemistry for students in agriculture, natural resources, and biological sciences should include a good introduction to the chemistry of living systems. With further study of organic chemistry and biochemistry, in the second course, students can build on these basic ideas.

Present-day teaching of inorganic chemistry is seriously inadequate. The crust of the earth, the oceans, and the atmosphere provide the inorganic environment for all forms of life. Yet, despite the obvious essentiality of geochemistry, textbooks in college chemistry tend to subordinate descriptive chemistry of the elements to general physical chemistry. Even discussions of the periodic table of elements fail to give students clear ideas about geochemistry.

In considering the types of courses needed for students in agriculture and natural resources, we should remember that an appreciable—and growing—proportion of these students are in junior colleges. The courses proposed here are believed to be well suited for adoption in junior colleges and liberal arts colleges.

We should also remember that chemistry requirements in high schools differ widely. We must take these differences into account.

The proposed courses are designed for students who expect to use their knowledge of chemistry in developing their careers. These courses should not be confused with survey courses. Indeed, the Committee believes that the courses would be appropriate as the first steps in the professional training of chemists, which is in danger of becoming too narrowly channeled.

First College Course in Chemistry

GENERAL CONSIDERATIONS

The beginning course in chemistry discussed here is intended primarily for students in agriculture and natural resources. It would also be appropriate for students in other fields who need a general knowledge of chemistry.

The course differs from courses currently offered to nonchemistry majors. First, it is not a watered-down version of a course for chemistry majors; it should be taught at the same level as a course for majors but with greater coverage of organic chemistry and biochemistry. Second, it occupies a full academic year.

The course should show the impact of chemistry on society and should present an adequate overview of the subject. We suggest that it consist of 90 to 100 lectures, 30 discussion sessions, and 30 laboratory periods of 3 hours each. We suggest total credit of 10 semester hours.

The Committee believes that this course is minimal and that, by itself, it is adequate for only a few areas in agriculture and natural resources (e.g., agricultural economics). The 2-year sequence suggested here should probably be regarded as the eventual minimum for students in colleges of agriculture, schools of forestry, schools of home economics, and departments of conservation. Specialties that include sizable components from plant and animal sciences already need the 2-year sequence, and some of them need more. Since the period required for completion of a bachelor's degree continues to be 4 years, our recommendation implies that more attention should be devoted to basic science and that less should be devoted to "how to do it" courses. This proposed shift of emphasis would be beneficial only if the basic-science courses are in harmony with student needs and interests.

Teachers in the first course should make every effort to motivate students. Motivation is best achieved by choosing examples that are relevant to agriculture, natural resources, biology, and everyday life. It is especially important that relevant examples be chosen for the discussion sessions. There may be an advantage in assigning to this course teachers who are themselves working in agricultural or biological applications of chemistry. Assigning teachers on this basis might be facilitated by making joint appointments to chemistry departments and agricultural science departments.

Placement tests would be useful for evaluating students before enrolling them in the course. In the test, they should show, as a minimum, competence in arithmetic; competence in simple algebra, including quadratic and simultaneous equations; and the ability to use logarithms and exponents. In general, students with 3 years of high school mathematics would be prepared for the test, and those who had continued mathematics through the senior year would have an advantage. Those who had studied physics in high school would have a further advantage.

The course should have a strong experimental orientation, with many demonstrations. Laboratory exercises should, as far as possible, keep pace with the lectures.

A sourcebook should supplement a standard textbook. With a sourcebook, inexperienced teachers could give the course its proper agricultural and biological impact. Since few textbooks adequately cover the subject matter that we believe should be included in the first and second courses, it seems advisable to let the sourcebook include supplementary material and examples that would be suitable for both courses.

RECOMMENDED CONTENT

We believe that the subject matter recommended here is suitably balanced for a course of 30 to 32 weeks. The suggested arrangement of material is unorthodox but is justified by the expectation that, as a result of improved high school instruction, undergraduates of the future will have a better understanding of nomenclature and methods than do those of the present. Although the order in which the topics are presented may vary, topics having to do with organic chemistry and biochemistry should not be left until the end of the course.

Large groups in lecture courses can be taught satisfactorily if proper use is made of visual aids and if demonstrations are divided into those that are suitable for large groups and those that are not. Demonstrations not suitable for large groups can be presented in discussion sessions at which 20 to 40 students are present. As far as possible, examples should relate to biology and agriculture.

Lecture Course

The lecture course consists of four parts. Each of the first two would occupy a little less than one fourth of the time available for the course; each of the last two would occupy a little more than one fourth of the time.

