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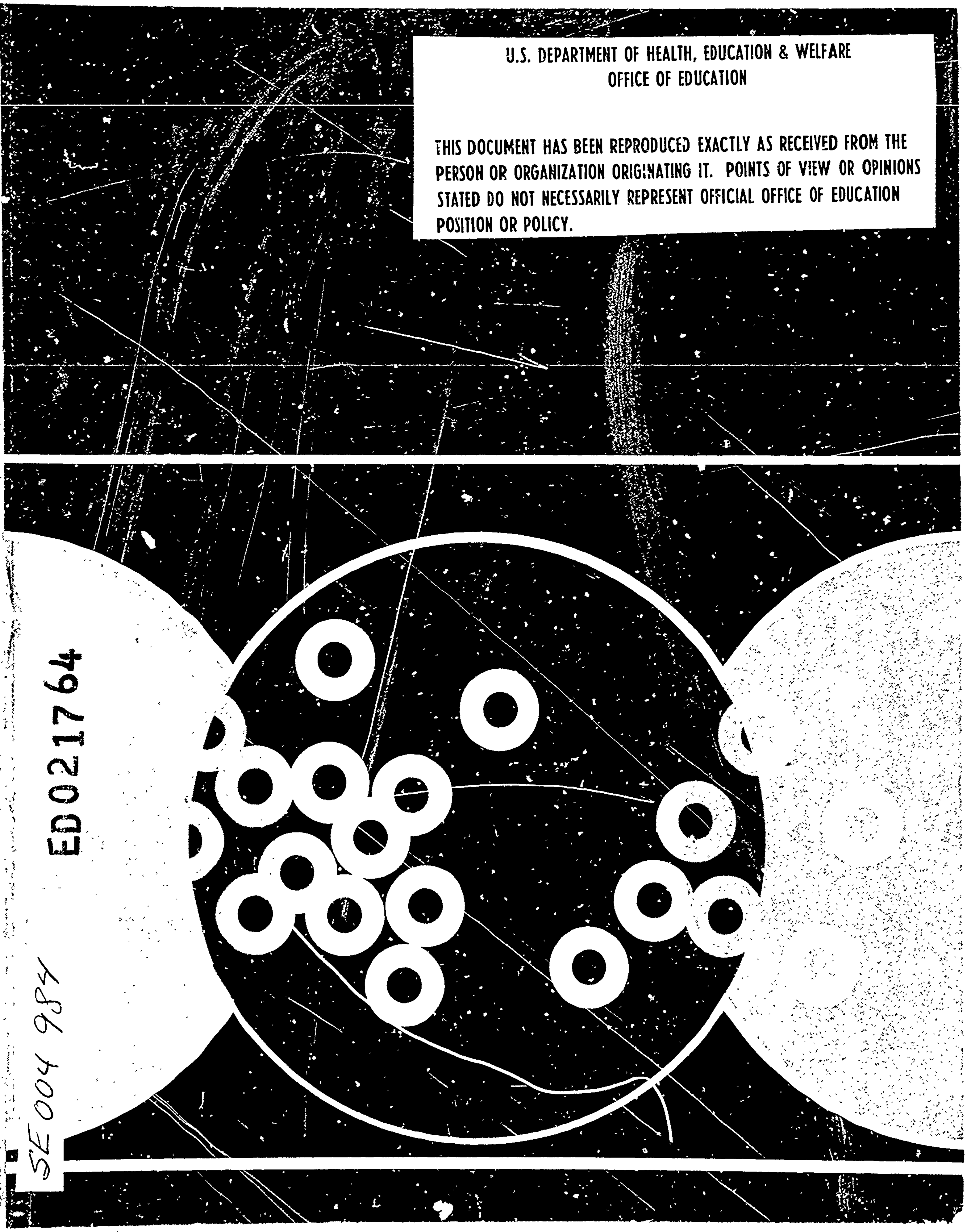
Identifiers-Commission on Undergraduate Education in the Biological Sciences, Panel on Undergraduate Major Curricula

Reported are the findings of the Panel on Undergraduate Major Curricula which define the specific content on an undergraduate core curriculum in the biological sciences. In-depth analysis of the detailed information content of the core program is presented. Content descriptions of the core programs at four colleges are provided, and a composite picture of a core program is developed. Conclusions and recommendations are provided. (DS)

Content of Core Curricula in Biology



CONTENT OF CORE CURRICULA IN BIOLOGY

Report of the Panel on Undergraduate Major Curricula

JUNE, 1967

Publication No. 18

COMMISSION ON UNDERGRADUATE EDUCATION IN THE BIOLOGICAL SCIENCES

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The National Science Foundation to
The George Washington University

COMMISSION ON UNDERGRADUATE EDUCATION IN THE BIOLOGICAL SCIENCES

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FOREWORD

This study constitutes the final report of the CUEBS Panel on Undergraduate Major Curricula, and is the culmination of nearly two years of intensive work on the part of a great number of people.

While the Commission and the Panel accept overall responsibility for the ideas and concepts herein expressed, the credit for carrying out the mission and assembling the report rests largely on the shoulders of Drs. Jay Barton II and Clifford Grobstein. As a Staff Biologist in the CUEBS office, it was Dr. Barton's responsibility to gather and analyze the data presented here; he carried the major burden of formulating this report in conjunction with Dr. Grobstein and the Panel. He was helped immeasurably by David F. Carroll, CUEBS Staff Associate, who assisted in gathering and analyzing the raw data and assumed responsibility for processing the data. Control and transfer of the data to IBM cards was done by Elizabeth M. Barton, James Brockenbrough, Audrey J. Livermore, Jerline Robertson, Lonnie G. Schein, and Carol J. Swanson, under the supervision of Mr. Carroll. Joanne Reese and James F. Williams worked with Dr. Barton and Mr. Carroll in devising computer programs to handle the data and were helped in turn by Dr. E. C. Keller, University of Maryland. We are indebted to the University of Maryland Computer Center and The George Washington University Biometric Laboratory for permission to use their computational equipment.

It would have been impossible to even begin the study, let alone carry it to completion, without the active assistance of many faculty members at the four institutions that were examined in detail. We are especially grateful to Drs. R. W. Barratt, D. S. Dennison, R. P. Forster, W. T. Jackson, T. B. Roos, and G. B. Saul II at Dartmouth College; to Drs. E. O. Beal, G. H. Elkan, E. W. Glazener, J. W. Hardin, G. C. Miller, G. R. Noggle, T. L. Quay, J. A. Santolucito, R. H. Schaible, and H. T. Scofield at North Carolina State University; to Drs. A. I. Aronson, J. A. Chiscon, Albert Kahn, Henry Koffler, F. C. Neidhart, E. H. Simon, J. W. Vanable, and R. H. White at Purdue University; and to Drs. Paul Ehrlich, Arthur Giese, Richard Holm, Donald Kennedy, J. F. Oliphant, and R. M. Page at Stanford University.

Finally, we acknowledge with thanks the assistance, advice, and critique provided by Commissioners and members of the CUEBS staff during the course of this study; it would be impossible to list all of the names here, although many individuals contributed many hours to the project.

Martin W. Schein
Director, CUEBS
June, 1967

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1

INTRODUCTION

The founding members of the Commission on Undergraduate Education in the Biological Sciences be' ›ved that the content of curricula had fallen far behind the spectacularly advancing front of biological investigation and subscribed to the notion that something could be done about narrowing the gap. Early discussions led to the concept of a "core curriculum," encompassing that body of knowledge essential for all students of biology. An enthusiastic consensus developed on the importance of this concept, but it soon became clear that "the core" meant different things to different people. To resolve this problem, the Commission assigned to a panel the task of defining the specific content of a core curriculum; thus, in 1965 the Panel on Undergraduate Major Curricula (PUMC) came into existence.

While the Panel could have attempted to write an ideal core curriculum, this approach was rejected for several reasons. It was clear that the product of such an effort might well vary with the composition of the group and hence would carry little weight with the biological community. Moreover, on several campuses across the country considerable time and effort had already been invested in the problem, and any new attempt would duplicate these efforts. Accordingly, it was decided to concentrate on compiling and analyzing some existing core programs, thus providing at least some beginning guidelines towards constructing an "ideal" core of biological information. Such an approach would amount to a pragmatic definition of what the core in operation *is*, without introducing new value judgments about what it *ought* to be.

To achieve its goal, the Panel's strategy was as follows:

1. Select four high quality institutions that had recently given serious attention to the content of their biology curricula.
2. Record the curricula in sufficient depth and detail so as to enable them to be analyzed and compared.
3. Identify the common materials and organize them in a form permitting effective communication with other interested institutions.

The Panel and the Commission have no illusions that an ideal biology curriculum emerges from this study. No one of the institutions selected for analysis believes that it has achieved an ideal curriculum; therefore, integration of their efforts could not have yielded perfection. Rather, this report presents a working model to stimulate and assist curriculum evaluation, modification and improvement.

Clearly, there are no final answers in curriculum design; such design must follow the growth and expansion of our knowledge and understanding. It is hoped that this publication will provide some guidelines to orient the process.

2

PROCEDURES: DESCRIPTION AND ASSESSMENT

Selection of the Sample

The decision to analyze existing biology programs, rather than attempt to create an ideal program *de novo,* necessitated a sampling of currently operating programs. The Panel established a number of criteria to guide it in its selection of a suitable sample. First, to be included in the sample an institution must have recently given serious and intensive thought to the content and organization of its biology curriculum. Second, the institution must be one whose professional judgment on curricular matters would receive favorable consideration by the biological community. Third, the sample of institutions must reasonably represent the diverse needs for which biology curricula are developed (e.g., programs in agriculture, secondary education, and liberal arts, as well as preparation for graduate study in biology or professional careers in the healing arts). Fourth, the sample should be of optimum size to achieve the goals of the analysis. Such factors as ease of access and institutional interest in cooperation were also considered.

The sample ultimately agreed upon was composed of the following institutions: Purdue University, Lafayette, Indiana; Stanford University, Palo Alto, California; North Carolina State University at Raleigh, North Carolina; and Dartmouth College, Hanover, New Hampshire. This list includes a large private institution (Stanford), two state institutions (Purdue and North Carolina State) that are organized and oriented quite differently, and a relatively small private liberal arts institution (Dartmouth). The Panel considered that institutions much smaller than Dartmouth College would offer constraints imposed more by the number of faculty members than by professional judgments on what should or should not be included in the core curriculum.

Collection of the Data

In-depth analysis of the detailed information content of the core programs at the four selected institutions was the goal. Attempts were made to identify every item, concept, or piece of factual information to which a professor teaching in the core program devoted as much as five minutes of discussion. (An instructional *unit* was one 50-minute lecture; five minutes equals 0.1 units.) It was arbitrarily decided to regard information which received less than five minutes consideration as only a passing reference or illustration, and to weight items in terms of the basic 50-minute lecture unit. The decision to perform the analysis on this level of detail avoided the ambiguity and indeterminancy of course titles and lecture topics. It also imposed the necessity of making one or more visits to each campus to gain the detailed information. Each professor was interviewed and some or all of the following material was requested: instructor's syllabus and lecture notes, student lecture notes, laboratory exercises, examinations, lists of textbooks and reading assignments, and other pertinent material descriptive of the course. Usually, the course material was reviewed during the interview with the professor; in some cases, it was also reviewed with the graduate assistants running the laboratories. All of these data enabled staff judgments to be made about items of information discussed in any particular lecture and on the amount of time spent on each item.

The information content of the lectures and laboratories was recorded in detail and provided the basis of the analysis. The supporting materials (e.g., textbooks and reading lists) were used to gain insight into the level of detail and sophistication at which any given topic was discussed by the instructor. Textbooks were not analyzed *per se*; therefore, materials that the student might be expected to know solely from reading assignments were not included. Some of these materials, however, are implicit in the level of sophistication at which particular information is given in lectures or laboratories. Descriptions of the required courses in each core curriculum are presented in the next chapter.

Data Reduction

The first step in the reduction of the raw data was to transcribe the items of information identified in the lectures and laboratories of the individual courses to "item analysis forms." The form provided space for a summary statement of the item itself and as much supporting detail as the notes permitted. The information on the item analysis form, transcribed to IBM punch cards, became the basic data for all subsequent analyses. Coded information on the form indicated the institution from which the item was taken, the year and semester in which it appeared, and an identification number indicating the sequential position of that item in a particular course. In addition, each item was examined and coded according to whether it was on the molecular, cellular, organismal, or population level of biological information. Further coding identified its zoological, botanical, microbiological, or general biological orientation; the kind of organism used, if any; and, finally, whether the item reflected a technique or manipulation, e.g., operating a spectrophotometer as compared to simply learning about absorption spectra.

Vocabulary

After the items at one institution had been identified and reduced to item analysis forms, a master vocabulary list was constructed. The detailed list allowed similar and identical items to be identified and a common terminology to be established for all four institutions. Each item in the vocabulary list was given an unequivocal identification number. The list was sorted into categories, topics, and subtopics; groupings were chosen as convenient devices for searching the list, rather than as representatives of any particular insight into the structure of biology.

Each item analysis form was then coded with the relevant information number for the vocabulary term. As similar forms were prepared for the other institutions, items could be compared against the existing vocabulary list and a number assigned if identity was found. If no equivalent item was extant on the list, a new term was created and the list expanded. In the analysis of the four institutions reported here, some 3200 different vocabulary items were established in the inclusive list (Appendix 1).

Assessment of Procedures

Certain limitations in the methods of gathering and reporting data are apparent. First, it is clear that these data cannot directly reflect the logical structure of the course as seen by the professor presenting it. In preparing summary statements for the item analysis forms, such features as personalized introductory phrases and approaches, transition illustrations, etc., tended to disappear. The logical pattern is maintained only insofar as the sequence of items of information can be reconstructed. Nevertheless, the item analysis forms did contain information on subordinate items of detail, as well as the relationship of the item to these subordinate items and superordinate categories; thus, if an extended analysis had been necessary, the entire logical structure of the course might well have been reconstructed.

Second, the development of a master vocabulary list, through which specific items of information from specific courses are translated into a common language useful for all institutions, means some further loss of information. The words of the original instructor can not always be transferred directly. The compensation for this loss of information is that the curricula of two or more institutions can now be more directly compared.

Third, professional judgments by CUEBS staff members involved in the study inevitably entered into decisions on vocabulary identification and comparability of items. How different the results would be if developed by a second set of analysts is not clear.

Thus, anyone attempting to interpret the results of this report must keep clearly in focus the limitations of the procedures by which it was prepared. The seriousness of these limitations depends greatly upon the purposes to which the study is applied.

3

THE CORE PROGRAM IN FOUR INSTITUTIONS

In each of the four schools chosen for the sample, all biology majors take a prescribed sequence of courses in biology, *the core program.* The sequence varies in length and structure, reflecting the special interests of each institution. At the time of this study, the core program at three of the four institutions had been in operation long enough so that some students had completed the whole sequence. During the initial period of operation, many revisions were made at each institution. The data presented below refer to the academic year 1965-66; the programs offered in 1966-67 are already different in some detail.

It is interesting to note that at none of the institutions has the period of revision ended. It seems a valid generalization that once a faculty commits itself to a serious examination of its teaching responsibilies, it continually revises its curriculum.

Purdue University

The Purdue University program, shown in Table 1, extends over seven semesters. The core program is required of all biology majors, which include those preparing for graduate study in the biological sciences, those preparing for careers in secondary school biology teaching, and those aiming at careers in the health-related areas. However, other programs on the Purdue campus still demand more traditional introductory programs; hence an introductory zoology and botany course are also taught.

Following is a description of the core program at Purdue.*

Principles of Biology (2 one-hour lectures, 2 hours of laboratory, 3 credits, each of two semesters). An introductory course offered to potential majors in the biology department and students seeking to fulfill the general

*Catalogue descriptions of courses offered at all four institutions, as well as a list of textbooks and major assigned readings, are given in Appendix 2. It must be kept clearly in mind that the material presented here represents only the core programs for the academic year 1965-66. The evolving nature of curriculum reform makes the material presented in Appendix 2 obsolete if applied to any subsequent academic year.

science requirement. The aim of the course is to introduce the major principles of biology as currently defined. A laboratory program has been developed for this course. Some audio-tutorial and television instruction is used.

Structural Biology (2 one-hour lectures, 2 two-hour laboratories, 4 credits). This course represents a major effort by the Purdue faculty to avoid the artificial separation of morphology and anatomy from function and physiology. The complementarity of structure and function and the evolutionary development of organisms are discussed for both plants and animals.

Environmental Biology (2 one-hour lectures, 1 three-hour laboratory, 3 credits). The content of this course is a mixture of ecology, population biology, genetics, and evolutionary mechanisms.

Cell Biology (2 one-hour lectures, 2 two-hour laboratories, 4 credits). The analysis of the structure and function of a bacterial and mammalian cell makes up the major portion of this course. Much molecular biology is included. The student has already received information on cytology in the introductory and structural biology courses; such material is not repeated in this course.

Developmental Biology (2 one-hour lectures, 2 two-hour laboratories, 4 credits). The lecture material for this course is almost entirely analytical and experimental. The student's previous preparation in molecular and cellular biology permits an in-depth analysis of differentiation and development. Laboratory work includes a good deal of descriptive material, as well as some experimental work. Both plants and animals are discussed.

Genetic Biology (2 one-hour lectures, 1 recitation, 2 two-hour laboratories, 4 credits). Although much of traditional and modern genetics has been taught or touched upon in the previous courses in the core, a separate course in the senior year permits a thorough discussion of the integrative power of genetics over all levels of organization. An emphasis on molecular genetics allows this strong interest of the Purdue biology department to be expressed.

Stanford University

The Stanford University core program is apparently shorter than that at Purdue, occupying the student during only his sophomore and junior years. However, the quarter system allows the Stanford core almost as much variety and as many total instructional hours as the Purdue program. Table 2 illustrates the Stanford core program, along with the auxiliary science requirements.

Following is a description of the core program at Stanford.

Fundamentals of Biology (4 one-hour lectures, 2 hours of discussion, 5 credits). The introductory core course at Stanford is offered in the sophomore year to biology majors having previous preparation in chemistry. This course is designed primarily as a "catch up" or equalizing course for a frequently heterogeneous student population. Most members of the department are involved in the lecturing and in the discussion sections.

TABLE 1.

BASIC REQUIREMENTS FOR BIOLOGY MAJORS AT PURDUE UNIVERSITY

YEAR		BIOLOGY	CHEMISTRY	MATHEMATICS	PHYSICS
FRESHMAN	1 Sem	Principles of Biology	Advanced General Chemistry	Finite Mathematics	
	2 Sem	Principles of Biology	Advanced General Chemistry and Qualitative Analysis	Finite Mathematics	
SOPHOMORE	1 Sem	Structural Biology	Analytical Chemistry	Analytical Geometry and Calculus	Mechanics and Sound
	2 Sem	Environmental Biology	Organic Chemistry	Calculus	Heat, Electricity and Optics
JUNIOR	1 Sem	Cell Biology	Organic Chemistry		
	2 Sem	Developmental Biology			
SENIOR	1 Sem	Genetic Biology			
	2 Sem				

TABLE 2.

BASIC REQUIREMENTS FOR BIOLOGY MAJORS AT STANFORD UNIVERSITY

	YEAR	BIOLOGY	CHEMISTRY	MATHEMATICS	PHYSICS
FRESHMAN	1 Qtr		General Chemistry	Analytical Geometry and Calculus	
	2 Qtr		General Chemistry	Analytical Geometry and Calculus	
	3 Qtr		General Chemistry	Analytical Geometry and Calculus	
SOPHOMORE	1 Qtr	Fundamentals of Biology	Organic Chemistry	Analytical Geometry and Calculus	
	2 Qtr	Plants as Organisms	Organic Chemistry	Analytical Geometry and Calculus	
	3 Qtr	Animals as Organisms			
JUNIOR	1 Qtr	Molecular Biology			Introductory Physics
	2 Qtr	Cell Physiology			Introductory Physics
	3 Qtr	Population Biology			Introductory Physics
SENIOR	1 Qtr				
	2 Qtr				
	3 Qtr				

TABLE 3.

BASIC REQUIREMENTS FOR BIOLOGY MAJORS AT NORTH CAROLINA STATE UNIVERSITY

	YEAR	BIOLOGY	CHEMISTRY	MATHEMATICS	PHYSICS
FRESHMAN	1 Sem	General Biology	General and Qualitative Chemistry	Analytical Geometry and Calculus	
	2 Sem		General and Quantitative Chemistry	Analytical Geometry and Calculus	
SOPHOMORE	1 Sem	General Morphology	Organic Chemistry	Finite Mathematics	General Physics
	2 Sem	Animal Life	Organic Chemistry		General Physics
JUNIOR	1 Sem	General Microbiology			
	2 Sem	Plant Physiology or Animal Physiology	Introduction to Biochemistry		
SENIOR	1 Sem	Genetics			
	2 Sem				

TABLE 4.

BASIC REQUIREMENTS FOR BIOLOGY MAJORS AT DARTMOUTH COLLEGE

YEAR		BIOLOGY	CHEMISTRY	MATHEMATICS	PHYSICS
FRESHMAN	1 Term		General Chemistry	Introduction to the Calculus	
	2 Term		General Chemistry	Calculus and Differential Equations	
	3 Term			Introduction to Finite Mathematics	
SOPHOMORE	1 Term	Life Science (optional 1st or 2nd yr.)			
	2 Term	Life Science (optional 1st or 2nd yr.)			
	3 Term				
JUNIOR	1 Term	Cell Physiology			
	2 Term	Required electives: one in Animal Science and one in Plant Science			
	3 Term				
SENIOR	1 Term				
	2 Term				
	3 Term				

Hence the student is introduced to areas of biology that he will consider later in greater detail in other core courses. There is a heavy cellular and molecular emphasis in the course. A separate "liberal arts" course is offered to non-majors.

Plants as Organisms (3 one-hour lectures, 2 two-hour laboratories, 5 credits). **Animals as Organisms** (3 one-hour lectures, 2 two-hour laboratories, 5 credits). These two quarters of the Stanford core present organismal biology in the plant and animal kingdoms. Structure and function, evolution, and development are covered. The animal course stresses developmental and integrative biology.

Molecular Biology (3 one-hour lectures, 2 two-hour laboratories, 5 credits). By the time students have reached their junior year, they have had the equivalent of two years of college chemistry, and are thus well prepared for a sophisticated course in molecular biology. Protein and DNA structure and function, and metabolism, make up the bulk of the course.

Cell Physiology (3 one-hour lectures, 2 two-hour laboratories, 5 credits). A fairly traditional cell biology course emphasizing those aspects of cell physiology not covered in the previous molecular biology course.

Population Biology (3 one-hour lectures, 3 credits). This course is a discussion of the ways in which aggregations of organisms behave. Aspects of the structure of populations are considered, as well as the various ways in which populations change in size and structure.

North Carolina State University

The North Carolina State University at Raleigh faced an administrative problem similar to that found in many large State and Land Grant institutions. The unity of biology was not at all reflected in the departmental structures on the campus. At North Carolina State there were separate departments not only for botany and zoology, but for entomology, genetics, plant pathology, etc., as well. Previous experience on the research level demonstrated the value of cooperation. An Institute of Biological Sciences became the administrative tool whereby the various biological departments on the campus, including the commodity-oriented agricultural departments, established a common core program in biology; Table 3 illustrates the program. As a first step, existing courses in various departments were utilized with relatively minor changes to constitute the core program required of every biology student at North Carolina State. An "ideal" biology curriculum has been outlined as a goal; the core continues to evolve toward this ideal.

Following is a description of the core program at North Carolina State.

General Biology (3 one-hour lectures, 1 two-hour laboratory, 4 credits). A new introductory program created by the cooperative efforts of a botanist and a zoologist. It is a modern introduction to biology, and not simply a fusion of botany and zoology.

General Morphology (3 one-hour lectures, 1 three-hour laboratory, 4 credits). This is intended eventually to be a course in plant life. At the present stage of development it is still primarily a survey of the plant kingdom.

Animal Life (3 one-hour lectures, 1 three-hour laboratory, 4 credits). Previous courses in invertebrate zoology and vertebrate zoology were combined to form this course which deals with structure and function, development, and evolution.

General Microbiology (3 one-hour lectures, 1 two-hour laboratory, 4 credits). A standard microbiology program that completes the student's introduction to biology.

Plant Physiology (2 one-hour lectures, 4 hours of laboratory, 4 credits) or **Animal Physiology** (3 one-hour lectures, 3 hours of laboratory, 4 credits). The option here reflects the occupational interests of the students at North Carolina State. Approximately half take plant physiology; the others, animal physiology. Because of this even split and because the two courses will soon be replaced by a single cell physiology course, components of both programs have been included in the item analysis.

The Principles of Genetics (2 one-hour lectures, 1 two-hour laboratory, 3 credits). A somewhat standard course in genetics, emphasizing traditional aspects.

Dartmouth College

At Dartmouth College a considerably shorter and somewhat more flexible core is offered to biology majors; Table 4 shows the pattern. Four quarters are specified and required of every student, while an additional two quarters are required but can be selected from a number of alternatives chosen generally from organismal courses in plant or animal science.

Following is a description of the core program at Dartmouth.

Life Science (4 one-hour lectures, 1 four-hour laboratory, 1 credit* for each of two semesters). A course designed to give the student a detailed and coherent picture of biology. Conceptual schemes emphasizing the unity of biology receive a good deal of consideration. Such logical structures are not easily maintained in the item analysis. A complete description of this course can be found in an article by T. B. Roos (*BioScience* 15(10): 660-664; 1965.).

Cell Physiology (4 one-hour lectures, 1 four-hour laboratory, 1 credit). A course designed to explore cell function at the molecular level, using animal, plant, and microbial cells for demonstrations of common tenets. The laboratory is designed to introduce the student to techniques used in biological research, as well as to demonstrate biological phenomena.

Genetics (4 one-hour lectures, 1 four-hour laboratory, 1 credit). This course includes much classical material as well as modern genetics. The laboratory exercises are original and involve some organisms not normally found in undergraduate laboratories.

*One unit of credit is given for every course taught at Dartmouth College.

4

THE SHAPE OF THE CORE

Although the four programs described above were designed to achieve the same end, the unity of purpose is not apparent in the course titles. All that can be said with certainty is that each institution has realized the need for more than one year of biology as an introduction to any specialization and, further, that divergent specializations are best grounded in a common introduction. Hence, a core program.

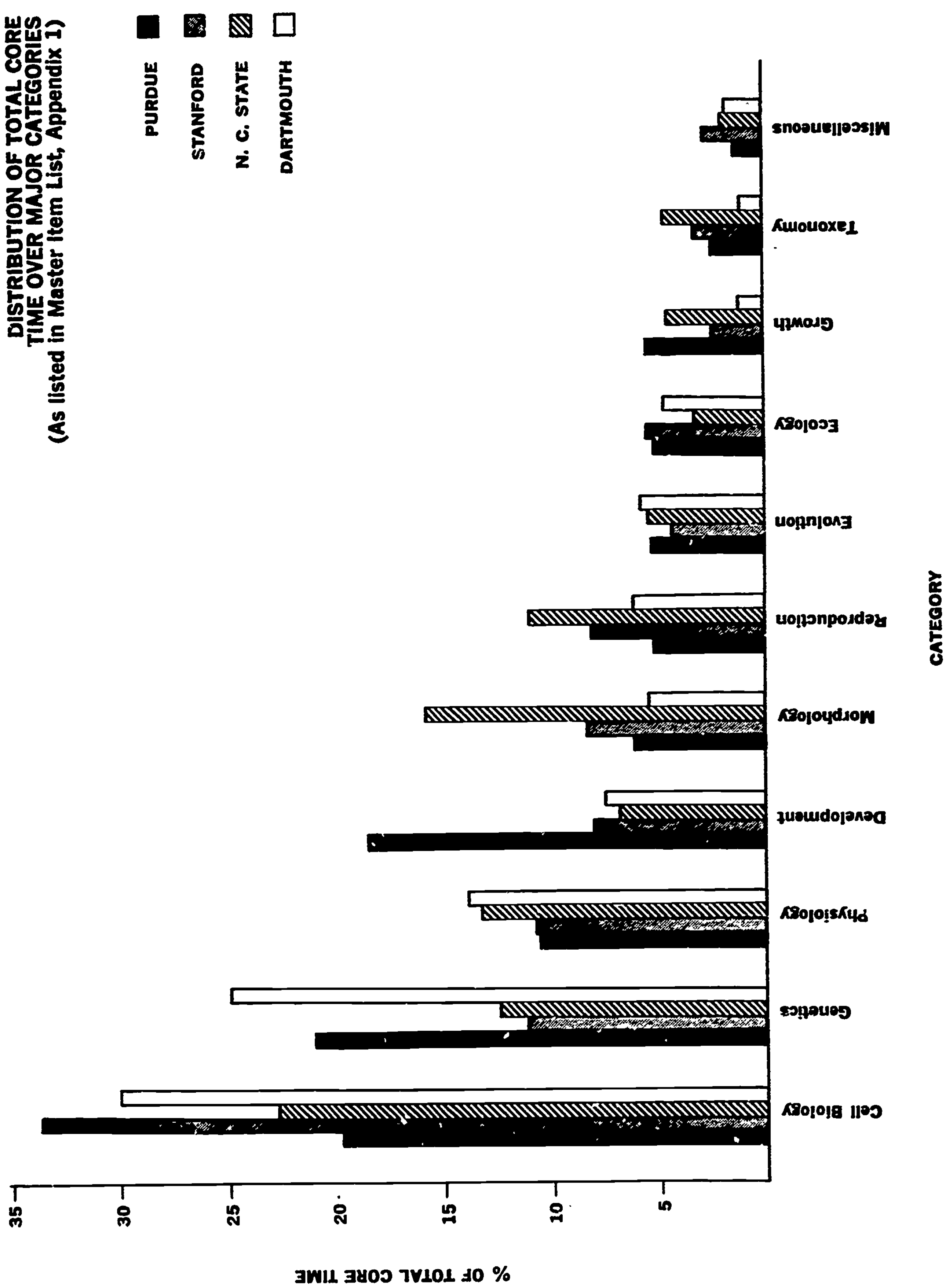
Course titles suggest a diverse organization of information in core programs, but this is misleading to some extent. For example, the Stanford and Dartmouth core programs have no developmental biology course, Purdue no molecular biology course, and North Carolina State no cell biology course. Yet on closer examination the programs of each of these institutions do contain information on all of these areas.

To analyze the course contents, CUEBS extracted the information items from each course, thereby allowing them to be reshuffled and compared at will. Each item of information was classified according to category, topic, and subtopic. Although the classifications were chosen primarily for convenience in the analysis, the structure of the core program emerges from a summarization of the data according to these classifications. Figure 1 shows the percent of total core time devoted to the major categories at each of the four institutions.

The pattern is clear. Three out of the four institutions are in reasonably close agreement on each major category (though not necessarily the same three from category to category). There is greater divergence, however, as the degree of resolution increases. In Figure 1, a spread of emphasis is indicated for the Cell Biology category while the Evolution category seems to have no such spread. However, on the topic level (Figures 2 and 3), a spread within the Evolution category first becomes apparent; as would be expected, the spread in the Cell Biology category becomes even wider.

Each item of information was independently examined to determine the level of biological organization reflected in the item. For example, an item dealing with the molecular structure of muscle was charac-

FIGURE 1.


DISTRIBUTION OF TOTAL CORE TIME OVER MAJOR CATEGORIES
(As listed in Master Item List, Appendix 1)
PURDUE
STANFORD
N. C. STATE
DARTMOUTH
% OF TOTAL CORE TIME
35
30
25
20
15
10
5
Cell Biology
Genetics
Physiology
Development
Morphology
Reproduction
Evolution
Ecology
Growth
Taxonomy
Miscellaneous
CATEGORY

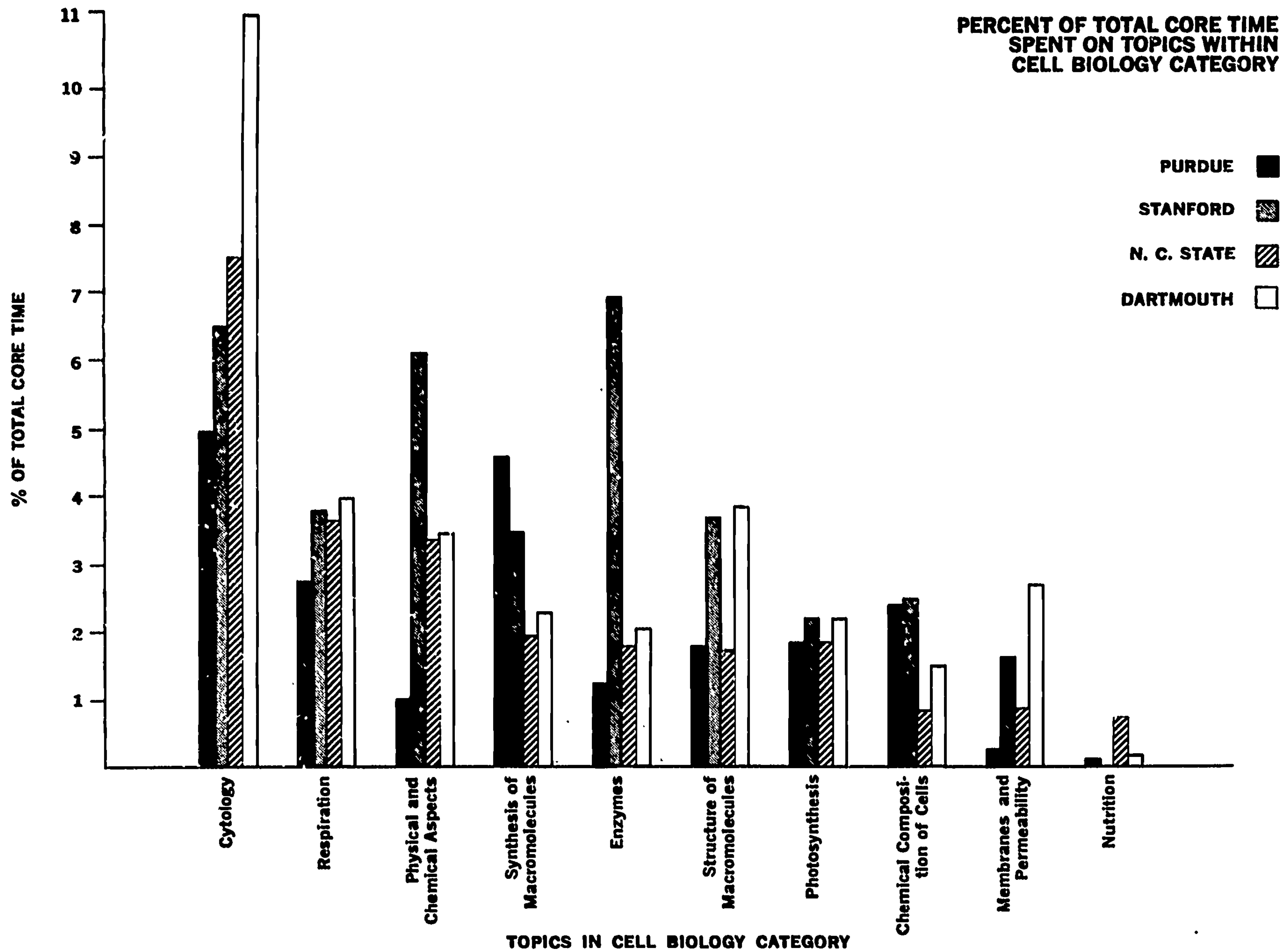
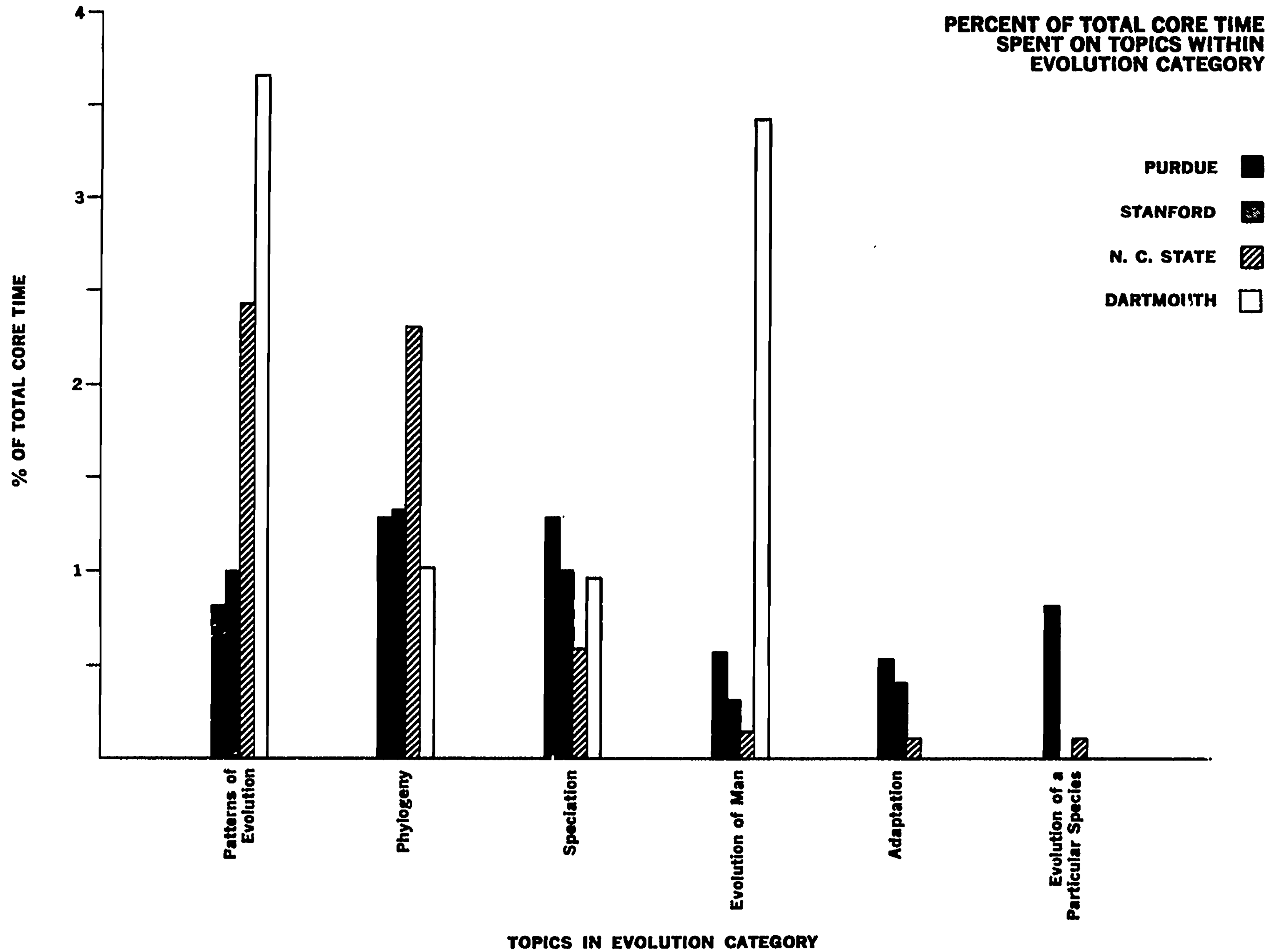

PERCENT OF TOTAL CORE TIME
SPENT ON TOPICS WITHIN
CELL BIOLOGY CATEGORY
PURDUE
STANFORD
N. C. STATE
DARTMOUTH
% OF TOTAL CORE TIME
11
10
9
8
7
6
5
4
3
2
1
Cytology
Respiration
Physical and Chemical Aspects
Synthesis of Macromolecules
Enzymes
Structure of Macromolecules
Photosynthesis
Chemical Composition of Cells
Membranes and Permeability
Nutrition
TOPICS IN CELL BIOLOGY CATEGORY

FIGURE 2.

FIGURE 3.


PERCENT OF TOTAL CORE TIME
SPENT ON TOPICS WITHIN
EVOLUTION CATEGORY
PURDUE
STANFORD
N. C. STATE
DARTMOUTH
% OF TOTAL CORE TIME
4
3
2
1
Patterns of Evolution
Phylogeny
Speciation
Evolution of Man
Adaptation
Evolution of a Particular Species
TOPICS IN EVOLUTION CATEGORY

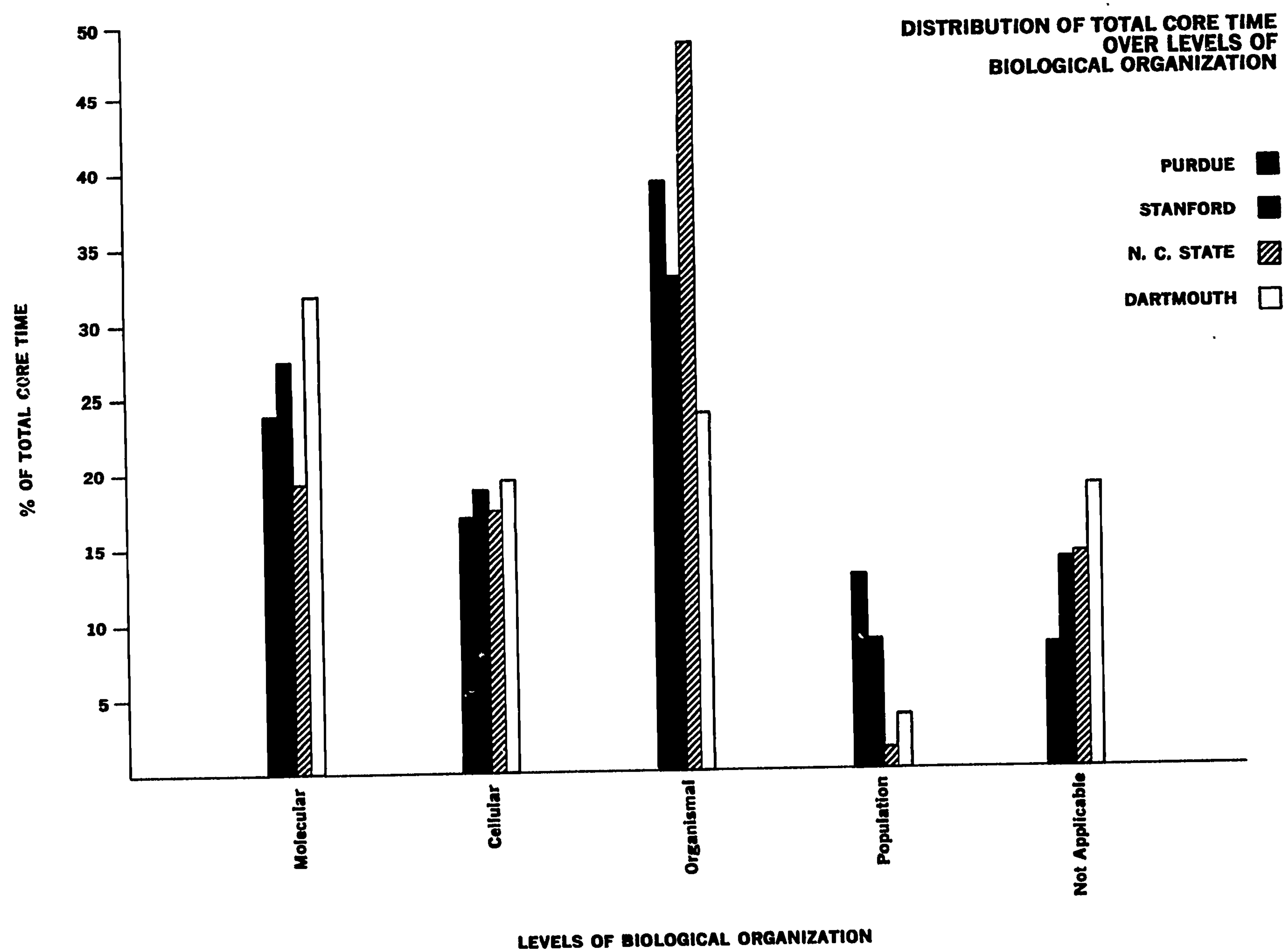

DISTRIBUTION OF TOTAL CORE TIME
OVER LEVELS OF
BIOLOGICAL ORGANIZATION
PURDUE
STANFORD
N. C. STATE
DARTMOUTH
% OF TOTAL CORE TIME
50
45
40
35
30
25
20
15
10
5
Molecular
Cellular
Organismal
Population
Not Applicable
LEVELS OF BIOLOGICAL ORGANIZATION

FIGURE 4.