1. Introduction, atomic theory, chemical bonding, nature of molecules, gases, solids, liquids
2. Organic compounds, with emphasis on those having biochemical significance
3. Principles of chemical energetics: thermochemistry, thermodynamics (with emphasis on free energy), colligative properties, homogeneous equilibrium, phase rule. Physical chemistry of aqueous solutions: elementary electrochemistry, oxidation–reduction, colloidal systems. Stoichiometry in its application to analysis, nuclear chemistry, use of radioactive isotopes
4. Descriptive inorganic chemistry. This part would be based on the periodic table of elements, and consideration would be given to ionic sizes. Thus, students would be prepared for geochemical considerations and for the chemistry of aluminosilicates. Particular attention should be given to H, O, N, C, S, P, halogens, Na, K, Mg, Ca, Al, Si, and Fe. Some attention should be given to other elements of biological importance: trace elements in plants and animals, B, Zn, Co, Mo, and Mn.

Laboratory

Experiments should be truly illustrative. The following suggestions are roughly in the order of the lecture materials.

Simple gravimetric techniques, such as finding specific gravity of solid powders by pyknometry
Comparison of PVT properties of ideal and nonideal gases
Melting point and sublimation
Purification and identification of organic compounds
Decomposition of proteins by enzymes
Electrophoretic patterns (gel electrophoresis)
Heat measurements
Kinetic experiments
Vapor pressure, depression of freezing point
Chemical equilibrium
Aqueous solutions
Colloidal systems
Volumetric analysis to illustrate stoichiometry
Nuclear isotopes and applications
Qualitative analysis
Quantitative analysis

Second College Course in Chemistry

GENERAL CONSIDERATIONS

The second course is a continuation of the organic, biochemical, and analytical components of the first course. Students with both courses will have:

- The equivalent of a standard one-semester course in general and organic chemistry, a standard one-semester course in organic chemistry, and a one-semester course in qualitative and quantitative analysis (with emphasis on quantitative aspects).
- Enough physical chemistry to provide a basis for the analytical and biochemical components.
- An introduction to biochemistry.

Students with this preparation can readily move into intermediate and advanced courses in chemistry after taking the appropriate prerequisites in physics and mathematics.

Students wishing to prepare for biochemical investigation should take general physical chemistry, which leads to special topics such as colloid and surface chemistry, chemical kinetics, and chemical thermodynamics.

RECOMMENDED CONTENT

The second course builds initially on the organic and analytical components of the first course. It is in three parts: systematic organic chemistry; analytical organic chemistry, with extensive use of instrumental methods; and biochemistry. It should probably extend over two semesters, and about 8 hours of credit should be given.

The proposed course is almost identical with the second-year chemistry course at the University of California, Los Angeles. The UCLA course is described by W. H. Eberhardt in the May 1967 Newsletter of the Advisory Council on College Chemistry.* The laboratory work described by Dr. Eberhardt seems particularly challenging.

The organic component in the course proposed by the Committee is less than that in the UCLA course because the first course proposed by the Committee includes a good beginning in organic chemistry and in analytical techniques.

*Copies of Dr. Eberhardt's article can be obtained from the Advisory Council on College Chemistry, Department of Chemistry, Stanford University, Stanford, California 94305.

REPORT OF THE COMMITTEE ON MATHEMATICS

Preliminary Statements

COLLEGE-PREPARATORY MATHEMATICS

Present-day curricula and activities in agriculture and natural resources (agnare) rest on a broad base of physical science, engineering, and the biological, management, and social sciences. Undergraduate curricula in the physical sciences and engineering have always included many courses in mathematics, and the mathematical requirements of curricula in the biological, management, and social sciences are rapidly increasing.

A high school student who expects to obtain a degree in agnare or in one of the supporting fields should take 4 years of college-preparatory mathematics. By doing so, and by continuing to study mathematics in college, he will broaden the spectrum of specialties from which he may choose at any stage of his education. This freedom is especially valuable to a student who wishes to change his specialty. A college student who lacks 4 years of preparatory mathematics will find many choices closed to him unless he takes time to overcome high school deficiencies.

MATHEMATICS AND OBSOLESCENCE

In this age of rapid change, the graduate who has learned only the mechanics of a current technology may soon find himself out of a job because his specialty is outdated. But one who has learned the fundamentals will be able to adapt readily to new concepts and techniques. Solid training in mathematics is insurance against occupational obsolescence.

MATHEMATICS AND COMPUTERS

The introduction of electronic computing machines revolutionized computing technology and stimulated, more than any other event in history, the application of mathematics to learning. Instead of reducing the need for mathematics, as many persons suppose, computers have increased the need.

Before the advent of computers, many problems were left unsolved. Even though mathematical theory for solving them was available, there was no way to perform the computations. Also, mathematical theories were sometimes left uncompleted because the implied computations were seen to be unfeasible.

Now, mathematical theory can be teamed with computers in a variety of ways. Huge masses of data can be analyzed and interpreted. With the aid of computers, mathematicians have developed new theories and techniques, many of which are relevant to agnare.

In the future, most scientists and technologists will need both a knowledge of mathematics and the ability to use computers.

MATHEMATICS IN BIOLOGICAL, MANAGEMENT, AND SOCIAL SCIENCES

Until the twentieth century, the applications of mathematics were largely in the physical sciences. There were few connections between mathematics and agnare.

This situation changed rapidly after the development of probability theory, statistics, and mathematical programming. These branches of mathematical science have many applications in the biological, management, and social sciences, which support agnare.

Probability theory is the mathematical foundation for genetics and for statistical theory. It is the basis of all mathematical models used in studying events with chance outcomes.

Statistics provides principles and methods for gathering and summarizing data. Many important developments in statistics were stimulated by the need to solve problems related to agnare.

Mathematical programming provides techniques for solving many optimization problems that cannot be solved in any other way. Such problems arise, for example, in formulating a minimum-cost feed mixture that has specified nutritional values, in allocating farm resources to maximize profits, and in allocating natural resources to maximize public benefit.

In the last 5 years, significantly more mathematics has been integrated into the curricula for the biological, management, and social sciences. With these components of their education becoming more mathematical, students in agnare must take more mathematics.

Bases for Recommendations

COMPLEXITY OF ACTIVITIES

Agnare includes many complex, intricate activities and many problems that are difficult to isolate and define. For example:

- Several criteria must be applied jointly to a welter of physical, biological, and human factors.
- Because of tangled interrelations among objectives, it is difficult to set priorities.
- Cause–effect relations are manifold and often unclear.

Managerial personnel in agnare must be equipped to conceptualize these intricacies quantitatively, to appreciate the extent of the uncertainty involved, and to assess the appropriateness of decisions. Many must have competence in mathematical ideas and techniques in order to provide data and advice to their superiors. Others must be able to direct specialists in mathematical techniques. For these duties, some knowledge of multivariable calculus, linear algebra, probability, statistical approaches, computer use, and optimization techniques is required.

GROWING APPRECIATION OF MATHEMATICS

In general, agnare faculty members are not well trained in mathematics and do not fully realize how useful it is. Yet one finds growing appreciation of the subject.

Some faculty members, perhaps through their graduate programs, have discovered the value of certain mathematical concepts and techniques and are trying to improve their skills. Those who have an unusually good background are able to apply new techniques that are relevant to their fields. Those who lack such background are acquiring it by studying mathematics while on the job.

Many graduate students take undergraduate courses in mathematics, realizing that they need greater knowledge of mathematics in their research and advanced study. And some graduates, finding that they are not fully qualified for the positions that they desire, enter graduate school to acquire the knowledge of mathematics that they should have acquired as undergraduates.

Increased use of computers contributes to the growing appreciation of mathematics.

MATHEMATICAL BASIS FOR TECHNIQUES STUDIED IN UPPER-DIVISION COURSES

Students who lack a firm grasp of mathematical theory are handicapped when they take upper-division courses in which instruction is given in techniques that are based on mathematics. The students' lack of background also handicaps the instructor. Some of these techniques and the branches of mathematics on which they are based are listed below.

Technique(s)	Mathematical Basis
Linear programming	Vector spaces, linear algebra
Estimating breeding value of domestic animals and plants	Calculus, vector spaces, linear algebra, probability, statistical theory
Techniques for studying evolution and ecosystems	Vector spaces, difference-differential equations, probability, statistics
Techniques for studying soils	Mathematics associated with physical chemistry

The handicap follows students into their careers, making it difficult for them to extend their knowledge of techniques that are part of their jobs. Workers thus disadvantaged may also fail to recognize situations in which they should seek the aid of professionals in the mathematical sciences.

DUPLICATION OF SUBJECT MATTER

Duplication of subject matter is common in agnare courses, especially in the upper division. Instruction in certain basic disciplines, including mathematics, statistics, and computing, is repeated from course to course. This duplication reflects an attempt to prepare students for professional responsibilities by adding courses. One result is that full attention cannot be given to the main subject matter because time must be devoted to bolstering background. Far more could be accomplished, and fewer substantive courses would be necessary, if students were adequately prepared before they reached the upper division.

TECHNICAL VERSUS PROFESSIONAL EDUCATION

Some agnare courses are mainly technical; others emphasize professional development. The two kinds of emphasis are needed, but students must choose between them. No student can be trained adequately in both kinds of courses.

There is a trend to relegate technical training to 2-year programs. If it continues, the pressure to provide technical training in 4-year programs will diminish, and professional courses in the 4-year programs can be strengthened.