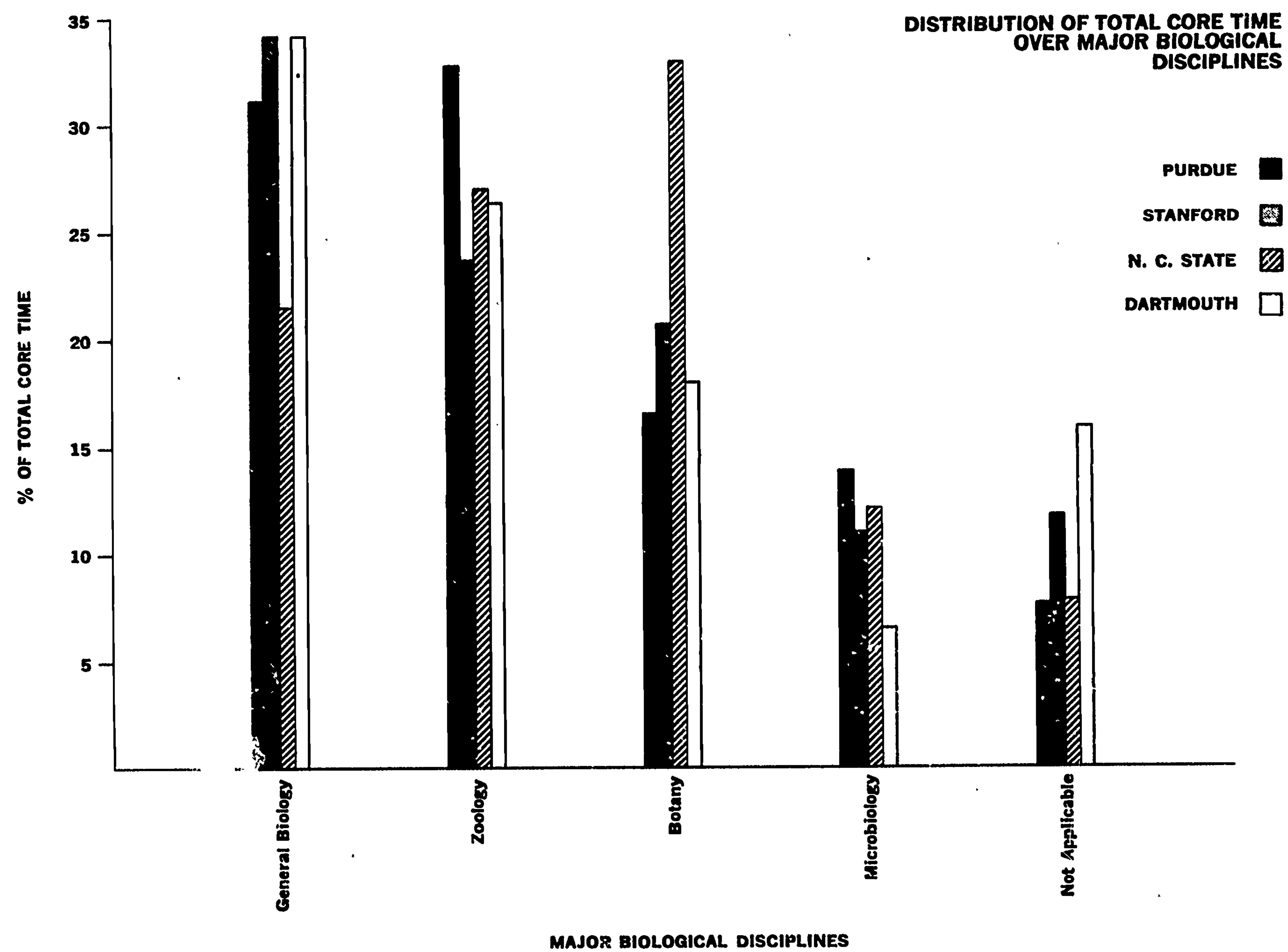

DISTRIBUTION OF TOTAL CORE TIME OVER MAJOR BIOLOGICAL DISCIPLINES
PURDUE
STANFORD
N. C. STATE
DARTMOUTH
% OF TOTAL CORE TIME
35
30
25
20
15
10
5
General Biology
Zoology
Botany
Microbiology
Not Applicable
MAJOR BIOLOGICAL DISCIPLINES

FIGURE 5.

terized under physiology and also included at the molecular level. Figure 4 shows the distribution of items according to levels of biological organization. Dartmouth appears to devote minimal time to organismal topics; however, through further requirements selected from a variety of organismally oriented courses, it offers the student as much exposure to this area as do the other institutions.

A significant amount of information is presented at the cellular and molecular levels of organization, and there is close agreement among the four institutions as to the proportion of time devoted to these levels. The emerging pattern shows that the powerful unifying insights of molecular biology *are* reaching the classroom. However, the more traditional aspects at the organismic level are still receiving significant attention, though reduced in relative amount.

Items of information were also assigned to one of the traditional biological disciplines (zoology, botany, microbiology, or general biology). This comparison of the four core programs is presented in Figure 5. Probably the most significant feature is the identification of a large fraction of the information items as belonging to general biology, rather than to any specific subdivision. A sampling of the material assigned to this heading indicated that much of it is concerned with biology on the molecular and population levels, with elements from cell biology making up most of the remainder.

Thus, classification of the information content of existing core programs according to three different parameters points to a similarity of pattern in the shape of the core. The conceptual unity brought to biology by recent developments in molecular and cellular biology is reflected in the teaching programs. However, agreement on the broad outline of the program does not necessarily mean agreement in detail. The next section will examine this question more closely.

Variations of Detail

Each of the core programs contained approximately 2,000 individual items of information. Some 250 instructional units (lecture hours or equivalent) were devoted to these items in each program. It is now relevant to ask how many information items are shared in common by the sample institutions. The number is surprisingly small: only 140, or 7%, of the nearly 2,000 items appear in the programs of all four schools. Yet this 7% of the total information accounts for approximately 16% (40 instructional units) of the total core time. To continue along these lines, 500 items (approximately 25% of the total information) appear in the core programs of at least three of the four institutions; these common items account for roughly 50% (125 instruction units) of the total instructional time. It should be emphasized that these data reflect the *mini-*

mum quantity of commonness in the programs. The semantic problems inherent in "transliterating" information bits into "items," plus the technological necessity of defining "identity" rather rigidly, tend to mitigate against items being judged "identical"; the actual degree of commonness may in fact be *higher* than is suggested here.

It is even more relevant to ask *which* information items are shared in common by the four institutions. The quantity of time spent (in major categories) on items that appear in all four schools is shown in Table 5. Genetics and cell biology have a far greater number of information items in common than do the other categories. This result is perhaps not too surprising. Almost any approach to the teaching of classical mendelian genetics would tend to use the same examples (i.e., pea plants, fruit flies, etc.) and thus contribute to a commonness of items. Molecular genetics would also be expected to lead to item commonality among the four institutions, though for a different reason: because of the relative youth of the field, the number of organisms which could be called upon to demonstrate molecular genetic principles is rather limited. Thus, discussions of gene-enzyme synthesis or feedback control of gene activity are almost certain to draw on *Neurospora crassa* or *Escherichia coli* as examples.

The length of time devoted to common items at each institution is shown in Tables 6 and 7. It will be noted (Table 6) that this common

TABLE 5.

TIME SPENT ON INFORMATION ITEMS (in Major Categories*) COMMON TO ALL SCHOOLS

	Time Spent on Common Items
Taxonomy	0.0
Ecology	0.7
Evolution	1.1
Growth	1.3
Development	1.4
Physiology, General	2.2
Reproduction	2.5
Morphology	2.7
Genetics	12.1
Cell Biology	15.6
TOTAL	39.6 units

* As listed in Master Item List, Appendix 1.

TABLE 6.

LEVELS OF BIOLOGICAL ORGANIZATION: TIME SPENT AT EACH INSTITUTION ON INFORMATION ITEMS COMMON TO THE FOUR

	PURDUE			STANFORD			N. C. STATE			DARTMOUTH		
	No. of units	% of total common time*	% of total core time**	No. of units	% of total common time*	% of total core time**	No. of units	% of total common time*	% of total core time**	No. of units	% of total common time*	% of total core time**
Molecular	14.9	43.3	5.5	21.1	43.3	8.3	14.2	37.0	4.9	15.7	45.9	8.6
Cellular	5.7	16.5	2.1	14.2	29.1	5.6	8.8	22.9	3.0	8.2	23.5	4.5
Organismal	5.9	17.1	2.2	7.2	14.7	2.8	9.7	25.3	3.3	4.0	11.4	2.2
Population	4.8	13.9	1.8	2.3	4.7	0.9	0.8	2.0	0.3	1.0	2.8	0.5
Not Applicable	3.1	9.0	1.1	3.9	8.0	1.5	4.8	12.5	1.6	5.9	16.9	3.2
Total Common Time	34.4			48.7			38.3			34.8		

*Calculated as the percentage of time in each institution devoted to information items common to all four.

**Calculated as the percentage of core time devoted to levels of biological organization at each institution.

Total number of units: Purdue, 270; Stanford, 255; N.C. State, 292; Dartmouth, 183.

TABLE 7.

MAJOR BIOLOGICAL DISCIPLINES: TIME SPENT AT EACH INSTITUTION ON INFORMATION ITEMS COMMON TO THE FOUR

	PURDUE			STANFORD			N. C. STATE			DARTMOUTH		
	No. of units	% of total common time*	% of total core time**	No. of units	% of total common time*	% of total core time**	No. of units	% of total common time*	% of total core time**	No. of units	% of total common time*	% of total core time**
Zoology	2.4	6.9	0.9	4.8	9.8	1.9	4.6	12.0	1.6	2.9	8.3	1.6
Botany	5.3	15.4	2.0	7.7	15.8	3.0	11.4	29.7	3.9	7.1	20.4	3.9
Microbiology	5.0	14.5	1.9	9.1	18.6	3.6	3.3	8.6	1.1	2.6	7.4	1.4
General	19.8	57.5	7.3	22.6	46.4	8.9	16.6	43.3	5.6	16.0	45.9	8.7
Not Applicable	1.9	5.5	0.7	4.5	9.2	1.8	2.4	6.2	0.8	6.2	17.8	3.4
Total Common Time	34.4			48.7			38.3			34.8		

*Calculated as the percentage of time in each institution devoted to information items common to all four.

**Calculated as the percentage of core time devoted to the major discipline categories at each institution.

Total number of units: Purdue, 270; Stanford, 255; N.C. State, 292; Dartmouth, 183.

material makes up varying proportions of each of the four core curricula with, again, the greatest agreement found in the molecular biology portion of the core. In the non-molecular portions, however, the general conformity in pattern evident with lower degrees of resolution (Fig. 1) is not reflected in absolute identity on the item level. Thus, for example, the total lack of commonness shown in Table 5 for taxonomy is not surprising; there would be a wealth of different examples with which principles of systematics could be illustrated. Table 7 shows the quantity of time spent on items common to the four institutions when the items are categorized into the major biological disciplines. These data further amplify the unity to be found at the molecular and cellular level. The large amount of time spent in common on the general biology category would be predicted; it is into this category that most of the items concerned with the molecular and cellular levels of investigation fall.

Why is there not a higher degree of common detail? It has already been suggested that these data reflect the *minimum* quantity of commonness in the four programs. Still, one might expect an even greater degree of common detail to be visible. It is possible, of course, that the sample of institutions is poor, i.e., one institution may be so atypical as to distort the results. On the other hand, the variation might be considered as intrinsic to the structure of core programs.

To test the hypothesis that one institution might be deviant, the number of common items within each of the four possible sets of any three schools was examined. In such an analysis the degree of agreement should change substantially when the exceptional institution is dropped out of the analysis. Such a change did not occur (Table 8): for all four

TABLE 8.

COMMONALITY IN THE FOUR SETS OF THREE OUT OF FOUR INSTITUTIONS

	No. of Common Information Items		No. of Units Devoted to Common Information Items	
	n*	n-1**	n*	n-1**
Purdue	140	391	34.4	95.6
Stanford	140	409	48.7	114.9
N. C. State	140	435	38.3	105.5
Dartmouth	140	408	34.8	95.6

*n = all four schools

**n-1 = any set of three of the four schools which includes the institution indicated.

sets of three schools the number of identical information items varied between 391 and 435. The time in instructional units ranged from 95 to 115. Thus, there is general agreement between sets of three schools; no one school is holding back the concordance. The variation must therefore be considered intrinsic to the structure of the core programs, and its source is still to be explained.

Obviously, a multiplicity of judgments exists among the many biologists contributing to the structure of the four cores. Does the variability in judgment reflect the feeling of the instructors that many different examples can be used to illustrate the same basic ideas? Alternatively, does the multiplicity of judgments reflect uncertainty and difference of opinion concerning the central concepts and factual foundation of biology? Does the high degree of concordance at the molecular level and in the genetic category suggest that the fundamental character of this area brings agreement; or, is it mainly the recency of the knowledge which brings this agreement? The evidence is insufficient to answer such questions. The questions are intriguing enough, however, to suggest that continuing analysis of the changes being made in core programs would provide further important insights into the emerging logical structure of biology.

5

PERSPECTIVES ON CHANGING CURRICULA

There is a common and usually valid observation in universities that a course runs downhill unless it is subject to continual modification. In a static situation, the professor becomes bored, his notes out of date, his textbook obsolete, and his laboratory equipment antiquated. The relevance of one course to another is no longer pertinent, since courses change or are dropped. In short, the excitement, dedication, and pressing need surrounding the inception of the new course is lost.

The same is true for curricula. The material presented in Section 4 represents the shape of curricula in transition. These developing programs are different from those taught at the same schools a few years ago, and the instructors involved indicate that changes are now taking place and will continue to take place. The changes represent consistent attempts by the teaching faculty to reflect the structure of biology more clearly in the classroom. At each institution, adaptations are made to the interests and capabilities of the faculty, the facilities, and the needs of the students.

The costly and sometimes painful soul-searching necessary for extensive curriculum revision has had a number of less tangible benefits. Clearly involved is the stimulation that results from mutual education of the biology faculty. In addition, deans and other administrators have been educated to the necessity and costliness of curriculum reform. The emphasis put on continuing change by the developers of each of these curricula is an important one. It would be helpful to be able to make generalizations about the current direction of change of biology curricula. This is impossible from a survey of four schools at one point in time. Nevertheless, it *is* possible to compare these four curricula with programs generally accepted a generation ago and to identify some important trends.

First and foremost, it is recognized that there is a common body of knowledge to be transmitted to all biologists, irrespective of specialization. The four curricula presented are built on this concept, and in part they were chosen for this reason. It is significant that four professionally strong institutions are proceeding in a common direction. Each is extending the core approach beyond the introductory courses, into middle and upper-level courses presented in the second and third years.

Second, increasing emphasis is being put on preparation in mathematics, physics, and chemistry to allow the introduction of more sophisticated quantitative material and symbolic analysis into undergraduate biology instruction.

Third, emphasis is increasing on the molecular and cellular levels of organization at the relative expense of courses in morphology and systematics. The data in this report suggest that perhaps half the time in a core sequence is being spent on material at these levels.

Fourth, as an organizing principle for biology instruction, the phylogenetic approach has been largely replaced by heredity, the cell, development, mechanisms of integration, and evolutionary dynamics. In the process, there is less emphasis on the variety of organisms and more emphasis on general phenomena illustrated by the most appropriate organism.

Fifth, there is a noticeable tendency toward greater emphasis on the biology of populations as a distinctive level of analysis. Though not nearly so impressive quantitatively as the shift toward molecular and cell biology, the phenomenon has considerable implication for the future.

Sixth, while a common pattern has been demonstrated, it is clear from this study that different institutions seek their own solutions to fit their particular situations. This indicates that there is no shortcut to curriculum revision, nor is there a single ideal curriculum. It is doubtful that any one of these four schools could or would adopt *in toto* the curriculum of any of the others. Given this fact, and considering the obvious state of flux in present curriculum planning, departmental mechanisms to provide continuing examination and modification of curricula are essential in all forward-looking institutions.

Seventh, although it is not obvious in the objective data of this study, interview data suggest caution against "over-shoot" in curriculum modification. Some tendency exists to include new knowledge because it is new and to exclude old knowledge because it is old. The primary task of a curriculum is to present essential knowledge as a sound foundation for advancement. *The basic criterion for inclusion or exclusion is not recency but significance.*

6

CONCLUSIONS

The sample studied shows that current curriculum revision at the four institutions is characterized by the following:

1. A set of courses offered in fixed sequence and extending over approximately two years is needed to communicate information commonly required in all biological specialties. This is designated the "core curriculum."

2. The titles and content of these courses vary widely and depart considerably from traditional biology courses.

3. Although no preferred course pattern is apparent, it is clear that a primary factor in restructuring curricula has been the de-emphasis of phylogenetic considerations.

4. There is surprising agreement concerning major concepts and categories of information and the relative amount of time needed for each.

5. There is a general departure from earlier curricula in placing greater emphasis on molecular, cellular, and population biology at the expense of organismal biology. However, the developmental and physiological aspects of organismal biology continue to be strongly represented.

6. The relatively greater emphasis on molecular, cellular, and population biology necessitates increased collateral preparation in mathematics, physics, and chemistry.

7. Within general categories of information there is much variation in specifics, but there is less variation in cellular and molecular biology than in other areas.

7

RECOMMENDATIONS

The Panel and the Commission approach the problem of recommendations with some misgivings. The resistance of college and university teachers to external dictation of course content is well known and, for the most part, justified. Further, the present mood is experimental and hardly warrants pressure toward a conformity which may or may not be eventually desirable. Nonetheless, we cannot resist setting down views we hold at the conclusion of this study for whatever merit and interest they may have.

First and foremost, we recommend early examination of curricula which have not recently been analyzed. The four institutions in our sample have been bellwethers, but the process of curricular evaluation is spreading widely and changes are occurring rapidly. An institution which does not engage in self-analysis is neither fulfilling its scholarly responsibility nor keeping faith with its students.

Second, we recommend that the technique of in-depth analysis be used wherever possible in curriculum examination and redesign. What is important is not the package, but its contents. Because an institution does or does not have a given course does not mean it is or is not communicating a particular concept or body of fact. The essential question is whether the student, at the end of his set of courses, is well educated.

Third, we recommend that curriculum analysis and redesign proceed on the assumption that effective teaching requires the expression of the individuality of the teacher and his department. Careful curricular design *encourages* teacher individuality while insuring that students are well prepared for further professional advancement.

Fourth, we recommend that careful attention be given to relating biology courses to the background of the student in mathematics, physics, and chemistry. In this connection, we recommend that training in biology beyond the introductory course not begin until the student is grounded in mathematics, at least through the level now generally taught as calculus, and has had at least one year of college chemistry. We further believe that students concentrating in biology should have the equivalent of at least one year of physics and some background in physical and organic chemistry.

Fifth, we recommend that the common or core preparation for biologists in any speciality be extended over a minimum of two years. We believe it desirable that this common set of courses be taken in a fixed sequence, so as to allow instructors in successive courses to build logically on what precedes.

Sixth, we recommend that the content of the curriculum be carefully balanced so as to cover what are now recognized to be fundamental biological concepts. These include, at all levels of biological complexity: structure-function relationships; growth and development; the nature of hereditary transmission; the molecular basis of energetics; synthesis and metabolic control; the relationship of organisms to one another and to their environment; and the behavior of populations in space and time, especially in reference to evolution. The relative emphasis placed upon these areas will undoubtedly vary from institution to institution; some may even decide to omit certain of them. Our purpose is to urge that students be made sufficiently aware of the full scope of biology so that they may appreciate the potentials, as well as the limits, of the training they are receiving.

1

APPENDIX

Master Item List

The following vocabulary terms are the information items derived from the core programs of the four institutions used in the study. Each item is classified under categories, topics, and subtopics; these classifications are used for convenience and do not necessarily represent the present day structure of biology. Letter designations to the left of each information item indicate the school at which the item was taught: P = Purdue University, S = Stanford University, N = North Carolina State University, and D = Dartmouth College. Items in boldface type appear in the core programs of at least three of the institutions.

ECOLOGY

ECOLOGICAL ENERGY TRANSFER

Trophic Levels

PSD **Trophic level identification and preparation of a food web for woodland invertebrates**
PSD **Food chains and webs**
PD Predator chains
PD Parasitic and saprophytic chains
PN Producers of the woodland community—angiosperms, algae, bryophytes and ferns
PN Consumers, primary, of the woodland community—herbivores
PN Consumers, secondary, of the woodland community—predators
P Decomposers of the woodland community
N Heterotrophism, i.e. *Paramecium*
ND Autotrophism—concept of
ND Photoautotrophism—concept of

Energy Flow

P Energy flow diagrams—Silver Springs, Fla.
PSD **Biomass pyramids**
PSD **Energy utilization and exchange by producers and consumers**
SD Productivity in various regions of the biosphere
SD Biomass—qualitative and quantitative measurement
SD Biomass relation to organism number
S Energy flow—ecological efficiencies
S Energy pyramids
S Net productivity—concept of
S Productivity rates
S Ecological classification of fresh-water organisms

Biogeochemical Cycles

PSND **Carbon cycle**
PSND **Nitrogen cycle**
PS Phosphorus cycle
N Ammonification by bacteria and fungi
N Nitrogen fixation by bacteria
N Denitrification by bacteria
N Microorganisms as geochemical agents—history

SN	Sulfur cycle
N	Oxygen cycle
S	Iron cycle

POPULATION ECOLOGY

Intra-Specific Interaction

PD	Population density and frequency of species in a community—the circle plot method
P	Population sampling (benthic) in a pond ecosystem using a scoop net
PSD	**Population—definition and characteristics of**
PSD	**Population interaction—density and dispersion of individuals in a population determine degree of interaction**
PSND	**Dispersion—types of ordered patterns**
PS	Population size estimation—methods
SN	Symbiosis, e.g., protozoan, fungal and bacterial
S	Spatial distribution of populations—factors affecting
S	Population distribution—mapping of
S	Population distribution—physiological and automated telemetry
S	Population structure—Allee's principle
S	Population size—emigration and immigration effects
SD	Migration effects on population structure
S	Density-independent factors in population control
S	Density-dependent factors in population control
PS	Population unit—the individual
PS	Ecological range of an organism
S	Dispersal—barriers affecting
S	Population structure—factors governing gamete union
S	Human population size and the Malthus theory

Inter-Specific Interaction

PD	Populations—possible interactions between (Haskell and Burkholder)
PSD	**Population density—*Tribolium* experiments**
PSND	**Competition among populations—Gause's principle**
P	Competition—population density effects
PSD	**Competition, interspecies, between *Paramecium caudatum* and *P. aurelia*—the Gause experiment**
PN	Syntrophism—concept in the culturing of microorganisms
P	Parasitism—life cycle of the guinea worm

PS Parasitism—life cycle of the human liver fluke
PS Parasitism—life cycle of the dog tapeworm
P Parasitism—life cycle of the beef tapeworm
PS Mutualism—termite gut protozoans, using crushed termites
PN Parasitism—life cycle of *Ascaris*
PS Parasitism—adaptations for
S Mutualism—green algae in *Paramecium bursaria*
S Protozoa and human activity
SD Ecological niche, concept of
SN Mycorrhizae—concept of
N Mutualism—concept of
N Parasitism—concept of
N Helotism in lichen fungus-alga relationship
N Commensalism in lichen fungus-alga relationship
N Symbiosis in lichen fungus-alga relationship
N Saprophytism—concept of
N Parasitism—life cycle of pork tapeworm
N Parasitism—sheep liver fluke life cycle
SN Ecological equivalents—definition
N Parasitism—life cycle of the trichina worm
N Ruminant symbiosis
S Competition, effect on growth rate of a population
S Competition, effect on habitat distribution—interspecific and intraspecific
S Competition—the Lotka-Volterra equations
S Competition in flour beetles
S Interactions between two species—types of
N Coral formation
S Ecological studies—autecology and synecology

Ecological Succession

PSD Succession, ecological—definition
PD Pioneer community in ecological succession
PSD Seral stages of ecological succession
PSD Climax community in ecological succession
PSD Succession in Lake Michigan dunes
PSD Succession, ecological—primary and secondary
P Succession, ecological—patterns of
PSD Succession, ecological, of organisms in pond water—a lab model
PD Ecological succession—graphic representation of a lab model
S Ecological distribution—factors affecting
S Succession, longitudinal, in streams
S Evolution of water snakes along western Lake Erie

BIOGEOGRAPHY

Biomes and Biogeographical Regions

P Biomes, Holdridge System—the relationship of climate to life forms
PS Man and the biosphere
SD Biosphere—concept of
P Biomes, Holdridge's Hexagon Chart—bioclimatic formations as determined by mean annual biotemperature and precipitation
P Biomes—Holdridge's Altitudinal Chart—regions and altitudinal belts, determined by altitude and mean annual biotemperature
PSN Biome—definition of
P Comparison of Holdridge's life forms with Odum's biomes of North America
P Forest types of the eastern U.S.—application of the Holdridge system to finely subdivided areas
SN Biosphere—physical extent on earth
S Biomes—types and characteristics of
S Terrestrial zoogeographical regions
S Terrestrial biogeographical regions

Community Structure

P Community structure—the influence of temperature and precipitation
S Community structure and composition
PD Communities, grassland
PD Communities, desert

ECOSYSTEM

Aquatic Ecosystems

P Oxygen stratification in a pond ecosystem
P Temperature measurement of water in a lotic ecosystem
P Carbon dioxide in a lotic ecosystem using NaOH titration method
P Phosphate in a lotic ecosystem—amino-napthol, sulfonic acid method
P Current velocity measurements in a stream using a floating object
P pH measurement in a lotic ecosystem, using pH paper
PS Oxygen in a stream using the Winkler method
P Oxygen in a pond ecosystem—analysis using the Winkler method
P pH of a pond ecosystem—analysis by use of a pH meter

P Hardness in a pond ecosystem—analysis using the soap method
P Ortho-phosphate concentration in a pond ecosystem—colorimetric method
P Temperature measur[illegible]ent of air and water in a pond ecosystem
P Light penetration [illegible] ecosystem—the Secchi disc
PS Oxygen analysis [illegible]—techniques of the Winkler method
PN Lake, thermal prop[illegible]es of
PSN Marine ecology
P Lakes—origin of
PS Communities, fresh water
PN Lakes and streams—their parameters and divisions
P Biological oxygen demand (B.O.D.) in a pond or lake
SD Water as a temperature stabilizer in the environment
S Oxygen content of water—effect of temperature on
S Oxygen content of water—effect of salt concentration
S Biokinetic zone—10 to 45 degrees C
S Organism adaptation in lotic habitats
S Classification of lakes
S Lotic habitats—types and characteristics
S Lentic habitats—types and characteristics
S Aquatic communities—structure and characteristics of

Terrestrial Ecosystems

P Animals of the forest floor—Macrofauna, Mesofauna and Microfauna
P Basal area calculation in a woodland community—methods
SD Man as an ecological dominant
SN Ecosystem—concept of
S Ecosystem—communication as an integrating mechanism
SND Adaptive radiation
SND Terrestrial ecosystems—structure and characteristics of

EVOLUTION

PHYLOGENY

P Eubacteria—evolutionary relationship to higher organisms
P Thyroid cell origin—phylogenetically and ontogenetically

P Phylogeny—trends and orientation—Cope's law
P Phylogeny—trends and orientation—Williston's law
P Phylogeny—trends and orientation—Dollo's law
PN Phylogeny of plant kingdom
P Evolutionary morphological trends in seed plants
PN Phylogenetic relations of bilateral animal phyla
P Pharyngeal development as clue to evolution of the vertebrate
PND Kidney evolution—comparative anatomy
P Divergence index—expression of evolutionary data (after W. H. Wagner)
P Divergence index—graphic representation using a concentric graph (after W. H. Wagner)
SND Coelenterates—tissue vs. cellular level of organization
SN Organ level of organization in Platyhelminthes
SN *Peripatus*—structure and evolutionary significance
SN Circulatory system evolution
S Endocrine system evolution
S Coelom—significance of
PS Vertebrates—origin of
PS Vertebrate jaw—origin of
PS Metazoans—origin of
SD Trematoda—evolution of
SD Nematoda—evolutionary relationships
N Tracheophyte evolution
N Telome theory of leaf origin (Zimmerman)
N Mammalian reproduction—evolutionary aspects
N Protozoans—origin of
N Larval forms—significance in phylogenetic studies
ND Porifera—evolutionary origin of
SND Annelida metamerism—evolutionary significance
N Trilobite—arthropod evolutionary significance
N Chiton—evolutionary significance
ND Echinoderm evolution and significance
N Teeth evolution in mammals
N Egg structure—evolutionary significance
N Birds—origin of
N Bird evolution—adaptive advances over lower animals
N Cartilaginous fishes—evolution of
N Reproductive system evolution
N Excretory system evolution
S Microphyll leaves—origin of
S Pollination system evolution
N Reptile evolution
N Respiratory system evolution

N	Placoderms—evolutionary significance
N	Bony fish evolution
N	Ostracoderm structure—evolutionary significance
N	Acoel evolution—significance of
N	Arthropod evolution—significance of
N	Gymnosperm evolution
ND	Flower evolution
N	Angiosperm evolution
ND	Procaryota—evolutionary significance of
SN	Polyploidy—evolutionary significance of
ND	Amphidiploidy—origin of
SD	Multicellularity—the origin of
PD	Multicellularity—problems of
S	The tetrasporine pattern of multicellular organization
D	Colonial organisms—level of cellular organization
D	Psilophytales—evolutionary significance of
D	Molluscs—evolutionary origin of
D	Sexual reproduction—origin of
D	Flower modifications—types and function

SPECIATION

P	Species—potential modes of origin
P	Species transformation
P	Species—fusion of two
P	Species multiplication—sympatric and delopatric
PS	Clinal variations in animals
PS	Reproductive barriers and speciation
PS	Allopatric species
PS	Sympatric species
P	Extinction, species—mechanisms of
SN	Vertebrate transition to terrestrial life
S	Patterns of population differentiation—Darwin's finches
PS	Adaptive differences between birds and mammals
S	Primates—adaptation
S	Size of mammals—metabolic relations
S	Life forms—tendency toward greater size and complexity
SN	DDT resistance in mosquitoes
PD	Race differentiation—origins of species
PSND	**Reproductive barriers in speciation—types of**

SN	Species concept (old) as taxonomic unit
PD	Hybridization—origin of species
PSN	**Species concept (new) as population unit**
S	Clinal variations in plants
S	Ecotypic variation in plants
D	Race—definition of
S	Population interaction—pollination systems
D	Speciation—need for geographic or genetic isolation

ADAPTATION

PS	Mimicry, Batesian
PS	Mimicry, Mullerian
PSN	**Coloration, adaptive**
P	Size—disadvantages of large size
PN	Size—the upper limit of organisms
PN	Size—the lower limit of organisms
P	Size limitation of terrestrial insects
S	Adaptation in bacteria
S	Adaptive types—analysis of

PATTERNS OF EVOLUTION

PD	Evolution—definition of
PND	**Geological time scale**
PSND	**Fossil record—deficiencies of**
P	Paleontology and its relation to evolution
PS	Vertebrate evolution—general pattern (Romer)
P	Darwinism—problems with
PND	**Evolution concept—the development of**
PD	Macroevolution—some viewpoints (Goldschmidt)
SND	**Evolution as a diversifying process**
SD	Serial homology—concept of
SND	**Life origin—hypotheses**
PSND	**The Darwinian thesis of evolution**
PD	Mutation and evolution
N	Fungi evolution—theories of
ND	Fossil record—use in phylogenetic studies

PSD	**Genetic material—biochemical evolution of**
N	Evolution, parallel—concept of
N	Bryophyta evolution from pre-*Psilotum* ancestor
N	Atavistic evolution—concept of
N	Convergent evolution—concept of
SN	Reticulate evolution—concept of
N	Algae evolution—theories of
ND	Fossils, classification methods
SND	**Fossil types**
ND	Origin of life—spontaneous generation concept
N	Mechanistic evolution concept
N	Vitalism concept
N	Bacteria and the fossil record
PND	**Lamarckian thesis of evolution**
N	Evolution—evidence for
S	Tachytely—the Wright model
S	Bradytely—causes of
S	Horotelic rates of evolution
S	Horotelic rates—pelecypod and mammal curves
S	Sequential or phyletic evolution
S	Fossils—methods of formation
ND	Moss adaptation to terrestrial habitat
S	Structural evolution—organelle formation
S	Genetic mechanisms—evolutionary origin
D	Spontaneous generation—Pasteur's experiments
D	Origin of life—improbability of occurrence now
D	Origin of life—Oparin's hypothesis
D	Origin of life—structure of the primitive earth
D	Origin of life—energy source for synthesis of organic compounds
D	Origin of life—organic compound synthesis (Miller's experiments)
D	Life origin—organic substance synthesis (Groth's experiments)
D	Origin of life—coacervate hypothesis of cell formation (Oparin)
D	Origin of life—evolution of autotrophic organisms
D	Life on other planets or solar systems
D	Inorganic evolution—concept of
D	Organic evolution—concept of
D	Catastrophism—a theory of evolution
D	Genetic drift—role in evolution
D	Land plants—migration to terrestrial mode of life
D	Pre-Cambrian fossil records
D	Catastrophism and special creation
D	Plant adaptation to a terrestrial habitat
S	Preadaptation—role in evolution
D	Mollusc adaptation to sedentary life

EVOLUTION OF A PARTICULAR SPECIES

P Horse evolution (after Simpson)
P Genera—relation in evolutionary trends of the horse
PN Skulls, horse—an evolutionary series of
PN Forefoot evolution analysis in the horse
P Brain size and limb development—comparison in the evolution of the horse
P Horse evolution—evolutionary patterns

EVOLUTION OF MAN

PSND Human evolution
PS Human cultural evolution
PND Race differentiation in man—aspects of
N Fossil record—evolution of man

PHYSIOLOGY, GENERAL

TRANSPORT SYSTEMS

Problems of Transport

PN Exchange problems in multicellular organisms—e. g., digestion products, oxygen and waste materials
PN Gas exchange problems in multicellular organisms
P Multicellularity and exchange problems—surface area restrictions on diffusion
P Transport from absorptive surface
N Exchange problems in unicellular organisms, i. e., *Paramecium*
D Vertebrate activity—gaseous exchange mechanisms
D Vertebrate activity—efficiency of transport, utilization and excretion

Circulatory Systems

PD Fetal circulation pathway in mammals, e.g., the fetal pig
PN Heartbeat, frog—preparation by pithing and dissection

P Arterial system (anterior) modification in the salamander, pigeon and alligator compared to the fetal pig
PSD Heart structure of the mammal—e.g., beef heart
PN Heart structure in the dogfish shark (*Squalus*)
ND Capillary blood flow in the frog foot web
PS Heartbeat—adrenalin effect on the heartbeat of a frog
PN Heartbeat—temperature effects on the heartbeat of a frog
PS Heartbeat—systole and diastole in the turtle
P Heartbeat—the effect of temperature on the heartbeat of the extracted frog heart
PN Heart structure—major blood vessels leading to and from the heart in the frog
PD Blood vessels—histology of arteries, arterioles, capillaries and veins
PSD Circulatory system fundamentals—arteries, capillaries, venules, veins and lymphatic system
PSD Circulatory system—functions in the vertebrate
P Arterial system—structure of pharyngeal arteries in *Squalus*
P Circulatory system—the portal system (renal and hepatic)
P Arteries connected to the mammalian heart
P Veins connected to the mammalian heart
P Venous system—structure of the cardinal veins and hepatic veins entering the sinus venosus
P Arteries—efferent branchial arteries in *Squalus*
PS Heartbeat—measurement in the dissected frog
P Venous system (postcaval) in the fetal pig
P Venous system (precaval) in the fetal pig
P Arterial system (anterior) in the fetal pig
P Arterial system (posterior) in the fetal pig
N Blood platelets—structure and function in blood clotting
ND Circulatory system structure in mammals—general
N Bony fish circulatory system structure
SN Crayfish—circulatory system
SND Earthworm—circulatory system
SND Blood composition in mammals, e.g., man
SND Blood clotting mechanisms in mammals, e.g., man
SND Capillary exchange
SN Blood circulation—hydrodynamics of
N Clam circulatory system structure
SN Hemoglobin in mammalian red blood cells—molecular structure
SD Muscle contraction recording on a kymograph
S Threshold stimulus value in muscle contraction, e.g., gastrocnemius of frog
S Tetanus induction in the gastrocnemius muscle of frog
S Fatigue and recovery in muscle contraction

SD Heartbeat—the heart pacemaker, using the frog heart
SD Heartbeat—the refractory period of heart muscle using an induction coil
SND Heartbeat—all-or-none response of cardiac muscle
S Respiratory problems of diving mammals
SN Respiratory pigments—the Bohr effect
SN Oxygen dissociation curves for respiratory pigments
S Pigments, respiratory—types
S Pigments, respiratory—hemocyanin found in crustaceans and molluscs
ND Frog circulatory system structure
N *Amphioxus*—circulatory system structure
N Vascular constriction—ionic concentration effect on
N Chemoreceptors—role in circulatory regulation
N Pressoreceptors—structure and function in circulatory control
N Heart rate—autonomic and intrinsic control of
N Cardiac valves—function and possible defects of
N Cardiac cycle—events of systole and diastole
N Heart sounds—systole and diastole relationships
N Heart output—concept of stroke volume
N Vascular dilation and constriction—control by autonomic centers
N Leucocytes—general characteristics and functional properties
N Plasma—concept of colloid osmotic pressure
ND Blood—buffering capacities of
N Blood—pH and ionic composition of
N Coagulation of blood—influencing factors and mechanism of
ND Blood groups—properties of O, A, B, and AB groups
N Red blood cells—production of
N Cardiac contraction—impulse transmission of syncytium and Purkinje system
D White blood cells—types of
D Block of conduction system in heart—1st and 2nd stannius ligatures
D Hemoglobin—oxygen and carbon dioxide relations
D Blood circulation pattern in primitive tetrapods
D Blood flow through the mammalian heart
D Blood circulation pattern in primitive fishes
D Mechanical and thermal injury effects on capillary circulation in the frog web
N Circulation—mechanisms of venous and lymphatic return
D Capillary circulation in frog tongue, effect of chemical injury

Xylem Transport

PS Organ function in plant water movement

PN	Xylem of stem and root—a component of the plant transport system
ND	Root pressure
SND	**Transpiration in plants—mechanisms of**
P	Capillary action—mechanism and inadequacy as complete explanation of water movement in plants
PD	Xylem vessels—structure and function
PD	Xylem transport pathways—methods of analysis
D	Water movement in plants—path of
SD	Xylem structure—radial, tangential and transverse sections of *Pinus*
ND	Xylem—anatomy and cell types of
SN	Diffusion pressure deficit (DPD)
P	Cohesion theory of xylem transport
PN	Xylem transport, possible mechanisms
SN	Transpiration, cohesion, tension theory of water movement in plants
SN	Vascular rays—lateral transport in plants
ND	Active absorption by roots—method
ND	Water uptake by plant cells—S = (PI·PO)·T
N	Xylem structure—cellular components
S	Tyloses—plugging of secondary xylem
S	Xylem differentiation from fusiform initial
S	Xylem—factors influencing patterns of organization
SN	Guttation—mechanism and function of
SND	**Transpiration rate measurement using a potometer**
S	Transpiration—hydrophyte adaptation
SND	**Transpiration—effect of morphological and environmental factors**
SN	Stomatal movement—theories of
S	Transpiration—xerophyte adaptations
N	Casparian strip—barrier to water entrance in the root
N	Plant structural resistance to transpiration
N	Transpiration as a cooling mechanism
N	Atmospheric tension in xylem of transpiring trees
N	Stomatal control of transpiration

Phloem transport

PSND	**Phloem anatomy and cell types**
P	Phloem of stem and roots—a component of the plant transport system
PSD	**Phloem transport**
PND	**Pressure—flow hypothesis of phloem transport (Munch)**
PND	**Phloem transport pathways—methods of analysis**

S Phloem, primary—function of
SN Mass flow transport—concept and evidence for

Ingestion, Digestion, and Assimilation

N Bile—control of secretory rate and release from the gall bladder
N Bile salts—functions of
N Bile—composition of
N Gastric secretions
N Carbohydrate digestion as a hydrolytic reaction
SN Digestion, cellular—observation of
N Exoenzymes—external digestion by
N Digestion (vertebrate)—pattern
PSN Malt diastase and starch digestion
P Pancreatin and lipid digestion, using litmus milk
P Invertase (sucrase) and sucrose digestion, using yeast cells
PSND Amylase and starch digestion, using the iodine test
SND Hydrolytic enzymes—distribution and function
N Digestion—ptyalin effect on starch
S Protein digestion using pepsin, trypsin and papain
S Digestion—intracellular and extracellular enzymes
S Ingestion of yeast and food vacuole formation in *Paramecium*

INTEGRATION

Homeostatic Mechanisms

PSN Constancy of internal environment—examples of
PS Feed-back mechanisms
SD Temperature regulation—significance and complexity of
SD Resistance of cells to pH changes
N Homoiothermy in mammals
D Poikilothermy in mammals
N Temperature regulation—role of thermostatic center of the hypothalamus
N Temperature regulation—mechanisms of increased heat loss and heat conservation
N Temperature regulation—poikilothermy vs. homoiothermy
N Rate of metabolism—conditions influencing

Endocrine Mechanisms

PND Hormonal control of estrous cycle
PND Hormone control in pregnancy

PD	Thyroxin effect on cell metabolism—stimulation of new mRNA, sRNA, and ribosomal RNA
P	Thiouracil effect on oxygen uptake in the rat using a Phipps-Bird respirometer
P	Iodine uptake by the thyroid gland in 2-thiouracil fed, iodine deficient, and control rats
N	Hormone influence on sex organ formation in fungi
D	Neural and hormonal differences—stimulatory or inhibitory action
PD	Thyroid cell regulation by TSH from the pituitary gland
PND	**Thyroxin synthesis in the thyroid cell**
PN	Hormonal control of milk production in mammary glands
PN	Thyroxin and TSH production—a negative feedback system
P	Thyroxin effect on metabolism and oxygen uptake in the rat
P	Thyroxin formation—biosynthetic pathway
P	Thyroxin formation—the effect of thiouracil on production
P	Thyroxin production—the effect of 2-thiouracil
P	Thyroid tissue—histological study of 2-thiouracil fed, iodine deficient, and control rats
PS	Thyroid gland—gross structure of
PND	**Thyroid gland—histology of**
PD	Hormone control of Na/K ion concentration in the kidney
P	Isotope incorporation into thyroid tissue—use of a well-scintillation detector for measurement
S	Hormone specificity
SD	Hormones (animal) types and action
D	Parathyroid gland and physiological effect of parathormone
SND	**Hormones—chemical integration (general)**
ND	Adrenocortical secretions—stimulation and function of
ND	Pituitrin effect in water uptake in the frog
N	Adrenal medullary hormones—function of
ND	Parathyroid secretion—regulation of
ND	Hormones—Starling's experiments
ND	Pituitary gland—physiology of
ND	Insulin—origin and physiological effect
N	Human gonads—hormones secreted by
N	Pineal gland—hypothesized functions of
N	Thymus gland—function of
N	Hypophyseal secretions—control of
N	Adenohypophysis and neurohypophysis—hormones and functions of
N	Adrenal glands—anatomy and physiology of
N	Endocrine glands—secretory malfunctions of
N	Pancreatic hormones—effects of
N	Islets of Langerhans—histology and function of