HIGH SCHOOL PROGRAMS IN MATHEMATICS

Present Situation

Standard high school programs in mathematics offer a course in each semester of each of the 4 years. The following sequence is considered standard:

Grade	Course(s)
Ninth	Algebra
Tenth	Plane and solid geometry, with an introduction to analytic geometry
Eleventh	Algebra and trigonometry
Twelfth	
First semester	Elementary functions (polynomial, logarithmic, exponential, and trigonometric)
Second semester	One of the following:
	Probability and statistics
	Matrix algebra
	Analytic geometry

Although this sequence is standard, there is variation both in what is offered and in what students take. Some small high schools offer only the first 2 years, and some require only 1 year for graduation. Some schools exceed the standard, offering the equivalent of 5 years of mathematics.

Schools that exceed the standard accelerate the program, beginning in the ninth grade. Accelerated students complete the standard program by the end of the eleventh grade; in the twelfth grade, they take the Advanced Placement Program, which consists of a year of calculus. Students who make a satisfactory grade in the Advanced Placement examinations are accepted into sophomore mathematics by many colleges and universities.

Although the situation is changing, most students who enter agnare have had weak preparation in high school mathematics. One reason is that many of them come from schools that offer only 2 years of mathematics.

Projected Situation

Over the next 10 years, mathematics training in high school is likely to become more variable than it is now, but on the average, it will become stronger. It is almost certain that a greater proportion of high schools will offer calculus, linear algebra, and probability and that some will offer computer science; but the less progressive schools may remain as they are today. Thus, students entering agnare may range from those having only a year of high school mathematics to those having college-sophomore standing in mathematics and some training in computer science.

DEMAND FOR EMPLOYEES COMPETENT IN MATHEMATICS

The demand for employees with competence in mathematics is growing. Employers in agnare tend more and more to look for evidence of this competence in prospective employees. In 10 to 15 years, the demand will exceed the supply unless mathematics is given greater emphasis in agnare curricula.

Even now, agnare graduates with only 9 or 10 credits in mathematics, statistics, or computer science, or with equivalent extracurricular experience, have substantially better employment opportunities than graduates whose competence is less. The few who have 20 to 25 credits (or equivalent) in mathematics have a distinct advantage in seeking support for graduate work or in competing for agnare positions.

Employers in agnare cannot hope to meet their personnel needs by hiring a combination of (1) persons who, as students, specialize in mathematics, statistics, and computer science but have little agnare training, and (2) persons who specialized in agnare but have little mathematical training. Many persons are needed who bridge the two extremes.

SOURCE MATERIAL

The Committee on Mathematics found valuable guidance in the following bulletins:

A General Curriculum in Mathematics for Colleges, published by the Committee on the Undergraduate Program in Mathematics (CUPM) in 1965

Tentative Recommendations for the Undergraduate Mathematics Program of Students in the Biological, Management and Social Sciences, published by a CUPM panel in 1964

The general curriculum described in the first of these bulletins was designed to provide mathematics suitable for all undergraduates. The program starts with introductory calculus, but a remedial course is outlined for students whose high school study did not prepare them for calculus. Early introduction to probability, statistics, and linear algebra is a prominent feature. Geometry is not set off in special courses but is fully integrated with other topics. Individual courses and sequences are structured to ensure flexibility. None is terminal. A student can satisfy his needs by proceeding an appropriate distance along a prescribed path. If he changes his field of specialization, he is required only to add the courses covering the new topics; he does not have to backtrack.

The program provided by CUPM's general curriculum is the kind that agnare students need. Many colleges and universities have programs patterned after it. Thus, the needs of agnare students can be met without delay.

The CUPM program seeks to provide understanding without sacrificing development of competence in the algebraic and arithmetic procedures required to solve specific problems. For persons concerned with making recommendations that will be applicable 10 to 15 years in the future, an advantage of the CUPM program is that it gives detailed information on topics and subtopics of individual courses. Because of the rapid evolution of mathematics teaching, some topics now included at the college level may be treated at the high school level in the future. If this shift occurs, fewer college-level courses, differently named and structured, would suffice to provide the recommended overall education in mathematics.

Recommendations

The Committee on Mathematics recommends eight courses for students in agnare. These courses, listed in Table 1, are recommended in different combinations for curricula in three fields of specialization: education, technology, and science.*

*Business is a fourth field of specialization for agnare students, but separate consideration of business curricula is not needed. Some business curricula are for students who will enter junior-level managerial positions upon graduating; the mathematics needs of these students are comparable with those of students specializing in science.