N	Parathyroid activity—the role of vitamin D
N	Parathyroid gland—function of
N	Thyrocalcitonin—effects of
N	Hormonal control of digestion
N	Endocrine glands—control of
N	Thyroxin—functions in the tissues
N	Estrogen and androgen metabolism—role of the liver
D	Insulin—effects of hypo- and hypersecretion
D	Insulin—regulation of carbohydrate metabolism
D	Parathormone—regulation of calcium and phosphorus levels
D	Thyroid function—human diseases resulting from thyroid malfunction
D	Adrenal medulla secretions—effect on sympathetic nervous system
D	Insulin level in blood—regulation by blood glucose level
D	Endocrine glands—methods of investigation
D	Hormones of the pituitary gland—anterior and posterior
D	Hormones produced by testes—physiological effects
D	Hormones produced by the ovaries—physiological effects
D	Hormones of the adrenal glands—physiological effects

Neural Mechanisms

PSD	**Decerebrated frog—method of preparation**
SD	Conduction characteristics of the neuron
PD	Nervous coordination
PS	Purposive reflexes in the spinal frog using acetic acid
P	Strychnine effects in the spinal frog
P	Stimulus level in the normal, decerebrated, and spinal frog skin
P	Behavior reflexes in the spinal frog
P	Reflexes (unilateral and bilateral) in the normal, decerebrated, and spinal frog
P	Behavior reflexes in the normal frog
P	Behavior reflexes in the decerebrated frog
P	Neurosecretion—integration in animals
SD	Nerve impulse recording with a cathode ray oscilloscope
PS	Threshold values in nerve fibers—size relationships
SND	**Nerve excitation—refractory period**
S	Nerve stimulation—concept of receptive field
S	Threshold area—two-point in nerve stimulation
S	Vision—the blind spot (optic nerve area)
SND	**Reflex, simple—description of mechanism**
SND	**Potential—resting and action potentials in nerves**
SN	Reflex suppression of antagonistic muscles

SN Neurosecretion at synaptic junctions and motor end plates
S Neurosecretion by the posterior pituitary gland
PSND Nerve impulse—strength-duration relationships
PSND Nerve impulse—synaptic transmission of action potentials
PSD Nerve impulse—saltatory conduction
SD Core conductor theory of nerve impulse
PSD Nerve impulse—rate of conduction
S Crossed stepping reflex
S Acetylcholine effect on contraction of visceral muscle of frog
SN Acetylcholine breakdown by cholinesterase
SN Digestive tract—humoral and neural control
N Nervous and endocrine system affinities
S Neuron membrane changes during impulse transmission
N Nerve impulse—synaptic transmission of action potentials
S Conduction velocity in the sciatic nerve of the bullfrog
S Action potential of the sciatic nerve in the bullfrog
SN Spindle sensitivity in CNS control via gamma loop
SN Peripheral inhibition
N Adaptation and accommodation—concept in nerve response
N Nerve impulse—the all-or-none law
N Human brain—subdivisions and characteristics of
N Central nervous system—general structure and characteristics
ND Autonomic nervous system—structure and characteristics of
ND Autonomic innervation—effects on various structures
N Muscle spindle—structure and innervation of
N Reflex activity—role of the synapse in
D Nerve pathways—divergent and convergent
D Operation of stimulators
N Deafness—types of
D Reflexes—divergent and convergent
D Vagus inhibition of turtle heart
D Stimulus artifact
D Integration of body activities by the cerebral hemispheres

Receptors

N Vertebrate activity—efficiency of sensory mechanisms
N Rhodopsin of the cone—role in color vision
P Spinal nerves in *Squalus*—structure and position
P Cranial nerves in *Squalus*—structure and position
PN Brain structure in *Squalus*
P Lateral line canal structure in *Squalus*
N Crayfish nervous system
N Lamprey nervous system

N Nervous system in bony fish—structure and characteristics
N Frog sense organs—structure and function
N Grasshopper—nervous system and sense organs
ND Earthworm—nervous system structure
PND Nervous system structure in the mammal (general)
D Clam—nervous system structure
SND Neuron metabolism
SND Vision—the rhodopsin cycle
SN Neuron synaptic junctions—structure and function
S *Amphioxus* nervous system structure
N Nervous tissue—characteristics of
N Stimuli (electrical)—types used in nerve impulse initiation
D Afferent and efferent nerve conduction—function of
N Nerve impulse initiation—subminimal and threshold stimuli
N Synaptic connections—possible arrangements and effects
N Vestibular apparatus—structure and function of
D Starfish nervous system
D Peripheral nervous system—components of
D Cranial nerves of man—afferent origin and efferent distribution
D Spinal nerve structure
D Spinal nerves—dorsal, ventral, and communicating rami
D Cranial nerves of man
D Retinal rod ultrastructure
D Structure of visual cones

Effectors

N Muscle tissue—characteristics of
PSND Sliding filament theory of muscle contraction
PSD L-meromyosin folding—Szent-Gyorgyi theory of muscle contraction
PSN Muscle components—hierarchy of
SN Muscle contraction—the concept of tetanus in
SN Muscle contraction—concept of the motor unit
SN Muscle innervation and contraction—the all-or-none effect
S Muscle contraction in the frog—measurement with a kymograph
SN Muscle contraction—latent, contraction, and relaxation periods
SN Muscle contraction—threshold stimulus
SN Muscle contraction—temporal summation
N Crayfish muscle structure and function
N *Squalus* muscle structure
SD ATP effect on excised muscle contraction in the frog
SD Muscle contraction—work and heat relations
SND Contraction of skeletal muscle

SND **Starling's law of cardiac cell contraction**
SND **Contraction of cardiac muscle cells—the pacemaker**
SND **Contraction of visceral muscle cells**
SD Muscle fibers—action potentials in
SD Myosin—function in muscle contraction
SD Tropomyosin and paramyosin function in muscle contraction
SD Actin function in muscle contraction
SND **Contraction—ATP as the energy source**
S Myogenic contraction of visceral muscles of the frog
SN Source of afferents in spindles
N Glycogenolysis and glycolysis—role in muscle contraction
N Acetylcholine—mediator of neuromuscular transmission
S Formation of actinomysin in the absence of ATP
S Extraction procedures in preparation of actinomysin
S Chemical composition of thick and thin myofilaments in striated muscle—myosin and actin
SN Muscle contraction—sarcomere appearance during contraction and relaxation
SD Muscle contraction—excitation
S Muscle contraction—preparation of the gastrocnemius muscle of frog
N Neuromuscular junction—structure and characteristics of
N Muscle tonus—modification by higher brain centers
N Myostatic (stretch) reflex—concept of

Behavior

P Coordination—problems of
PS Irritability in unicellular organisms
P Irritability in multicellular animals
P Irritability of cells—a fundamental property of life
P Irritability in multicellular plants
P Irritability—the response of *Paramecium* to dilute Sanford's ink
P Irritability—the response of *Paramecium* to dilute acetic acid
P Irritability—the response of *Paramecium* to temperature
P Irritability contact responses of *Paramecium*—positive and negative
P Movements in plants—types
P Peck-order in chickens
P Territoriality in birds
PSN **Phototropism (Lionel Jaffre)**
PND **Tropisms—types of**
S Irritability—*Planaria* responses to external stimuli
S Irritability—earthworm response to external stimuli
S Irritability—*Artemia* responses to external stimuli

SN	Learning and memory
S	Learning—brain stimulation studies
S	Learning—EEG correlations with conditioning
S	Learning in isolated ganglia of invertebrates
SN	Learning—neurophysiological problems
SN	Behavior as a complex stimulus-response reaction
S	Innate behavior as a reflection of neural architecture
SN	Feeding response in *Hydra*—stimulation by glutathione
SND	**Diurnal rhythms**
S	Irritability in *Hydra*
N	Feeding mechanism of the leech
N	Innate behavior—definition of
N	Adaptive behavior—principles in evolution
N	Innate behavior—types of
N	Learning—psychological aspects
N	Spider web structure and formation
S	Trichocysts discharge in *Paramecium*
S	Chemotropism—guided pollen tube growth
S	*Stipa*—movement of needle grass
S	Social hierarchy—types of
N	Honeybee social hierarchy—the hive
N	Feeding and honey production of the bee
N	Honeybee communication—the dance
D	Statoliths—perception of geotropic stimulus in plant roots
D	Reflexes—conditioned (Pavlov)
D	Vertebrate activity—efficiency of food source utilization
N	Endogenous rhythms—independency of temperature
N	Endogenous rhythms—relation to photoperiodism
N	Endogenous rhythms in plants

EXCRETION

Urogenital System Structure

P	Urogenital system of *Squalus* (male)—structure
P	Urogenital system of *Squalus* (female)—structure
P	Urogenital system of the female pig—structure
P	Urogenital system of the male pig—structure
SND	**Earthworm excretory system**
D	Vertebrate excretory system—structure

Kidney Structure and Function

P	Blood circulation in kidney—schematic flow
P	Kidney of pig—structure of
P	Kidney types in vertebrates
PND	**Kidney structure, general**
PN	Kidney function—an example of a control system
SD	Kidney function—osmotic relationships
D	Kidney types—holonephros, pronephros, and metanephros
PN	Counter-current flow in mammalian kidney

Nephron Structure and Function

PSN	**Excretion of nitrogenous wastes among vertebrates**
S	Malpighian tubule absorption of neutral red dye in insects
N	Plasma clearance—mechanism
PN	Mechanism of reabsorption in tubules
PSN	**Filtration—mechanism of**
PND	**Filtration and selective reabsorption**
PS	Nephron—functional unit of the kidney
P	Glomerulus ultra-structure
PND	**Nephron structure in mammals**
N	Flame cell structure and function in *Planaria*
N	Earthworm—nephridium structure and function
N	Nephridia structure—*Amphioxus*
D	Isolation of fish kidney tubules
D	Accumulation of chlorophenol red by kidney tubules—oxygen dependence
D	Accumulation of chlorophenol red by kidney tubules—temperature dependence
D	Accumulation of chlorophenol red by kidney tubules—ATP dependence
D	Accumulation of chlorophenol red by kidney tubules—competitive inhibition of

Water Balance

P	Salt regulation in marine invertebrates
P	Salt regulation in brackish water marine invertebrates—e.g., *Hemigrapus*
PS	Salt regulation in marine bony fish
PS	Salt regulation in fresh water bony fish and amphibians
PSD	**Salt regulation in terrestrial vertebrates**
P	Salt regulation in cartilaginous fish
S	Water balance in *Phascolosma*—passive regulation

S	Osmotic regulation in *Paramecium*
PN	Filtration rate and volume in mammalian kidney
SN	Osmotic relationships in euryhaline animals
SN	Osmotic relationships in stenohaline animals
S	Water regulation in *Artemia*
PS	Reabsorption problems in mammalian kidney
P	Filtration rate—control of
P	Hormone control of Na/K ion concentration in the kidney
P	Control of water in the body

PHYSIOLOGY OF DISEASE

Constitutive Host Resistance

N	Host resistance to parasitic microorganisms—mechanisms
N	Constitutive host resistance—surface barriers
N	Constitutive host resistance—the mammalian circulatory system
ND	Leucocytes—structure and function in host resistance
N	Phagocytic cells found in the human body
N	Reticulo-endothelial system function
N	Phagocytosis—function in host resistance
N	Inflammation—role in host resistance
N	Inflammation—role of histamine in
N	Antimicrobial substances found in cells

Microbial Pathogenicity

N	Pathogenicity—ability of a parasite to cause disease
N	Virulence—relative pathogenicity
N	Aggressins—role in microorganism invasion
N	Pathogen (plant) invasion—methods
N	Leukocidin production by bacteria—role in virulence
N	Toxins—discovery
N	Bacterial exotoxin production
N	Exotoxins—mechanisms of activity
N	Exotoxins as enzymes
N	Neurotoxins—botulinum and tetanus toxins
N	Bacterial endotoxins—chemistry of
N	Bacterial endotoxins—effects on the host
N	Lysogeny in bacteriophage infection
N	Microbe role in disease—history
N	Germ-free animals—physiological implications
N	Microbial flora of the human body

N Bacteria—relations to man
N *Plasmodium vivax*—development in red blood cells
N Microbial examination of food—techniques
N Microbial flora of raw milk

Inducible Host Resistance

N Bacterial agents—types of physicochemical damage
N Antibiotics—types and mode of
N Bacteriostatic and bactericidal chemical agents
N Antibodies—composition and role in host resistance
N Immunization—history of discovery
N Antibodies—chemical nature of
N Antibodies—effects on molecular toxins, virons, and microbial cells
ND Antibody formation—hypotheses of
N Immunological tolerance—Burnet's experiments
N Hypersensitivity—immediate and delayed
N Antigens and antibodies, chemical nature of
N Antigen-antibody reactions
N Antibody detection *in vivo*, e.g., the Schick test
N Antibody detection *in vitro*, methods
N Immune response—kinetics of transfusion reaction
D Immunization—concept of
D Immunity—natural, active, and passive
N Serological techniques
D Rh factor—an inherited antigenic factor
D Rh factor—role in erythroblastosis fetalis

LOCOMOTION

General Aspects of Locomotion

PS Locomotion—problems of
P Locomotion as a food-getting and escape mechanism
P Sessile organisms—adaptations of
N Arthropod locomotion and growth
N Earthworm locomotion
N Bird skeleton and muscle structure
N Bird adaptations for flight
N Locomotion of the dogfish shark (*Squalus*)
N Electric eel locomotion
S Myoneme movement in *Spirostomum* or *Vorticella*
D Vertebrate activity—motility efficiency

Cilia and Flagella

PSND	**Cilia and flagella—distinction between**
PND	**Flagella, bacterial—occurrence, type, structure, and chemical composition**
PSND	**Cilia and flagella structure**
P	Cilium—motion patterns
PSD	**Ciliary movement in *Stentor***
P	Ciliary movement in *Euplotes*
P	Ciliary movement of cork particles in the esophagus of the frog
P	Ciliary movement—the effect of temperature in the frog esophagus
SD	Flagellar movement in *Euglena*
SN	Ciliary movement in *Paramecium*
S	Ciliary movement in mussels or clams—temperature effects
S	Ciliary movement of mussel gill cells using carmine dye
S	Ciliary movement—salt antagonism to mussel gill cilia
N	Flagellar movement—changes in protein bonding patterns

Amoeboid Movement

PSND	**Amoeboid movement in *Chaos (Pelomyxa)***
S	Amoeboid movement of amoebocytes in sea urchin blood

CELL BIOLOGY

CYTOLOGY

Cell Theory and History

P	Cell theory—the structural aspect
P	Cell theory and organism theory—properties of a complex organism
P	Cell—a definition of
PSD	**Cell theory—the functional aspect of Schwann**
PSD	**Cell theory—the developmental aspect of Virchow**
P	Cell theory—evolutionary aspects
P	Cell theory—history of
PSN	**Cell concept—essence of**
PND	**Leeuwenhoek—first observations and descriptions in 17th century**
N	Cell theory—Hooke's experiments

Cell Structure, General

PSND	**Cell organelles—types of**
P	Cell structure using *Elodea* leaf cells
PD	Cell structure using cells of the human oral mucosa stained with Sanford's ink
PD	Cell structure using *Allium* bulb scale cells
PS	Cell structure of cork (Hooke's experiment)
PSND	**Erythrocyte (mammalian)—cell structure and composition**
P	Cell structure of mucosa cell of *Necturus* gut
PS	Cell structure comparisons of higher vs. lower protists
PN	Eucaryotic organisms—structural characteristics of
PSND	**Procaryotic organisms—structural characteristics of**
S	Columnar epithelium tissue structure using frog intestine
S	Ciliated epithelial tissue structure—using lining of frog mouth
SN	Nematocysts of *Hydra*
SN	*Hydra* structure—cell types
SD	Cell—heterogenous system
S	Cell structure using internodal cell of *Nitella*
S	Cell structure using *Valonia* cells
SD	Cell types—plant
SD	Protein localization in the cell, methods of isolation
S	Fibrillar nature of the cytoplasm—Flemming's theory
N	Root hair structure and function
N	Plasmodesmata—cytoplasmic connections between cells
N	Statocysts of *Aurelia*
ND	Sponge structure—cell types
S	Dikaryotic phase—characteristics of
S	Meristem cell—structure of
N	Surface area-volume relationships in cells—size limitations
D	Extraction of water-soluble pigments from plant leaves

The Bacterial Cell

PN	Protoplast concept in cell structure
P	Spheroplast formation in *Escherichia coli* using penicillin
PN	Cell wall characteristics and composition in bacteria
PN	Capsule structure of *Bacillus megaterium* using direct staining (Hiss) technique
PN	Capsule structure of *Bacillus megaterium* using negative staining technique (India ink)
P	Bacteria structure—methods of study
PN	Endospores in *Bacillus megaterium*
N	Chemosynthesis in bacteria—mechanisms
PN	Bacteria structure—the droplet wet mount technique

PN Bacteria structure—staining with methylene blue
PSN Nuclear bodies in bacteria
PN Flagella of *Proteus vulgaris*, using Leifson's stain
PN Capsule formation and structure in bacteria
PSN Bacterial cell structure—common tenets
P Cytoplasmic composition of bacteria
PS Bacterial cell membrane composition and properties
PSND Bacterial cell wall—structure and chemical composition
PND Bacterial capsule—occurrence, composition, antigenicity, and pathogenicity
N Bacterial enzyme system—association with plasma membrane
P Cell wall removal in *E. coli* with lysozyme
N Digestion in bacteria—exoenzymes
N Saprophytism in bacteria
N Pathogenicity and bacteria
ND Endospores—function in reproduction and survival
N Eubacteria, stalked—structure and characteristics
N Eubacteria, filamentous—structure and characteristics
N Eubacteria, budding—structure and characteristics
N Eubacteria, mycelial (Actinomycetes)—structure and characteristics
N Pleuropneumonia group—structure and characteristics
N Bacterial L-forms—structure and characteristics
N Bacterial L-forms—penicillin induction of
N Rickettsia—structure and characteristics
N Pleomorphism concept in history of microbiology
N Cell size—eucaryota vs. procaryota
N Bacterial staining—the spore stain
N Bacterial staining—acid fast stain
N Physiological characteristics of gram + and — bacteria
N Heat resistance of gram + and — bacteria

Viruses

PSND Structure and composition of a phage (general)
PN T4 and rII mutant phage structure
P Lucerne mosaic virus—structure of
P Capsid and capsomere structures of viruses—flu, measles, etc.
P Viruses—occurrence of
PSN Tobacco mosaic virus structure
PN TMV—RNA and protein reconstitution (Fraenkel-Conrat)
SN Bacteriophage reproduction—characteristics
SND Bacteriophage replication—vegetative
N Viruses—ATP and movement of

N	Virus structure—adenovirus, type 5
N	Virus structure—techniques of evaluation
N	Viruses—history of discovery
N	Viruses—characteristics of
N	Viruses—structure and chemical composition
N	Virus reproduction—characteristics of
N	Virus (TMV) isolation by Stanley
N	Viruses—economic importance
N	Viruses—new strain formation, methods
N	Virus origin—theories of
N	Virus classification—methods
N	Viruses, animal and plant, infection—hypotheses
N	Latent viruses—e.g., aster yellows virus

The Nucleus

PSND	**Nucleus—structure and composition**
P	Follicular cell—nucleus and nucleolus
SND	**DNA constancy in nucleus within a species**
SD	Nuclear DNA content and chromosome complement

The Cell Wall, Membranes

P	Chlorophyll-containing membranes
PS	Cell membrane structure—Solomon's concept
PSND	**Plasma membrane—Robertson's unit structure**
P	Follicular cell—cell membrane
PND	**Cell wall (secondary)—tracheids**
PSND	**Cell wall (primary)—growth and structure**
P	Ussing system—potential difference across membrane
SD	Nuclear membrane structure
SD	Cell membrane thickness—methods of measurement
SD	Extraneous cell membranes
SD	Lipids in membranes—evidence for
SD	Protein in membranes—evidence for
SND	**Chemical properties of cell membrane—Danielli's lipid protein layer**
N	Cell wall pits—structure and function between cells
D	Cell membranes—types within the cell
D	Cell walls—chemical composition of the intercellular layer
SN	Chemical composition of the erythrocyte "ghost" or plasma membrane
D	Mitochondrial membranes—relation of structure to function
SD	Salt antagonism
SND	**Cells as osmometers**

D Myelin sheath structure-function relationships
N Respiratory membrane—ultrastructure and characteristics of
N Middle lamella of plant cells—chemical composition
N Cell vacuoles—structure and function
N Osmotic environment of cells

Cytoplasmic Inclusions

PSN Chloroplasts—substructure of lamellar systems
P Chloroplasts—specialization of
P Chloroplasts in lower plants
PND Chloroplasts—double membrane structure
ND Chloroplast ultrastructure
P Chloroplasts—the Van Wettstein model
P Chloroplasts—the Weier model
PS Chloroplasts—grana, stroma and frets
PD Chloroplast structure using extracted chloroplasts of spinach
PS Chloroplasts—origin of
S Monomolecular chlorophyll layer theory of grana structure
N Chloroplast pigments—types
S Chloroplasts—chemical composition of
D Chloroplast structure-function relationships
PSND Golgi apparatus—structure and function
P Centrioles—structure and function
PSND Endoplasmic reticulum—structure and function
PSND Mitochondria—structure and function
P Centrioles and homologies to basal bodies
P Golgi apparatus—follicular cell components
PSD Follicular cell lysosomes
PSND Cytoplasm—structure and composition
SND Plastids
SN Centriole ultrastructure—cylindrical nature
D Mitochondrion ultrastructure—Palade's description
SD Microsome fraction—concept of
SND Ribosome composition—RNA and protein structure
SND Lysosomes—structure and function
D Endoplasmic reticulum—origin from nuclear envelope hypothesis
D Endoplasmic reticulum—intracellular transport of protein hypothesis
N Protoplasm—physiochemical states of

Microscope

P Artifact problem of cell structure analysis
PND Electron microscope—fundamentals of

PSND Electron microscope—use in study of cell structure
P Dissecting microscope—adjustment and variable magnification
PND Resolution of compound, phase contrast, and polarizing microscopes
PN Resolution in cell structure
PND Phase microscopy for study of the living cell
PN Compound microscope for study of cell structure
PND Magnification—determination of in microscope
PND Depth of field measurement of microscope—using micrometer drum
PD Focusing, observation, and size measurements in the microscope
PSND Compound microscope—use and care
PS Microscope—use of an ocular micrometer
N Microscope—history of development
SD Kohler illumination—theory and practice
D Microscopy—ultraviolet
D Polarization microscopy—use of

PHYSICAL AND CHEMICAL ASPECTS

Energy

PSND Thermodynamics—first law of
PSND Thermodynamics—second law of
PSND Thermodynamic laws and living systems
S The energy source of living matter—the stars
SD Chemical energy
S Work—concept of
SD Entropy—concept of
SND Free energy—concept of
SN Energy relations of electromagnetic waves
S Coupled reactions and free energy exchange
SND Radiation, natural—properties of
SN Visible spectrum and the human eye
SN Spectroscopy—concept of the absorption spectra of a compound
SD Photodynamic sensitization of colorless cells to visible light using *Tetrahymena*
S Light (visible) effect on *Tetrahymena* or *Paramecium* morphology
SN U.V. light injuries (morphological) to bacterial cells
SND Ionizing radiation effect on cells
SND U.V. light effect on cells
S Photo-reactions and temperature effects
N Light—the photon concept

S Relationship of light and wavelength emittance from stars—the Hertzsprung-Russel diagram
S Star formation—condensation of primordial matter
N Photoelectric effect—displacement of electrons by light
N Quantum theory of light

Physical Phenomena

PN Osmosis—demonstration by plasmolysis of *Elodea* leaf cells
PN Absorption of light—concept of
PN Diffusion—the movement of molecules
PN Plasmolysis, incipient—determination using *Elodea* leaf cells
P Isomolar solutions and plasmolysis
PN Plasmolysis, incipient, of plant cells using sucrose, dextrose, and glycerol
PND Plasmolysis of *Elodea* leaf cell
PS Hemolysis of mammalian erythrocytes using distilled water
PSND Cyclosis—cytoplasmic streaming in *Elodea* leaf cells
SN Diffusion rate—temperature effects
S Stoma—mechanics of pore opening
SD Action potentials in plant cells
N Ear—mechanics of hearing
N Smell—structure, function, and sensitivity of the olfactory cells
N Taste—structure and functional characteristics of the taste bud
S Colloids—sol, gel changes in *Physarum*
S Emulsions—definition and examples
S Tyndall effect, using yeast
S Imbibition—effect of salt concentration
SN Imbibition of water by hydrophylic colloids
N Eye—basic mechanics and possible defects of the lens system
SND Turgor changes and movement in *Mimosa* leaves
SND Osmosis—Pfeffer's membrane and water movement
S Osmosis using sea urchin eggs or red blood cells and distilled water
SN Diffusion rates in air and water—Fick's law
S Buffer action using yeast in a nutrient solution
S Absorption spectra of oxygenated and deoxygenated hemoglobin
S Effect of electrolytes and non-electrolytes on osmotic pressure
SN Osmotic pressure $OP=CRT$
N Imbibition—relation to breaking of seed dormancy
N Osmosis effect on cell size (mass) using potato sticks
N Diffusion gradients
N Brownian movement, using colloidal particles of white ink
N Turgor pressure in cells—mechanisms of

Measurement of Physical Phenomena

PS Beer's law—graphic representation using optical density as the ordinate and concentration as the abscissa

SND Osmotic pressure determination of cell contents

PS Colorimetry—use of the Klett-Summerson photoelectric colorimeter

SND pH measurement—methods

SN Surface tension measurement using a tensiometer

S Light absorption—use of hand spectroscope

S Diffusion rate—use of crystalloids and colloids

S Imbibition pressure, using pea seeds in plaster of paris

S Imbibition (heat of) measurement, using starch

S Viscosity—stratification of cell inclusions as a measure of

S Viscosity—Brownian movement as a measure of

S Viscosimetric determination using water, glycerine and gelatin

SND Spectrophotometry—use of a spectrophotometer

S U.V. absorption spectral analysis of proteins and nucleic acids

S Chloride content of plant and animal fluids using $AgNO_3$ titration

S pH of protoplasm using *Physarum polycephalum*

S Redox potential measurement using ferrocyanide and ferricyanide mixtures

SN Light—U.V. measurement using a photocell

SN Light energy in a quantum—Planck's law

S Osmosis—use of an osmometer

S Osmotic pressure of a *Nitella* cell using melting point technique

S Cytochromes—absorption bands of extracted cytochrome C_1 from yeast

S pH measurement of plant and animal fluids

S Buffer capacity measurement using dilution method

SN pH meter—operational techniques

SD Redox potential measurement in living cells—methods

S Temperature control equipment—operational techniques

N Adsorption—measurement of

Chemical Principles

SN Energy of activation

S Temperature and reaction rate

SND Water—properties of

SD Carbon dioxide—properties of

SD Oxygen—properties of

SD pH scale

SD Buffers—the Henderson-Hasselbalch equation

SD Electrolytes—amphoteric

SD pK$_a$
S Surface tension—effect of soap and detergent on water
S Surface tension—concept of
S Carbonate buffer systems
S Buffers, ampholytes as
SD Peter's equation for redox potentials—derivation of
SD Redox potentials and the electromotive series
S Redox potential of quinhydrine at various pH values
SND Buffer systems—stabilization of pH
SN Hypotonic, isotonic, and hypertonic solutions
S Relation of pH to pK$_a$
SN pH derivation
S Dissociation constants and polarity of the water molecule
S Elements and the periodic table
SD Colligative properties
SN Polarity of molecules
S Temperature coefficients and limiting reactions
N Carbon dioxide concentration in the earth's atmosphere
ND Equilibrium, dynamic, concept of
S Buffer system preparation using the Henderson-Hasselbalch equation
P Avogadro's law
S Polymerization of organic molecules
S Nature and sequence of a monomer—primary, secondary and tertiary structure
S Cosmic collision theory of element formation

CHEMICAL COMPOSITION OF CELLS

Cell Fractions

PS Nucleotide structure—bases and sugars
P Water and inorganic ion fraction of bacterial cells—properties of
P Nucleotide (mono-, di-, and complex) fraction of bacterial cells
PSN Amino acids—structure, classification, and properties
P Sugar and acid phosphate fraction of bacterial cells—structure and properties
P Fatty acid and steroid fraction of the bacterial cell
P Nucleotides—U.V. absorption at 260 millimicrons
PD Nucleotide fraction of the bacterial cell—ATP, GTP, CTP, UTP, NAD, and deoxyribonucleotides
SN Ultratrace elements found in living material
S Elements needed for organic compound formation in living matter

P Elemental composition of bacterial cells
P Acid-soluble, low molecular weight fraction in bacterial cells
SND Water and salt content of cells
SN Colloids—sol, gel transformations
S Colloids—shrinkage of gels and adhesive forces on glass
S Nucleoprotein extraction from frog sperm
S Cytochemistry—methods
SD Cell as a polyphasic colloidal system
S Trace elements in living matter
N Elemental composition of living systems

Cell Structure—Chemistry of

P Cell wall—chemical composition of the primary cell wall
P Cell wall—chemical composition of secondary depositions
PN Flagella—chemical composition in bacteria
P Cell membranes—characteristics and chemical composition of the bacterial cytoplasmic membrane
SD Chemical content of cell membranes, e.g., erythrocyte "ghosts"
SD Nuclei—chemical composition of

Chemical Tests

P Egg yolk composition using silica gel chromatography
PS Amino acid extracts—identification using paper chromatography and standard amino acids
PSND Iodine test for presence of starch
P DNA presence in bacterial cells—identification using Giemsa's basic stain (Mason and Powelson technique)
PSD Biuret test for proteins
PS Sudan IV solubility in water and salad oil—test for fats
PS Benedict's test for reducing sugars (aldoses)
P Resorcinol test for ketose sugars, using sucrose, glucose and fructose
S Xanthoproteic reaction for proteins
S Dialysis—non-dialyzability of colloids
S RNA presence—use of pyronin dye
S Feulgen reaction for DNA
S Protein precipitation with ammonium sulfate
S Ninhydrin test for proteins
S Millon's reaction for proteins
S Salt content—silver nitrate titration method
S The Nadi reaction—cytochrome oxidase in tissue
S Histochemistry—methods
N Electrophoretic separation of blood proteins

SND **Electrophoresis—methods**
S Electrophoresis, polyacrylamide-disc—theory of
S Preparation of polyacrylamide gels for disc-electrophoresis
D Gas chromatography—fundamentals of
D Partition chromatography—fundamentals
D Paper chromatography—the RF value
D Adsorption chromatography—fundamentals
N Mineral elements in plant ash—tests for

Membranes and Permeability

PSD **Membrane permeability—methods of measurement**
PSND **Permeability of membranes—rate, molecular effect, active transport**
P Salt accumulation across frog skin
SND **Pinocytosis—mechanism of**
SD Permeability—partition coefficient definition
SD Permeability—Donnan equilibria
SD Permeability of membranes—effect of narcotics
ND Permeability, differential, of living membranes
SD Permeability—partition coefficients of alcohols
S Permeability of cells to weak and strong bases
S Permeability—injury by isotonic solutions of single salts to *Notoplana*
SD Active transport—mechanisms
SND **Active transport—examples of**
SND **Pinocytosis—significance of**
D Mitochondrial membranes—permeability properties
SD Fick's law and permeability constants
N Base exchange in mineral uptake by roots
SD Partition coefficient effects on membrane permeability
SN Temperature effects on membrane permeability
SN Carrier hypothesis of K^+ in active transport
S Active transport—temperature effects
SN Competitive interactions in active transport
SD Carrier hypothesis in active transport of non-ionic substances

STRUCTURE OF MACROMOLECULES

DNA

PND **Base pairing in DNA**
PSND **DNA—composition of**

PSN **Polynucleotide—the basic structure of DNA**
PSND **DNA structure—the Watson-Crick model**
PD DNA—history of discovery
PD DNA—localization within the cell
P DNA—modern chemistry of
D DNA stability in the cell
SND **Nucleosides and nucleotides in the DNA molecule**
PSND **DNA structure—x-ray diffraction studies**
S DNA, single stranded, of some bacteriophages

Proteins

PSND **Quaternary structure of proteins, e.g., insulin**
PSND **Primary structure of proteins**
PSND **Secondary structure of proteins**
PSND **Tertiary structure of proteins**
PD Fibrous protein structure
PD Hydrogen bonding and secondary structure
PND **Tertiary structure of proteins—determined by amino acid sequence**
PSND **Tertiary structure of proteins—disulfide, hydrogen, electrostatic, and hydrophobic bonds**
PN Tertiary structure of proteins and biological activity
P Tertiary structure of proteins—the hemoglobin molecule (Kendrew)
ND Proteins—amphoteric properties of
SN Molecular shape of proteins—fibrous and globular
S Methods of protein separation
S Proteins—criteria of purity
SND **Denaturation of proteins**
SND **Protein structure analysis—x-ray crystallography**
SND **Peptide bonds**
SN Proteins—functional types, simple and conjugated
SD Protein denaturation—temperature coefficients for
S DNA base ratios—nearest neighbor studies
SN Lipoproteins—structure and function in the cell
ND Reverse mutation—consequences for protein structure
SND **Protein structure—1,2,3,4 degree relationships**
SN Proteins—general classification of
S Proteins, conjugated
SD Protein solutions as colloidal systems
D Protein molecular weight determination—methods of
D Protein structure—electron microscopy analysis
D Protein analysis and purification—chromatography

D Primary structure of the insulin molecule
S Protein surface charge analysis using dyes to form colored precipitates
D Quaternary structure—effect on protein activity
D Tryptophan synthetase—subunit interaction and activity
D Cross-reacting material (CRM)—definition of
D CRM detection—immunological method of

RNA

PSND RNA, ribosomal—structure
PND RNA, transfer—structure
PSD RNA, messenger—properties and structure of
S RNA staining with basophilic dyes

Carbohydrates, Lipids, and Pigments

PSND Starch, cellulose, and glycogen—carbohydrate structure
PSND Fats, phospholipids and steroid structure
PSN Chlorophyll molecule—chemical composition of
P Photoreceptors—chemical comparisons in plants and animals (B carotene and vitamin A)
PN Cellulose fibrillar structure
PN Lipids—fatty acid and glycerol structure
S Photosensitive pigment in *Blepharisma undulans*
N Carotenoids—molecular structure
N Lignin—chemical composition of
N Pectic substances—chemical nature of
N Lipids—chemical classification
D Plant pigments—types of

SYNTHESIS OF MACROMOLECULES

DNA

P DNA synthesis—analysis of the replication of the *E. coli* DNA molecule
PSD DNA replication *in vitro*—analysis of the Kornberg system
PSND Semiconservative replication of DNA—Meselson and Stahl experiments
P Antimetabolite interference with DNA synthesis
P Thymidylic acid—role in DNA synthesis
P Fluorodeoxyuridine (FUDR) effect on the growth rate of cultured mammalian cells (HeLa)

PD	Tritiated thymidine analysis of DNA synthesis
SN	Replication of DNA during interphase of mitotic cycle
N	Polymerization of activated nucleotides
N	Nucleotide formation—mechanism of
P	DNA—procedure for isolation of

RNA

PSD	**RNA synthesis—RNA polymerase (Weiss and Hurwitz experiments)**
PN	Nuclear site of ribosomal, transfer and messenger RNA synthesis
PS	Hybridization studies of DNA and RNA (Speigelman and Hall)
S	Base ratio similarity of DNA and RNA—*in vitro* synthesis of RNA
S	Single strand DNA synthesis of RNA

Amino Acids

P	Arginine biosynthesis from alpha-ketoglutaric acid, and role of ATP
PSD	**End-product inhibition in amino acid biosynthesis**
P	End-product inhibition studies of Umbarger
P	End-product inhibition—L-isoleucine, L-leucine, L-valine effect on the activity of threonine deaminase
P	End-product inhibition of amino acid biosynthesis—allosteric inhibition
S	*In vitro* synthesis of proteins using radioactive amino acids and microsome fraction
S	*In vitro* synthesis of phenylalanine using polyuradylic acid and *E. coli* ribosomes
S	Biosynthesis of tryptophan in *Neurospora*
N	Arginine synthesis in *Neurospora*—multiple gene control
N	Reductive amination—glutamic acid production
N	Transamination—amino acid formation from glutamic acid

Concepts of Biosynthesis

PS	Biosynthesis—a specific use of energy
P	Metabolic pathway dependence on gene-enzyme hypothesis
PS	Metabolic pathways—the universality of biochemical pathways
P	Catabolic reactions—analysis of metabolic pathways
PS	Auxotrophic mutants of bacteria—analysis of metabolic pathways
S	Autotrophs and phototrophs—concept of
S	Biosynthetic pathway of prodigiosin production in *S. marcescens*
N	Inhibitors, competitive, of biosynthetic reactions—types
D	Metabolic antagonism—e.g., methionine metabolism
SN	Chemical approach in study of biosynthesis

Proteins

PN	Amino acid pool—concept in protein synthesis
PSND	**RNA and protein synthesis—Nirenberg experiments**
PSND	**Amino acid activation and binding to *s*RNA**
PSD	**Amino acid, *s*RNA complex formation**
PSND	***m*RNA binding to ribosome**
PSND	***s*RNA-AA complex binding to site on *m*RNA by base pairing**
PD	Peptide bond formation—ribosome function and RNA (*m* and *s*) relationships
PND	***m*RNA synthesis in nucleus as complement to DNA molecule**
PSD	**Specific transfer RNA production in the cell**
PSN	**Polysome concept in protein synthesis**
P	P-fluorophenylalanine effect on the growth of *E. coli* (strains KB and PFP10)
P	P-fluorophenylalanine activation by extracts of *E. coli* strains (hydroxamate assay)
P	P-fluorophenylalanine (radioactive) incorporation into protein in *E. coli* (strains KB and PFP10)
SND	**The genetic code and protein synthesis**
S	RNA distribution in the microsome fraction of the cell
SD	Stability of RNA fraction in ribosome
SD	Relationship of nucleotide combinations to incorporation of amino acids into proteins (Nirenberg and Ochoa)
N	Nucleoprotein synthesis—protein complex with DNA or RNA
S	Protein synthesis relationship to cell division cycle
SN	Protein synthesis—general description of events
N	Protein synthesis—hormonal control
N	Protein synthesis—role of liver

Carbohydrates

N	Glucose synthesis
D	Starch synthesis by phosphorylase using potato extract and glucose-1-phosphate
S	Starch formation in amyloplasts
N	Carbohydrate metabolism—role of the liver
D	Starch grains—observation in cells
D	Starch formation from glucose—biosynthetic pathways

Lipids

N	Glycerol synthesis from triosephosphate
N	Fatty acid synthesis from acetyl fragments
N	Lipid synthesis from fatty acids and glycerol
N	Lipids—transportation mechanisms of

N Lipid metabolism—catabolic and anabolic role of the liver
N Lipid synthesis—role of TPN
N Lipid metabolism—hormonal regulation

ENZYMES

Enzyme Induction

P Enzyme induction—citrulline production in *E. coli*—assay reaction of ornithine and carbamylphosphate

PSN Enzyme induction—beta-galactosidase production in microorganisms

PS Co-repressors—control of ornithine transcarbamylase synthesis in *E. coli* by arginine

P Catabolite repression in enzyme induction—beta-galactosidase system in *E. coli*

PS Enzyme induction—beta-galactosidase formation in *E. coli* assay by hydrolyzation of ONPG to galactose and o-nitrophenol

P Enzyme induction—metabolite inhibition, e.g.,arginine synthesis and histidine synthesis control

PS Enzyme induction—the repressor gene product and relief of an inhibition

PS Enzyme induction—concept of the inductor and production of *m*RNA

S Coenzyme function—enzyme activators

SD Enzyme induction—the permease system in *E. coli*

S Beta-galactosidase extraction from *Neurospora*

Enzyme Kinetics

PSND Activation energy and enzymes

PSND Enzyme kinetics—the effect of enzyme concentration on reaction rate

PSD Enzyme kinetics—the effect of substrate concentration on reaction rate

SD Competitive inhibition of enzymes
SD Activation of hydrolytic enzymes
S Catalase activity—effect of KCN
SD Effect of temperature on enzyme-catalyzed reaction rate
SD Michaelis constant (K_m)
S Reaction kinetics—general enzyme activity
S Enzyme kinetics—Lineweaver-Burke plot
SD Enzyme kinetics—Michaelis equation

Enzyme Structure and Function

PSND	**Proteins—importance in economy of cell as enzymes**
PS	Co-factors of enzymes—organic and inorganic
S	Catalase extraction from beef liver or *Sedum*
SND	**Enzyme catalysis—mechanics of**
SND	**Enzymes in organelles of the cell, e.g. mitochondria**
SD	Enzyme action—parameters of
S	Classification of enzymes
S	Stereospecificity of enzymes
SD	Enzyme and substrate—structural relationship and catalysis
S	Enzyme action—identification of specific groups in active site
S	Enzyme inhibition—specific inhibition
SND	**Enzyme reactions—effect of temperature on**
SND	**Enzyme activity—influence of pH on**
SD	Catalysis—mechanism of
SD	Enzyme specificity
S	Enzyme reactions—methods of study
S	Enzyme purification—methods of
SN	Enzyme activity—reversible reactions, mass action
SN	Enzyme nomenclature
S	Tryptophan synthetase extraction and properties
S	Tryptophan synthetase molecule—structure
S	Allelic tyrosinases in *Neurospora crassa*
S	Tyrosinase extraction and assay from *Neurospora crassa*
S	LDH isozymes—properties and preparation
SN	Exoenzymes—types and function
SN	Enzyme action, e.g., ribonuclease and chymotrypsin
S	Enzyme activity—obligatory coupling reactions
S	Ascorbic acid oxidase in plant tissue using ascorbic acid substrate
S	Catalase in living tissue—assay using hydrogen peroxide
S	Peroxidase in plant tissue using hydrogen peroxide and guaiaconic acid
SD	Preparation of an anion column for enzyme isolation
N	Respiratory inhibitors—effect on enzymes of respiration

PHOTOSYNTHESIS

Light Absorption and Relations

PND	**Chloroplast pigment separation using paper chromatography**
P	Chloroplast pigments—separation using silica-gel (thin layer) chromatography

PSND Chlorophylls a and b—light absorption analysis using a hand spectrophotometer
SN Fluorescence by chlorophyll—energy release
PS Chloroplast pigment extraction from bean leaves using ETOH
PD Chloroplast pigments—separation of chlorophylls and carotenoids, using petroleum ether
SD Pigment function in photosynthesis
N Phosphorescence by the chlorophyll molecule—energy release
ND Chlorophyll—fluorescence using U.V. light
ND Photosynthesis, bacterial—characteristics of
ND Pigments, photosynthetic, found in bacteria
PSN Chlorophyll—absorption spectrum of
S Photosynthesis—structural relationships in the leaf
SN Chlorophyll a and b—enhancement phenomenon
S Photosynthesis—relation to leaf structure
S Photosynthetic apparatus—form and function relationships in plants
S Chlorophyll necessity in photosynthesis using variegated *Coleus* leaves
P Wavelength effect on oxygen production in *Elodea* using light filters
PS Light intensity and oxygen production in *Elodea*
PS Photosynthetic rate determination using leaf disc method—tobacco or *Bryophyllum*
SND Quantum efficiency in photosynthesis
S Light necessity in photosynthesis—patch test