TABLE 1 Recommended Mathematics Courses for Students in Agriculture and Natural Resources

Course	Semester Hours	Education	Technology	Science
Introductory calculus	3–4	X	X	X
Multivariable calculus	3–4	—	X	X
Probability	3	X	X	X
Linear algebra	3–4	—	—	X
Theory and techniques of calculus	3–4	—	—	X
Statistical inference	3	—	X	X
Introduction to computing	3–4	X	X	—
Principles of programming	1	—	—	X
Semester hours		9–11	15–18	19–22

Six of the courses are from CUPM's general curriculum.* The other two are in computer science. The CUPM bulletin lists a computer course but furnishes only a brief description.

The courses for education students are comparable in difficulty with mathematics courses now being studied at the college-freshman level by majors in mathematics, physics, chemistry, and engineering. Statistical inference is a highly desirable course for education students, but it is not recommended as a requirement: these students must devote some time to education courses at the expense of time they might otherwise spend on subject-matter courses, even those in subjects they will ultimately teach.

The more advanced courses for technology and science students are comparable in difficulty with mathematics courses now being studied at the sophomore (second semester) and junior (first semester) levels by majors in the traditionally mathematical fields.

Five of the CUPM courses have two versions, and additional versions are feasible. The versions to be offered by a given mathematics department will depend on the size of the department and on the general needs of the institution.

The following list gives the names of the CUPM courses, the CUPM designations (e.g., CUPM 1), the recommended versions, and statements of prerequisites.

Introductory calculus; CUPM 1; first version. Prerequisite: Four years of high school mathematics or a remedial college course.

Multivariable calculus; CUPM 2; second version. Prerequisite: Introductory calculus.

Probability; CUPM 2P. Prerequisite: Introductory calculus.

*See A General Curriculum in Mathematics for Colleges (1965), a report to the Mathematical Association of America by the Committee on the Undergraduate Program in Mathematics. Copies of the report may be obtained from CUPM, P.O. Box 1024, Berkeley, California 94701.

Linear algebra; CUPM 3; second version. Prerequisite: Multivariable calculus.

Theory and techniques of calculus; CUPM 4; second version. Prerequisite: (1) linear algebra or (2) multivariable calculus and introduction to computing.

Statistical inference; CUPM; first version. Prerequisite: Probability.

Following are descriptions of the two other recommended courses (not taken from CUPM's general curriculum).

INTRODUCTION TO COMPUTING

This course is designed to develop skills in manipulating information by numeric and nonnumeric procedures on high-speed electronic digital computers and in using common programming techniques and languages. Problem definition, problem solution, and appropriate mathematical methods are emphasized. Programming syntax and coding are covered by assigned readings and by assistance from the instructor. Considerable time is spent on linear algebra for the benefit of students in the education and technology categories who do not take the course in linear algebra. Prerequisite: Probability.

Computers and computation (5 lessons). Hardware components and their organization (emphasis on digital machines). Internal and external representation of information, computer storage and addressing, machine instructions, machine arithmetic and logic, indexing.

Linear algebra (6–9 lessons). Introduction to vector spaces, matrices, basic matrix operations, transpositions. Determinants, rank of a matrix, inverse of a matrix. Special matrices. Correlation, multiple regression.

Programming procedures (5 lessons). Program logic, flow diagrams, documentation. Iterative and recursive procedures. Indirect addressing and subscript computation. Input–output procedures and formats.

Linear algebraic computation (4–6 lessons). Matrix operations and procedures, programming of matrix operations. Solution of linear equations, matrix inversion, multiple regression. Computational errors.

Subroutines (5 or 6 lessons). Subprograms, linking, program structuring, storage allocation.

Nonlinear equations (4–8 lessons). Series and approximations. Iterative and recursive procedures. Convergence, multiple roots, computational error, program and procedure efficiency. Simultaneous nonlinear equations.

Systems programming (5 lessons). Operating systems, programming specifications. Compilers, assemblers. Utility programs, library programs.

External information organization, structure and management (2 lessons).

List processing, searching and sorting (1 or 2 lessons).

Boolean algebra (1 or 2 lessons). Basic concepts, symbology, use.

File definition, structure and management (1 or 2 lessons).

PRINCIPLES OF PROGRAMMING

The purpose of this course is to acquaint students in the science category with the basic features of computer hardware and software and to introduce programming languages and techniques. Although the course can be taken at any time, there is some advantage in taking it immediately after linear algebra. Prerequisite: Four years of high school mathematics or a remedial college course.

Characteristics of computers (5 lessons). Essential components of computers. Digital, analogue, and hybrid machines: advantages, disadvantages, accuracy. Hardware and software control.

Programming (8 lessons). Machine versus other languages. Examples of commonly used languages and their use, advantages, and disadvantages. Outline of computing problems and techniques: flow diagrams, looping and iteration, modules and subroutines, optimization, information storage and retrieval, computing errors. Available programs.