Light Reactions

PSN Photosynthesis—the sun as ultimate source of energy
PSD Separating light and dark reactions of photosynthesis
PN Blackman reaction—1905
PSND Light reaction of photosynthesis—Van Niel's hypothesis
PSND Hill reaction as an analysis of the light reaction of photosynthesis
PD Hill reaction—extraction of chloroplasts from spinach
PD Hill reaction—dye reduction (2-6, dichlorophenol-indophenol by chloroplasts)
P Hill reaction—use of 2-6, dichlorophenol-indophenol as the hydrogen acceptor
P Light reaction analysis—experiments of Ruben et al.
PSND Electron excitation and splitting of the water molecule
PN Photophosphorylation system bound to membranes
SND Photosynthesis as a redox reaction
S Carbon dioxide uptake by *Chlorella*—effect on pH during photosynthesis
ND Photosynthesis—effect of CO_2 concentration on

D Reduced NAD oxidation—spectrophotometric analysis
D Hill reaction—action spectrum of dye reduction

Path of Carbon

PN Carbon dioxide fixation activity of fractionated chloroplast systems
SND Carbon reduction phase of photosynthesis
PSN Carbon path in photosynthesis—methods of analysis (Calvin)
N Carbon dioxide fixation—*Elodea* in phenol red solution
S Carbon dioxide necessity in photosynthesis using KOH

RESPIRATION

Oxygen Consumption

P Oxygen consumption by a goldfish—graphic representation
P Oxygen consumption by a goldfish, using the Winkler method
P Oxygen consumption—temperature effects in a poikilotherm, using goldfish and Winkler method
PS Oxygen consumption measurement in the rat, using a Phipps-Bird respirometer
P Oxygen and/or carbon dioxide deficiency effects on corn seedling growth
SND Respiratory movements—control in man, insects, and fish
S Oxygen carrying capacity of blood types
SN Oxygen diffusion and transport
S Oxygen dissociation curve in mammalian blood
S Oxygen dissociation curve in blood containing hemocyanin
S Oxygen content of water—effect of yeast on
S Oxygen tension, temperature and pressure relations
S Determination of QO_2 for yeast
SD Q_{10} determination in goldfish by gill flap movements
SN Determination of Q_{10} in a crayfish by movement of scaphognathites
SN Lung expansion and contraction—basic mechanics of
D Respiration in bacteria—types
N Temperature effects on respiration

Carbon Dioxide Production

P Carbon dioxide production in respiration—measurement using titration of acid (H_2CO_3) solution with 0.01 N NaOH

P Carbon dioxide production by germinating pea seedlings using BaOH

P Carbon dioxide production in aerobic and anaerobic respiration

PSN Carbon dioxide production by yeast during fermentation, measured with BaOH

PS Carbon dioxide production and measurement using yeast and a fermentation tube

SN Carbon dioxide transport in blood

Energy Relations of Respiration

P ATP production in bacteria

PSND Phosphorylation, oxidative

PSND Electron transport

PSND Krebs cycle

PSND Energy yield and ATP balance in respiration

PSN Fermentation as a redox system of form $AH_2 + B = BH_2$ energy

PD Fermentation—the hexose monophosphate shunt of Entmer-Doudoroff

PSND Energy metabolism—products of

PSN Fermentation—reduction of pyruvic acid by NADH—end product formation

PSND Glycolytic pathway of Embden-Myerhof

PSND Glucose metabolism

PSN Fermentation—the energy balance of

PSN Glucose as an energy source for heterotrophs

PND ATP—function in the cell

PSND ATP synthesis—energy coupling for

P Reduction reactions in bacterial energy metabolism—comparative aspects

PN Oxidation reaction in bacterial metabolism—comparative aspects

PN Oxidations and reductions in bacterial energy metabolism

SD Redox potentials of organic compounds

S Fermentation—effect of narcotics (KCN, NaN_3 and urethane) in yeast

S Fermentation of sucrose by yeast—effect of U.V. light

SND Hydrogen activation by dehydrogenases

SD pH and redox potentials of hydrogen transfer systems

SD Respiratory poisons—effect of KCN and ethyl urethane on red blood cells

SD Coupling of univalent and divalent redox systems

SND Fatty acid respiration

N Fermentation as a biological process—history of discovery

N ATP activation of macromolecule sub-units

N Respiration, bacterial, with inorganic substrates

N Bioluminescence—mechanism of
N Cyclic phosphorylation—mechanism of
N Phosphorylation, substrate level
N Pasteur effect in bacterial metabolism
N Carbon monoxide as a competitive inhibitor
N Aerobiosis—characteristics of
ND ATP molecule structure and energy relations
S Fermentation—lactic acid production by yeast, pH effect
SN The pentose phosphate pathway
D Krebs cycle—history of discovery
D Krebs cycle—relation to mitochondrial structure
D Glyoxalate cycle
D Electron transport and ATP formation—Chance's experiments
S Q_{10}—concept of
S Polymerization of activated subunits in respiration
S Biological oxidations—reactions unique to living systems
N Anaerobic respiration in flowering plants
N Proteins as energy sources
N Energy release—regulation of

Measurement of Respiration

PSND Respiration rate—carbon dioxide production per minute
SND Heat evolution during respiration—calorimetry
PSD Respiration measurement using a respirometer—manometric analysis
PN Respiratory quotient (R.Q.) = carbon dioxide produced/O_2 consumed
PSN R.Q. values for carbohydrates, organic acids, and fats
S R.Q. determination for yeast cells
S Oxygen and carbon dioxide concentration effect on respiratory rate
S Hydration effect on lichen respiration, using a Warburg apparatus
SN Temperature effects on respiration, using luminous bacteria
D Compensation point determination in plants
N Respiration rate—chemical limiting factors

Nutrition

N Essential elements in bacterial nutrition
N Chemicals as nutrients in bacteria
N Carbon compounds as nutrients—types
N Nitrogen sources in bacterial nutrition
N Nutrient uptake by microorganisms—methods
PN Plant nutrition—deficiency effects on plant growth

PN Plant nutrition experiments—preparation of nutrient media for
PN Plant essentials—destination of water, CO_2 and mineral elements
PN Nutrition—transport problems
ND Sporophyte formation in the fern—nutritional influences
ND Essential element deficiencies—growth abnormalities in plants
N Trace elements—plant mineral nutrition
D Elements essential for plant mineral nutrition
P Sources of plant essentials
D Bacterial nutrition—autotrophs and heterotrophs
N Plant nutrition—history of experimentation
N Plant nutrition—role of essential elements
N Plant nutrition—sources of nitrogen
N Plant growth—water availability and
N Plant growth—water, soil relations
SN Preparation of a micronutrient medium for plant nutrition studies

MORPHOLOGY

HISTOLOGY

Tissue Types

PSND Neuron—structure of
PS Neurons and neuroglial cells—structure of
SD Spinal cord—structure
S Fiber structure of the sciatic nerve cord in the frog
PSN Muscle structure, striated, using leg muscle of bee or cockroach
PSN Muscle structure, smooth, using prepared slides
PSND Muscle ultrastructure—the sarcomere
PSN Cardiac muscle structure, using prepared slides
PSN Connective tissue—classification of bone and connective tissue
P Fibroblasts and macrophages—types of loose connective tissue cells
PSN Bone—structure of fibrous connective tissue
PSN Hyaline cartilage—structure of fibrous connective tissue
P Collagen—ultrastructure
N Connective tissue, blood—components of
SN Tissue—concept of

Organ Structure

P	Intestine (small)—structure in *Necturus*, showing villi
P	Lobule structure in the liver of pig, using prepared slides
PS	Eye structure—medial section of a monkey's eye
P	Mesentery structure of *Necturus*, using prepared slides
PS	Gut wall structure in *Necturus*
SN	Stem structure—external features
PSN	**Leaf structure of *Pinus***
PS	Stem tip structure of *Coleus*, using prepared slides
PND	**Leaf structure—internal structure of a monocot (*Zea*)**
PSND	**Leaf structure—internal structure of a dicot**
P	Leaf structure—removal and study of *Impatiens* epidermis
PSN	**Root, lateral, formation from pericycle using *Salix***
PSN	**Root structure—primary tissues, using *Ranunculus***
PSND	**Stem structure—secondary tissue in a woody stem**
PSN	**Stem, herbaceous—primary tissues**
PSN	**Moss sporophyte structure, using *Polytrichum***
PND	**Stem structure of monocot—transverse and longitudinal sections**
SN	Axillary buds—structure and function
N	Epidermis and cuticle function in plant tissue
N	Epithelial tissues—types and characteristics
S	Root tip—structure of
SN	Fern sporangium structure
SND	**Leaf structure—external**
N	Organ concept in cellular organization
SND	**Root structure—external features**
SN	Root structure, internal, of a dicot—secondary growth
SN	Root types—tap, fibrous, and adventitious
P	Mucosa cell layer structure in the gut of *Necturus*
SND	**Earthworm digestive system structure**
SN	Respiratory epithelia—characteristics of
SND	**Stomatal apparatus—structure and function of**
S	Tuber of potato—structure and function of
S	Lenticels—gas exchange in the woody stem
S	Cambium of the woody stem—the ray initial
SD	Cambium of the woody stem—the fusiform initial
S	Dicot stem—differentiation of vascular bundles
S	Leaf—internal structure at the node
S	Stem—function in plant organization
N	Lamprey respiratory system structure
N	Lamprey reproductive system structure and function
N	Lamprey digestive system structure and function
ND	Stem structure—external

ND Stem structure in gymnosperms
SND Stem structure—primary tissues in monocots
SND Wood—transverse, radial, and tangential sections
S Honeybee—leg structure
PND Intestines, small—function of
SD *Selaginella*—internal structure of the stem
SD Stem structure—secondary tissues of a gymnosperm
SD Rhizoid structure using *Ricciocarpus*
SND Fruits—types of
S Fern rhizome—internal structure
D Bud, terminal, of a woody dicot—structure
D Wood identification—use of a key
N Respiratory unit—concept of
D Leaf venation—types of
D Stem structure, internal—primary tissues of a woody dicot
D Heart structure in the vertebrate (fetal)
D Lung structure in the vertebrate

Microtechnique

P Microscope slide—preparation of thyroid tissue of rats
P Microscope slide—preparation using plant material
P Microtechnique—principles of tissue preparation
S Microtechnique—preparation of the cell for cytological studies
SD Slide preparation—temporary mounts

GROSS MORPHOLOGY

Vertebrates

P Respiratory system structure of the pig
P Ear structure in *Squalus*
P Eye structure in *Squalus*
P Nasal sac structure in *Squalus*
P Abdominal cavity structure in the pig
PD Pleural cavity structure in the pig
PD Morphology, external, of the pig
P Mouth and pharynx structure of *Squalus*
PD Gill structure of *Squalus*
PN Pericardial cavity structure and contents in *Squalus*
PN Abdominal cavity structure and contents in *Squalus*
PN Morphology, external, of *Squalus*

PND Reproductive system structure in humans
S Brain structure of the frog
SD Brain structure in the mammal, e.g., sheep
ND Vertebrate brain—major parts and functions
ND Frog digestive system—structure
ND Frog—external morphology
SN Viscera structure in a frog
SN Gill structure in the fish
SN Digestive tract of the mammal
N Fish—external structure
N Lamprey—skeleton structure
N Skeleton structure of bony fish
N Enteropneust structure and characteristics
N Lamprey—external structure
ND Frog skeleton structure
N Feather structure and function
ND Skeleton structure—mammal
N Toad—structure and characteristics
N Lizard—external structure
N Bird respiratory system
N Turtle—structure of the shell
N Bird—digestive system structure
N Digestive system structure in the mammal (general)
N Swim bladder—structure and function
N Respiratory system structure—frog
N Organ system types—mammals
ND Ear—anatomy of external, middle, and inner ear
ND Vertebrate body cavity and mesenteries
N Retina—structure and function of
D Structure of the human eye
D Internal anatomy of the fetal pig

Invertebrates

PSND *Paramecium*—structure and physiology
PND Amoeba structure (*Pelomyxa*)
P *Euploides*—structure
PS *Stentor*—structure
PSN Crayfish—external anatomy
S Crayfish—internal anatomy
SN Crayfish structure—appendages
SND *Obelia* structure, external
S *Obelia* structure—reproductive and nutritive zooids
S *Obelia* structure—medusae

SN *Leucosolenia*—structure of a simple sponge
SN *Planaria*—structure
SND Earthworm structure—external
SND Earthworm, internal anatomy
N *Daphnia*—internal morphology
S *Artemia* structure
SN Grasshopper structure—external features
S Grasshopper leg structure
SN Grasshopper structure—mouthparts
S Honeybee—structure of mouthparts
ND *Daphnia*—external morphology
N Mollusc structure—general
ND Starfish structure—general
SND *Hydra*—structure
N Sponge—canal systems structure
N Sponge skeletal structure
N Leech—structure and characteristics
SND *Euglena*—structure
SN *Plasmodium*—structure
S *Trichonympha*—structure
SN *Tetrahymena*—structure
N Arthropod—exoskeleton structure
SN Trochophore larva—structure of *Urechis*
N Crayfish—respiratory system structure
ND Rotifers—characteristics and structure
N *Metridium*—structure of a sea anemone
N *Aurelia*—structure of a jellyfish
N Spider external structure
N Honeybee external structure
N Squid—external structure
N Squid internal anatomy
N Liver fluke—structure of
N *Planaria*—digestive system structure
N Starfish endoskeleton structure
ND Starfish water vascular system structure and function
N Clam shell structure
N Clam mantle structure
N *Amphioxus* structure and characteristics
N Ascidian larval structure
N Ascidian adult structure
N *Ascaris*—internal anatomy
N Filaria worm—structure
SN *Neanthes virens*—external structure of a polychaete worm
N Parapodia—structure of

N	*Amphiuma*—structure and characteristics
N	*Necturus*—external structure and characteristics
N	Insect—respiratory system structure
N	Crayfish digestive system
N	Clam digestive system structure
N	Clam—gill structure and function
N	*Amphioxus* respiratory system structure
D	External morphology of the wasp *(Mormoniella)*
D	Lobster—external anatomy
SN	Lobster—internal anatomy
[illegible]	Colonial hydrozoans—types
D	Snail—internal structure

Vascular Plants

PSND	**Seed structure, dicot**
PSND	**Seed structure, monocot**
PSND	**Root structure—regions of the root**
PSND	**Fern gametophyte structure using *Pteridium aquilinum***
PSN	**Fern sporophyte structure using *Pteridium aquilinum***
S	Liverwort—gametophyte structure and function
SN	Structure of the plant embryo (dicot)
PSN	***Equisetum*—structure**
PN	*Zamia*—structure of a cycad
PSN	***Psilotum*—structure**
PN	*Lycopodium* sporophyte structure
PSN	***Selaginella*—structure of the sporophyte**
PN	*Isoetes*—structure
PN	*Ginkgo*—structure
S	Dicotyledonous plants—concept of
N	Embryo structure (monocot)
N	*Rhynia*—structure
N	*Calamites*—stem structure of a fossil
N	*Sphenophyllum*—structure
N	*Lepidodendron*—structure of a fossil
N	Pine—external structure
S	Liverwort—sporophyte structure and function
ND	Organ systems in higher plants
S	Fruit—structure and function of
S	Monocotyledonous plants—concept of
ND	Seed ferns—fossil record and structure
N	Seed structure in pine
N	*Gnetum*—structure
N	*Ephedra*—structure

N	Seed structure in cycads
N	*Sigillaria*—structure of a fossil
N	Angiosperms—leaf structure, external

Non-Vascular Plants

PSN	***Marchantia*—structure of a liverwort**
PSN	***Polytrichum*—structure of a moss**
PN	Lichen growth forms—crustose, foliose and fruiticose
PND	***Polysiphonia*—structure**
PND	***Fucus*—structure**
PN	*Laminaria*—structure
P	*Nereocystis*—structure
PND	***Vaucheria sessilis*—structure**
PSND	**Diatom structure, using *Pinnularia***
PSN	***Chlorella*—structure**
PND	***Hydrodictyon*—structure**
PND	***Spirogyra*—structure**
PN	*Oedogonium*—structure
PN	*Ulothrix*—structure
PN	*Ulva*—structure
P	*Mougeotia*—structure
PN	Lichen structure—algal and fungal components
PSND	***Volvox*—structure**
N	*Dinobryon*—structure
N	*Scytonema*—structure
N	*Gloeotrichia*—structure
SN	Algae—forms and organization
N	*Gloeocapsa*—structure
N	*Oscillatoria*—structure
N	*Anabaena*—structure
ND	*Nostoc*—structure
SND	***Chlamydomonas*—structure**
N	*Protococcus*—structure
N	*Ectocarpus*—structure
N	*Batrachospermum*—structure
N	*Nemalion*—structure
N	*Porphyra*—structure
N	Division Chlorophyta—morphological forms
ND	*Gymnodinium*—structure of a dinoflagellate
S	*Pandorina*—structure
N	*Pleurococcus*—structure
N	*Chlorococcum*—structure
N	*Acetabularia*—structure

N *Nitella*—structure
N Desmid—structure
N *Porella*—structure
N *Ricciocarpus*—structure
N *Sphagnum*—structure
N *Anthoceros*—structure
S *Tetraspora*—structure
S *Chara*—structure
S *Bryopsis*—general structure
S *Macrocystis*—internal anatomy

Fungi

ND *Rhizopus*—structure
PSN Yeast structure and reproduction
N *Microsphaera*—cleistothecium structure
PN Perithecium structure in *Sordaria*, with asci and ascospores
P Basidiocarp structure of *Coprinus*
PS *Sordaria*—structure
PN *Absidia*—structure
P *Achlya*—structure
P *Blastocladiella*—structure
PSND Slime molds—structure and reproduction
N *Ustilago*—structure
SN *Neurospora*—structure
N *Aspergillus*—conidiophore structure
N *Penicillium*—conidiophore structure
SN *Agaricus*—basidiocarp structure
N *Puccinia*—structure
N *Tremella*—structure
N *Synchytrium*—structure
N *Albugo*—structure
SN *Saprolegnia*—structure
N *Allomyces*—structure
N *Claviceps*—sclerotium structure
N *Lycoperdon*—basidiocarp structure
N *Polyporous*—basidiocarp structure
SN *Amanita*—basidiocarp structure
N *Plasmopara*—structure
N *Peziza*—ascocarp structure
N *Mucor*—morphological characteristics

The Study of Organism Structure

SN Cellular organization—unicellularity
P Structure of organisms—possible approaches to the study of

PN Symmetry in organisms—spherical, radial, and bilateral
P Structure-function concept in organism existence
S Metazoa and protozoa compared morphologically
N Multicellularity—characteristics of
S Heterotrichous growth—concept of
S Multicellularity—patterns of organization in plants
N Symplast concept in multicellular organisms
S Environmental effects on morphology of the individual
S Colonial forms—characteristics of

GENETICS

CYTOGENETICS

Ploidy

PN Euploidy
P Aneuploidy in *Datura*
PD Aneuploidy in man
PSND Concept of polyploidy
PSND Concept of aneuploidy
PD Autopolyploidy—genetic basis of
N Diploidy—evolutionary consequences of
S Population origin—aneuploidy
S Population origin—euploidy
D Aneuploidy—monosomics and trisomics in *Drosophila*
D Autopolyploidy—phenotypic effects of
S Diploidy—origin of
PS Heterochromatin—role in chromosome number and shape

Chromosomes

PSND Chromosome breakage
P Chromosome changes—natural occurrences
PSD Chromosome breakage—two breaks in same chromosome
PN Chromosome breakage and consequences
PND Chromosome basis of heredity, nondisjunction
PND Cytogenetic correlation with genetic traits
P Chromosome analysis (karyotyping) in mammals—methods
P Chromosome counting, using human (HeLa) cells

P Sex determination—chromosome basis of (in birds)
PD Sex determination—chromosome basis of (in *Drosophila*)
SD Chromosome—molecular structure hypothesis
PSND Reciprocal translocations and translocation heterozygotes
PSND Polytene chromosomes and aberration analysis
S Chromosome morphology during cell division
PSND Concept of the chromosome
P Chromosome changes, induced
ND Genes and chromosomal relationships
ND Chromosome deficiencies—cytological properties
P Telomeres—genetic consequences of
PSD Chromosome structure—gross morphology of
PSND Structural aberrations of chromosomes—consequences for homologous pairing
D Chromosomal duplications—nature of

Crossing Over

PSN Chiasmata and crossing over—cytological correlations
P Crossing over—attached X evidence for four strand crossing
PS Chiasma formation and crossing over

POPULATION GENETICS

Selection

P Detrimental gene loss from human populations—factors
PSND Selection effects on gene frequencies
PND Mutation and selection effect in populations
N Genic adaptation—selection effects
P Long term selection effects on gene frequencies
P Selection coefficient—derivation of
D Selection—dependence on gene frequencies
S Selection, types of—directional, stabilizing and disruptive
PS Adaptive value W and selection coefficient S
S Inbreeding mating system—Wright's coefficient

Migration

P Migration effects on gene frequencies
P Population evolution—geographically localized group of organisms of same species

S	Differential migration

Genetic Drift

PSN	**Drift (chance) effects on gene frequencies**
PSN	**Genetic drift and population size**
S	Genetic drift—definition of
S	Genetic drift—mutation effect on
S	Genetic drift, consequences of, decay of variability
S	Genetic drift—differential migration effect
S	Genetic drift—selective coefficient and adaptive value effects

Mutation

PSND	**Mutation effects on gene frequency**
PSD	**Mutation rates and gene frequencies**
P	Mutational loads

Hardy-Weinberg, Gene Equilibrium

PN	Finite population size and gene frequencies
S	Panmictic populations
S	Effective breeding size—evolutionary significance
S	Random mating system—paramictic populations
S	Negative assortive mating system
S	Positive assortive mating systems
PSD	**Gene equilibrium conditions in populations**
PSND	**Gene frequencies in a population**
PD	Gene frequency and offspring derivation for P.T.C.
P	Sex-linked gene frequencies in populations of *Drosophila*
P	Autosomal gene frequencies in a population of *Drosophila*
PSND	**Population as the unit of evolution—the gene pool**
S	Recombination frequencies and fitness of a population
PN	Mating systems—effects on gene frequencies
PSND	**Hardy-Weinberg law**
S	Gene combination potential—role in adaptation