Uses for Mathematics in Agriculture and Natural Resources

The statements below are intended to call attention to the many uses of mathematics in agnare and to show that the recommended requirements are justified. Uses are listed for each branch of mathematics named; where appropriate, they are divided into direct and indirect uses.

DIFFERENTIAL AND INTEGRAL CALCULUS

Direct. Rates of change, acceleration, areas and cumulative phenomena; forest mensuration, chromatographic analysis, facets of many specific problems; model building.

Indirect. Through physics, chemistry, and engineering; through calibration of instruments; through exponential functions, optimization theory and methods, differential and difference equations, probability, statistical inference, computer use, and simulation.

LINEAR ALGEBRA

Direct. Mixing ingredients to satisfy standards (e.g., milk, milk products, and fertilizers); visualizing in several dimensions; solving simultaneous equations; model building.

Indirect. Through extending calculus to many variables; through optimization theory and methods, differential and difference equations, statistical inference, computer use, linear programming, and simulation.

EXPONENTIAL AND LOGARITHMIC FUNCTIONS

Direct. Growth and decay phenomena; disappearance of radioactivity, degradation of pesticides, loss of nutrients from soils, kill of organisms as related to time and temperature, runoff from watersheds, and response to drug dosage and nutrient supply.

Indirect. Through physics, chemistry, and engineering; through differential and difference equations, statistical inference, computer use, and simulation.

OPTIMIZATION THEORY AND METHODS*

Direct. Setting inputs to maximize profits given an input–output function and the corresponding cost–price data for a specific effort (e.g., setting fertilizer levels to maximize profit from a certain crop); deciding among alternative efforts in order to maximize returns from available resources (e.g., deciding which animals or crops should be raised on a given farm or how natural resources should be exploited).

Indirect. Through computer use and mathematical programming.

DIFFERENTIAL AND DIFFERENCE EQUATIONS*

Direct. Radioactive tracer studies, drug absorption and distribution, physiology, and biochemistry; genetic, ecological, sociological, and economic systems.

Indirect. Through physics, chemistry, and engineering; through probability, computer use, and simulation.

PROBABILITY*

Direct. Genetics; pasteurization problems; prediction of rainfall, moisture deficits, and flood and drought incidence; dam theory; birth and survival processes; epidemiology.

Indirect. Through physics, chemistry, statistical inference, computer use, and simulation.

STATISTICAL INFERENCE†

Direct. Designing experiments and surveys, summarizing and interpreting data, estimating interrelations, formulating prediction equations, estimating

*Based on calculus and linear algebra.
†Based on calculus, linear algebra, and probability.

uncertainties, estimating populations, numerical taxonomy, correlation and dependency patterns, quantitative genetics, evaluating dairy herds, and time series analysis.

COMPUTER USE

Applying statistical theory and methods, linear programming, simulating behavior of complex systems, storing and retrieving information.

MATHEMATICAL PROGRAMMING

Optimizing the management of individual farms; formulating at lowest cost feeds and foods that satisfy stipulated nutritional requirements; transportation problems (e.g., warehouse location and delivery routes); management of natural resources in general.

SIMULATION

Studying the behavior of forest systems as a basis for management decisions; studying the behavior of ecosystems; studying genetic systems under selection; studying light interception and photosynthesis by crops; studying neural networks and the circulatory system.

Implementing the Recommendations

Implementing the Committee's recommendations in 10 years is a practical goal. But if the goal is to be achieved, the difficulties of transition must be recognized and overcome as soon as possible. The following steps should be taken:

1. Encourage general acceptance of the recommendations by agnare faculties.
2. See that high school students obtain an adequate background in mathematics.
3. See that proper instruction is given at the college level, both in mathematics and in agnare courses.
4. Find room in the crowded curriculum.
5. Obtain financial support for efforts associated with steps 1 and 3.
6. Maintain liaison among groups having common interests.

ACCEPTANCE

As noted under "Growing Appreciation of Mathematics" (page 29), many faculty members in agnare do not realize the need for more mathematics in their curricula. An effort should be made to provide experience that will give these faculty members a greater appreciation of mathematics and more capability in it.

Mathematics courses specially designed for faculty members in agnare might be possible on many campuses. At most institutions, faculty members can take one course a term without charge. A few institutions have postdoctoral programs that meet the need for continuing education in mathematics. Other possibilities are studying mathematics during sabbatical leave, attending short courses and summer school, and participating in conferences and symposia.

Stronger working relationships between faculties in mathematics and those in agnare would be helpful.

HIGH SCHOOL BACKGROUND

As stated previously (page 27), a high school student who expects to obtain a degree in agnare should take 4 years of college-preparatory mathematics. A plan for gradual adjustment of college-entrance requirements is needed, because many students now in high school have not had, and will not have, a chance to obtain the desired background before graduating.

The Committee suggests that the requirements be raised to the desired level over a period of about 5 years. The timetable might be as follows:

September 1971—announce that mathematics requirements for students entering agnare will be raised, effective September 1974.
September 1974—raise requirements to 3 years.
September 1976—raise requirements to 4 years.

If changes in programs and entrance requirements are properly announced, they will quickly be reflected in high school counseling. Students interested in agnare should be encouraged to take more mathematics, and those with special talent in mathematics should be apprised of the challenges in agnare.

Wherever possible, new programs in agnare that have strong requirements in mathematics should be implemented immediately. They can be offered as options to students who have the necessary high school background or can make up deficiencies after entering college.

Current offerings must be continued for a time. During the transition period, students should be permitted to take courses from both the new program and the old one in proportions that are appropriate to their backgrounds and interests.

INSTRUCTION AT THE COLLEGE LEVEL

Mathematics

Some teachers of mathematics at the college level are unable to make the subject appealing to students in agnare. They should be encouraged to learn more about agnare courses and activities and to gain a better understanding of the relation between these courses and mathematics. The mechanisms suggested above under "Acceptance" for improving the mathematical appreciation of faculty members in agnare also apply here.

Each year it might be possible to induce a few doctoral students in mathematics to minor in some phase of agnare. The experience would improve their ability to teach mathematics to agnare students. It might also be possible to find good mathematics teachers among doctoral students who have a major in agnare and a strong minor in mathematics.

Preparation of mathematics texts and reference materials for students in agnare should be encouraged.

Agriculture and Natural Resources

Mathematics should have a place in more agnare courses, but several factors make adjustment difficult. Faculty members in agnare need help in revising courses and in developing books and reference materials dealing with mathematics. Faculty members in mathematics departments could help prepare teaching materials. Perhaps the most useful step would be to ensure strong training in mathematics for doctoral students majoring in agnare.

FINDING ROOM IN THE CURRICULUM

Providing mathematics background in the manner recommended would make it possible to reduce the contact hours needed to cover nonmathematical subjects. In many areas of upper-division instruction, contact hours could be reduced by 50 percent. As a result of reductions, room for the recommended mathematics courses would become available in the curriculum.

Animal breeding is an example of an area in which contact hours could be reduced as a result of the proposed change in mathematics instruction. Two semesters are usually required. In general, the first semester is qualitative and the second is quantitative, but the extent to which the second can be quantitative depends on the mathematics background of the students. In the second semester, much of the material of the first semester is repeated with a mathematical treatment; then some advanced topics that cannot be presented without mathematics are added. If students had the preparation here recommended, the material could be condensed into one semester and presented more effectively than under the two-semester procedure.

Other specialties in which a reduction in number of courses could accompany a strengthened mathematics background include plant breeding, economics, ecology, and forest management. Total savings of 15 to 18 semester hours should be possible, and these savings would entail no reduction in the amount of material covered.

FINANCIAL SUPPORT

Special financial support would be needed to implement certain aspects of the Committee's recommendations. In particular, support would be needed for conducting summer programs to be attended by present faculty members and for preparing teaching materials.

Summer programs should provide courses in mathematics for the faculty of agnare, courses in agnare subjects for the faculty of mathematics departments, and courses devoted to mathematical concepts and techniques in specific fields (e.g., animal science, forest management, and ecology). The last-named courses should be structured so that members of both faculties could attend classes together. Funds would be needed to support the instructional staff and to defray costs of travel and subsistence for many of the people taking the courses.

With respect to teaching materials, the chief need is for a broad spectrum of texts that contain mathematics of the kind recommended by the Committee together with examples and exercises relating to agnare. Persons capable of preparing such texts should be encouraged to do so. A variety of activities, such as work conferences and symposia, should be part of this effort. Summer support and salaries for persons participating in the activities would have to be provided.

LIAISON

CEANAR should maintain liaison with CUPM. CEANAR can serve as a channel of communication between mathematicians and persons who are working to improve mathematics in agriculture and natural resources. CUPM can assist in preparing recommendations, course outlines, bibliographies, texts, and reference material.

REPORT OF THE COMMITTEE ON PHYSICS

Instruction in physics is a traditional feature of many of the programs administered by colleges of agriculture, but requirements vary. In most programs, the requirement is from one quarter to one year (A. G. Hazen, unpublished data). Some programs require no physics, and a few require more than one year.

Many reasons can be given for including one or more courses in physics in various curricula at the college level. Through such courses, one can develop mental discipline, learn to deal with the world quantitatively, become acquainted with scientific nomenclature, gain a better understanding of our environment, become more adaptable to scientific change, learn principles necessary for study in other fields, acquire a modest training in technology, and establish a basis for more rational consumer judgment.

Extension of physics study to more college students is made feasible by improvements that have taken place in high school mathematics instruction since the mid-fifties. The post-Sputnik era stimulated retraining and consequent enrichment of the mathematics offerings in both context and methodology. Unfortunately, there is little evidence of comparable improvement in physics instruction at the high school level. In most high schools, physics is a 1-year subject.

Strengthening Requirements

Compelling reasons exist for strengthening and broadening physics requirements in agricultural curricula:

- The basic reason is that more and more aspects of agriculture and related subjects are emerging as quantitative sciences. It follows that quantification is increasingly a factor in problem-solving, and quantification demands the application of physical principles.
- Because of the widespread accessibility of computers, it is highly desirable that students become familiar with the capability of these devices, and the beginning course in college physics seems the most appropriate place for introducing computer techniques.
- A strong background in physics is a valuable asset to agricultural research scientists.

Efficiency in Constructing Curricula

In constructing curricula, we should try to develop courses that have a large utilization factor for most of the students who take them, and we should eliminate courses that include large segments that are useful to no one. Parts of some courses will have particular appeal to different groups of students, but in a large school separate courses or sections of a course can be individualized to suit the needs of students with specialized interests.

Efforts to obtain maximum efficiency in curriculum structure should not produce a situation that requires students to pay heavy penalties for changing plans in midstream. Penalties inevitably result from some changes (e.g., changing a major sequence), but if allowance is made for the likelihood of changes, penalties can be minimized.

With these principles as guides, we approach the task of recommending a course in physics for students in agriculture.

New courses and a variety of course options make it possible for a student to build a program that is rich in material valuable to him. But when curricula are crowded, adding a course calls for application of a normalizing principle; an equivalent amount of course time must be eliminated without loss of vital course content.

Creation of a large variety of options can be extremely expensive, because the options necessitate the existence of a large teaching staff. Further, some of the specialized courses may be of interest to only a few students.

Recommended Course

The course recommended here extends over two semesters and carries 8 to 10 hours of credit. It can appropriately be made a requisite in most agricultural curricula. The few options in which it would not be appropriate are those in which students are not obliged to develop skill in mathematics.

The course should be more than a watered-down first course in physics for students planning to become physicists or engineers. It should be structured to meet the needs of students of agriculture. For most of the students for whom it is intended, it will be a terminal course in physics, but it should also provide preparation for the more advanced courses needed in some fields of agriculture and in graduate work.

Instructors should be professionally trained in physics, and they should be able to relate the instruction to agriculture. Whether they are members of the agriculture staff is unimportant.

The text should be oriented to agriculture. Such a text cannot be produced merely by injecting farmyard examples into standard engineering physics.

Supplementary material (examples, problems, readings) should be related to biology and meteorology. For such material to be satisfactory, it would have to be prepared by interdisciplinary experts.

Material should also be made available to help students learn to use computers, and laboratory work should include computer exercises.

A detailed outline for the recommended course seems unnecessary. Emphasis will depend in large part on the illustrative material that is selected. For example, rigid body mechanics might be played down in favor of elementary fluid mechanics, the ideas of thermodynamics might be emphasized more than a statistical theory of heat, and radiation laws might be treated empirically rather than derived theoretically.

Preparing Resource Materials

The success of the course envisioned by the Committee would depend largely on the preparation of resource materials.

Several modern texts on agricultural physics are available, but none is entirely suitable. The real need is to develop a discipline that lies between physics and the agricultural and life sciences, obtain teachers for the discipline (by training them or by reassigning teachers in other disciplines), and prepare resource materials for it.

Although a number of competent scientists have emerged in the interdiscipline, none has gained enough experience in it to qualify for the task of writing a good, comprehensive text.

A useful step would be to accumulate the highly effective teaching examples that are being used by some of our more creative teachers in junior colleges and 4-year institutions. Such an effort could begin at any time, and the cost would be low. Many of the modules and sourcebooks collected would be inappropriate, but they would be screened by competent interdisciplinary scientists. Those selected would be tested by classroom use. We may hope that through this process we could develop, in 2 or 3 years, first courses for agriculture and the biophysical sciences that would be much more than updated standard physics courses. Such source material could serve, without disruptive effect, as the basis for modifying existing courses.

There is ample precedent for developing source materials as suggested here and for basing courses on them. See Baker (1966), Committee on the Undergraduate Program in Mathematics (1967), Roll (1966), and Strassenburg (1965).*

After the materials have been collected and screened, it would be desirable to set up at least two pilot projects to test different course designs. Well-

*See also the seven papers published under the general title "Introductory Physics Education—College" in a 1967 issue of Physics Today (20:47–73).

publicized reports on these projects would be almost certain to stimulate better physics preparation for students in agricultural and biological sciences.

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APPENDIXES

APPENDIX A

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