Gene Interaction

PSD	**Heterosis**
PSND	**Polymorphism, balanced**
PN	Breeding systems—non-random (homozygosity)
PSND	**Genetic load—definition of**
S	Population differentiation—isolation and gene exchange
S	Fusion of populations

MOLECULAR GENETICS

Gene Action and Interaction

ND Complementation in *Neurospora*
PS Genes and enzymes—one-cistron, one-polypeptide chain hypothesis
PSND Genes and enzymes—one-gene, one-enzyme hypothesis of Beadle and Tatum
PSND Cis-trans heterozygotes and position effect
PN Gene interaction—gene products and adjacent non-alleles
S Close linkage of genes in tryptophan synthetase formation in *Neurospora*
S Tryptophan synthetase—mutation effects on synthesis in *Neurospora*
D Intragenic complementation—concept of
D Cis-trans test—complementation of cistrons
D Intragenic complementation—mechanism of

Transformation, Transduction and Recombination in Bacteria

PSN Transduction, general, in *Salmonella*
PSND Transduction—complete transduction and integration of transduced DNA in host
PND Transduction, abortative—Wollman and Jacob's experiments
PD Transduction—the genome of the transducing phage
PD Transduction, restricted, in *E. coli*
PSND Recombination in phage—mechanism of
PS Recombination frequency in bacteriophage
PND Recombination frequency in the bacteriophage T4, when crossing two phage mutants
PSN Transformation and recombination in bacteria
PSND Conjugation and recombination in bacteria
PSD Episomes
SND Transduction in bacteria, characteristics of
N Bacteriophage—use in genetic studies
N Sexuality and gene transfer in procaryotic organisms
D Conjugation—sexual polarity and genetic mapping
D Sex factor—incorporation in bacterial chromosome
D Phage heterozygotes—characteristics of

Genetic Fine Structure

PND Codon concept
P Cistron concept
PSD Colinearity of cistron and proteins

PD Recon—operational definition
PD Cistron—operational definition
P Muton—operational definition
PSD Genetic code
SD Deletion mutation and P^{32} decay in bacteriophage
S Fine structure analysis using bacteriophage
SND Gene—concept of
ND Complementation map—*Neurospora*
P Gene conversion—concept of
PSND rII region of T4 phage
N Genetic map of bacteria
D Phage linkage group—circular chromosome

Genetic Regulation

PSD Operator gene and genetic regulation
PD Operon—definition and operation in *Salmonella* and *E. coli*
PD Repressor of regulator gene
PSD Operon and the operator gene
P Biochemical mutant analysis of genetic regulation in *Neurospora*
D Structural gene—function of

Genetic Pathway Control

PD Eye pigment formation (brown) in *Drosophila*
PS Phenylketonuria and parahydroxylase
P Alkaptonuria and homogentisic oxidase
PD Eye pigments—chromatographic separation of pterin compounds in *Drosophila* mutant stocks
PD Eye pigments—chromatographic separation of pterin compounds in eyes of wild type *Drosophila*
PSND Alkaptonuria in man—example of a biochemical mutation
SD Genetic control of biosynthetic pathways
D Genetic block—accumulation of precursors
D Cross-breeding use in detection of biochemical pathways
D Genetic block—complete and leaky mutations
D Non-nuclear control of gene action

The Genetic Material—DNA

PN Chromosome—concept of the organization of DNA in eucaryotic cells
PSD DNA, cellular activities of—replication and direction of protein synthesis
PND DNA as genetic material—P^{32} and S^{35} experiments of Hershey and Chase

PND	**DNA as genetic material—experiments of Avery, MacLeod and McCarty**
PSND	**DNA as genetic material—transformation with extracts of *Pneumococcus* (Alloway)**
P	DNA as genetic material—Dawson's *in vitro* experiments with heat killed transforming cells
PN	DNA as genetic material—Griffith's transformation experiments in the mouse
P	DNA—lack of enzymatic properties and apparent poor choice for genetic material
PSND	**DNA—the genetic material**
PSD	**Genetic material, necessary properties of**
ND	RNA as genetic material in virus

Extra-Chromosomal Inheritance

PND	**DNA in chloroplasts—genetic significance**
PSD	***Paramecium*—genetic studies of Kappa particles**
PD	Conjugation in *Paramecium*—genetic consequences of
N	Extrachromosomal inheritance—evidence for
N	Shell coiling in snails
N	Antigen production in *Paramecium*
N	Kappa particles in *Paramecium*
ND	Mitochondrial inheritance
D	Kinetosome—DNA content and centriole homology
D	Centrosomes and centromeres—episome relationships
D	*Chlamydomonas*—mating types and streptomycin resistance
D	Extranuclear genes—CO_2 sensitivity in *Drosophila*

TRADITIONAL GENETICS

Recombination and Linkage

P	Crossing over—dihybrid crosses of linked genes in *Drosophila*
P	Crossing over—equally frequent reciprocal types
P	Crossing over frequency—inheritance of specific alleles present
PD	Crossing over frequency—constant for any two genes
PSD	**Chiasma between two linked genes—genetic expectations**
PSND	**Genes—crossing over frequency as a measure of distance between genes**
PSND	**Genes—linear arrangements in three-point crosses**
PSND	**Linkage maps**
PSND	**Mapping function**
PSND	**Interference and coincidence**

PSND	**Linkage groups—concept**
PD	Linkage—parental types in linkage experiments
PSND	**Crossing over—recombinations of genes**
PN	Linkage of non-allelic genes
N	Recombination—function in adaptation
PSND	**Tetrad analysis in *Neurospora***
PSD	**Double crossing over in tetrads**
SND	**Cytological detection of crossing over**
SND	**Cytological mapping**
S	Bacterial recombination—methods of detection
N	Mutation and recombination
S	Recombination in fungi
N	Hybrid—definition of
PND	**Recombination frequency—computation of**
N	Linkage-analysis of F_1 and F_2 combinations
ND	Cross-over suppressors—effect of inversion
S	Recombination in viruses
D	Synapsis—mechanism of genetic pairing
D	Recombination—possible molecular events
D	Recombination frequency—relation to crossing over
D	Map unit distance—definition of
D	Non-reciprocal recombination
D	Negative interference—mechanism of
S	Recombination as a diversifying process
PND	**Variation—genetic and environmental factors**
PND	**Multigenic or multiple-factor inheritance of quantitative traits**
PD	Pleiotropism
PS	Penetrance and expressivity
PNS	**Gene action—from gene to gene product to phenotype**
PND	**Epistatic and non-epistatic gene action**
PND	**Dominance and non-dominance**
PND	**Gene interaction in phenotypic expression**
PN	Phenotypic ratios and gene interaction
PND	**Pseudo-alleles**
PND	**Chromosome basis of inheritance**
PND	**Alleles—multiple**
P	Developmental genetics
PSND	**Chromosomal activity—Balbiani rings in *Chironomus***
S	Gene expression and heteropyknosis of the X chromosome
SND	**Genotype concept**
N	Heterozygosity—concept of
SN	Homozygosity—concept of
ND	Allele concept in gene function
N	Dihybrid regulation of single phenotypic characters

ND Gene interaction—cyanide in white clover
ND Phenotype—concept of
PND *Drosophila*—phenotypic characters
PD Quantitative inheritance—influence of dominant genes
D Differential gene action—chromosomal puff patterns
D Phenocopy—concept of
D Dominance—production of functional gene product
S Population origin—hybridization
D Phenocopy—genetic and environmental influence
D *Mormoniella*—phenotypic characters

Genetic Segregation

PSN Segregation—independent
PN Starch test for different starch types in normal and waxy corn kernels
P Starch test in corn pollen and genetic analyses
P F_2 segregation in field corn pollen starch (waxy-normal)
P F_2 segregation in field corn kernel starch (waxy-normal)
P Backcross studies—field corn kernel and pollen starch
P F_1 studies in field corn kernel starch (waxy-normal)
PND Segregation—genetic (in man)
PND Hypothesis of genetic units—segregation and independent assortment
PN Gene hypothesis and mendelian segregation
PN F_1 studies in field corn pollen starch (waxy-normal)
S Random assortment of chromosomes during meiosis
SN Significance of meiosis and fertilization
N Preferential segregation in maize
PND Monohybrids—analysis of F_1 and F_2 generations
PND Test cross—use in genetic studies
N Corn—endosperm genetics
PND Multihybrids—F_1 and F_2 generations
PND Dihybrid ratios—analysis of F_1 and F_2 generations
N Haploidization—concept of
N Backcross—use in genetic studies
N Parental phenotype—determination from F_1 and F_2 generations
ND Monohybrid ratios—simulation by coin toss

Sex Linkage and Sex Determination

PN Sex linkage
PND Y chromosome—role in man
PN Sex determination—genic balance theory in *Drosophila*
PN Sex-linked genes—barred feathers in chickens

PND	**Sex-linked genes—white eyes in *Drosophila***
PND	**Sex determination—genetic basis**
PN	Y chromosome in *Drosophila*—role of
PS	X chromosome—dosage compensation for the human female
PN	Bar eyes in *Drosophila*
PN	Gynandromorphs in *Drosophila* and moths
PN	Sex-linked genes—lethal
ND	Sex chromatin—Barr body
N	Sex determination in plants
N	Sex linkage—analysis of F_1 and F_2 generations
PN	Sex linkage in mammals
PD	Sex linkage in man—genetics of color blindness
D	Sex determination in man—role of chromosomal abnormalities
PND	**Breeding techniques—handling and crossing of *Drosophila***
PD	Twin studies in man
P	Concordance studies in twins
PD	Twin studies—roles of environment and genotype
PSND	**Mendel's experiments**
ND	Pedigree analysis—use in human genetics
D	Breeding techniques—handling and crossing of *Mormoniella*

MUTATION

Classical Studies and Techniques

PSND	**Auxotrophic mutant isolation—methods**
PSND	**Analysis of biosynthetic pathways using auxotrophic mutants**
N	Genetic symbols
ND	Basic technique for recessive X chromosome—lethal mutants
P	Maxy technique for recessive X chromosome—visible mutants
P	Point mutations—detection of
PS	Preadaptive origin of bacterial mutants
N	Mutants—isolation and selection of
PND	***Drosophila*—techniques of observation**
PN	Salivary gland dissection from *Drosophila* larvae
PN	Chromosome staining for observation
N	Wild-type standard—use in genetic studies
N	Mutation in the T2 phage—detection
PND	**Mutation, bacterial, detection using replica plating method**
N	Mutation, bacterial, recognition—the fluctuation test
PD	*Drosophila*—methods of culturing
P	Selection of streptomycin-resistant bacteria—methods for
S	Bacterial mutants—types

Spontaneous Mutation

ND Mutation—types of
PSN Mutation rates—natural
P Spontaneous mutation of bacteria and intracellular mutagens
P Mutants and reproductive potential
P Mutational loads—man-made radiations and mutagens
PSND DNA and base pairing of analogs
PSND Tautomerization and changes in base pairing of DNA
PS Mutation—definitions
N Paramutation—definition of
ND Mutational equilibrium in populations
PD Suppressor mutations—mechanisms of action
PS Reversion—principle of
P Reversion index—definition of
S Reversion mutations of T4 phage mutants
D Mutability spectra—concept of

Induced Mutation

PS Induction of auxotrophic mutants of *Aerobacter aerogenes* (requiring L-arginine) with U.V. light
PSND Mutagens
SND Biochemical mutations—effects on DNA and protein
P Biochemical mutants and one-gene, one-enzyme, hypothesis of Beadle and Tatum
P Mutation—effects of ionizing radiation
D Tryptophan synthetase—amino acid substitutions
D Mutagens—effect of acridine dyes on DNA
D Mutagens—genetic analysis of mutagenic action
SD Genetic block—complete and leaky mutants

REPRODUCTION

MITOSIS

PS Centrioles—role in chromosome movement
PSD Spindle mechanism—isolation of
PSND Cytoplasmic partition (cytokinesis)

P	Nuclear partition—details of
P	Mitosis and cell division—essential features of
PD	Mitosis—phase films of Bajer and Bajer
PSND	**Mitosis—mitotic figures using *Allium* root-tip smears**
PND	**Mitosis—preparation of *Allium* root tips for smears. using aceto-carmine stain**
PSN	**Mitotic stages using charts and models**
P	Mitosis—cell division in the whitefish blastula
PND	**Mitosis—mechanics of**
P	Mitosis and the cell cycle
PN	Chromosome staining—the Feulgen reaction for DNA
SND	**Cell division—synchronized in *Tetrahymena***
SD	Cell division—energy relations
SD	Anti-mitotic agents
SND	**Mitosis—induction hypothesis**
S	Weismann's tissue culture methods
SND	**Cytological stages in mitosis**
PN	Centrosome—function in nuclear division
S	Mitosis—evolutionary development and advantage of
D	Nuclear division in bacteria—amitosis
D	Mitotic crossing over—principle of
SN	Mitosis as the transfer of genetic material
N	Nuclear division in fungi, algae, and protozoans by karyochorisis
D	Mitosis and DNA replication
D	Mitotic crossing over—mechanism of
N	Characteristics of nuclear division in the procaryota and eucaryota
D	Mitosis in living endosperm cells—cause
D	Birefringence of mitotic spindle

MEIOSIS

PN	Segregation of chromosomes in meiosis
PND	**Meiotic division, first, in the primary spermatocyte of the grasshopper**
PND	**Meiotic division, second—spermatogenesis in the grasshopper**
PD	Divisions of meiosis—first and second
P	Centromeres, homologous—separation during meiosis
P	Centromeres, sister—separation during meiosis
PSND	**Synapsis—problems of**
P	Tetrad formation during meiosis
PND	**Chromosome pairing, homologous, during meiosis**
PSND	**Heterospory in *Selaginella***
PSND	**Homospory in *Equisetum***

PN Meiosis—importance and significance of
PN Gametic or terminal meiosis
PN Sporic or intermediate meiosis
PN Zygotic or initial meiosis
PN Chromosome number reduction in meiosis
PN Reduction-division in *Ascaris*
PSN Meiosis—general description of events
PSND Chiasma formation during meiosis
P Chiasma formation and 1st and 2nd division segregation in meiosis
PND Meiosis in *Ascaris*
PSND Cytological analysis of meiosis
PN Oögenesis—time of meiosis in
S Germ plasm continuity—chromosome reduction division
S Variation in cytokinesis accompanying meiosis
SN Chromosomes, homologous—concept of
N Haploid concept in chromosome number
PN Diploid concept in chromosome number
N Sexual reproduction in the Chlorophyta
S Meiosis—evolutionary development and advantages of
D Tetrad analysis—effect of first and second division segregation

GAMETOGENESIS

Gamete Structure

P Egg classification by yolk content
PSN Sperm structure—spermatogenesis in man
PSD Egg structure in mammals—internal growth
P Egg structure in mammals—external means of growth
P Oöcyte structure in the teleost, using salmon
P Oöcyte states of growth
S Sperm structure in sea urchin
N Egg structure—amphibian
N Gamete types in algae

Reproductive Structures

P Gill structure of *Coprinus*
PSN Cone structure of *Pinus* (female)
PSN Cone structure of *Pinus* (male)
PN Seed structure using prepared slides of *Capsella*
P Archegonium and antheridium structure in mosses

SD	Flower—general structure and development of
PSND	**Flower—structure**
PD	Man—accessory reproductive structures (male)
P	Plant oögenesis and structure
P	Ovary structure—oögenesis
P	Ovary structure in the mammal
PD	Seminiferous tubule structure in the grasshopper showing spermatogonia
PS	Gametangia structure of *Allomyces*
PD	Graafian follicle development in mammals
PS	Pollen grain and pollen tube structure in angiosperms
PN	*Marchantia*—reproductive structures, sexual and asexual
SN	Crayfish reproductive system
S	*Clonorchis sinensis*—reproductive system structure
SND	**Earthworm reproductive system**
N	Frog reproductive system—structure
N	Basidium formation in club fungi—events in
N	Grasshopper reproductive system and function
N	*Ascaris*—reproductive system structure
S	Sporophyte formation in *Funaria*
S	*Platyzoma*—a non-homosporous fern
SD	*Neurospora*—ascus formation
D	*Aspergillus*—heterokaryon and diploid spore formation
S	Gametangia structure in liverworts
S	Gametangia structure in mosses
S	Gametangia structure of *Anthoceros*
S	Gametangia structure in *Saprolegnia*
SD	Fern gametangia structure
S	Ovary position in the flower—hypogyny, epigyny and perigyny
S	Spore discharge from the sporangium in fern
ND	Zygospore formation
ND	Sperm release (induced) from antheridium in fern

Gamete Differentiation

P	Egg differentiation in the plant gametophyte
PSND	**Egg differentiation in human oögenesis**
P	Spermatid differentiation into spermatozoa in grasshopper
PSN	**Gamete differentiation in the male animal**
SND	**Megasporogenesis in plants**
SND	**Microsporogenesis in plants**
PSND	**Gametogenesis—micro- and mega- in an angiosperm**
PSN	**Gametogenesis—micro- and mega- in gymnosperms**
P	Vitelline membrane formation

P Egg development in the ovary of humans
D Hormone control of egg maturation in mammals
D Oögenesis in *Ascaris*—gamete formation

FERTILIZATION

Egg and Sperm Union

PS Fertilization—physiological changes after
PS Fertilization membrane
PS Fertilization reaction
SND Fertilization in angiosperms—description of events
PND Fertilization—fusion of male and female pro-nuclei
PSN Fertilization—sperm penetration
PS Acrosome reaction
PD Fertilization of egg by sperm in the sea urchin—observation of
PS Fertilization of frog eggs with sperm—observation of
P Gamete release in the sea urchin—stimulation of
PS Gamete release in *Allomyces*—observation of
PS Fertilization in *Allomyces*—observation of
SND Pollination—methods of pollen transfer
SN Sexual reproduction—fusion of two cells
N Copulation in animals—transfer of sperm
S Mating systems—definition of
S Pollination—concept of
D Fertilization—history of discovery
D Fertilization in *Ascaris*—description of events

Hormone Control

PS Ovulation, induced, in a female frog using pituitary hormone
P Fertilizin and antifertilizin
P Genetic hormones or gamones
PN Estrous cycle in humans—hormone control of
S *Achlya*—hormone control of gametangia formation
D Hormone control of pregnancy—the corpus luteum
N Menstrual cycle

Parthenogenesis

P Parthenogenesis—concept of
P Parthenogenesis and egg activation
N Parthenogenesis and genic variability
N Apomixis

REPRODUCTIVE CYCLES

Animal

P	Reproduction—maintenance of kind
SN	Nematoda—life cycles
SN	Cestoda life cycles
SN	*Clonorchis sinensis*—life cycle of
SN	Trematoda—reproductive cycle
SN	*Hydra*—life cycle of
SN	Earthworm—reproductive cycle
SN	Frog—life cycle of
N	*Planaria*—sexual reproduction in
SN	Alternation of generations in the animal kingdom
N	Asexual reproduction in the phylum Porifera
N	Sexual reproduction in the phylum Porifera
N	Starfish—life cycle of
N	Lamprey—life cycle of
PND	***Drosophila*—life cycle of**
D	*Mormoniella*—life cycle of
D	Reproduction in the coelenterates—types
D	Ovipary and vivipary—concept of
D	*Porphyra*—life cycle of

Plant

PN	Gymnosperm life cycle (Pine)
PN	Fern—life cycle of
PSND	**Liverwort—life cycle of**
PSND	**Moss—life cycle of**
PSN	**Alternation of generations in the plant kingdom**
PSN	**Haplobiontic haplont reproductive cycles in plants**
PSN	**Haplobiontic diplont reproductive cycles in plants**
N	*Psilotum*—life cycle of
SN	*Selaginella*—life cycle of
SN	*Equisetum*—life cycle of
N	Lichen—life cycle of
N	Antithetic theory of alternation of generations
N	Cycad—life cycle of
SN	Gemmae—asexual reproduction of liverworts
N	Isomorphic alternation of generations
N	Heteromorphic alternation of generations
N	Alternation of generations—morphological significance
N	Angiosperm—life cycle of

N Ginkgo—life cycle of
N Asexual reproduction by fragmentation
N Homothallism in plant reproduction
N Heterothallism in plant reproduction
N Corn—life cycle
S Asexual reproduction in plants—kinds of
S Diplobiontic life cycles

Protist

N Rotifer—life cycle of
SN Yeast life cycle
SN *Rhizopus* life cycle
N *Chondromyces*—life cycle of
N *Tetrahymena*—reproductive cycle
SND Reproduction by binary fission
SND Conjugation in *Paramecium*
SND *Paramecium*—life cycle of
SN *Plasmodium*—life cycle of
SN Slime mold—life cycle of
SN Reproduction by fission
N Vegetative reproduction—characteristics of
SN Asexual reproduction by budding
SN Asexual spore formation in fungi
N *Acetabularia*—life cycle of
N *Ectocarpus*—life cycle of
N *Ulva*—life cycle of
N *Vaucheria*—life cycle of
N Algae asexual reproduction—types of
N Parasexual cycle in fungi—characteristics of
N Asexual reproduction in the Cyanophyta—types of
N *Polysiphonia*—life cycle of
N *Laminaria*—life cycle of
N *Fucus*—life cycle of
PSND *Neurospora*—life cycle of
SN *Allomyces*—life cycle of
SN *Saprolegnia*—life cycle of
N *Albugo*—life cycle of
N *Synchytrium*—life cycle of
N *Puccinia*—life cycle of
N *Ustilago*—life cycle of
N Desmid—life cycle of
SN *Agaricus*—life cycle of
SN *Volvox*—life cycle of

N *Oedogonium*—life cycle of
N *Ulothrix*—life cycle of
N *Oscillatoria*—life cycle of
N *Gloeocapsa*—life cycle of
SN *Aspergillus*—life cycle of
N *Penicillium*—life cycle of
N *Neanthes virens*—life cycle
PN *Spirogyra*—life cycle of
PSN Bacteriophage—life cycle of T4
PN Diatoms, e.g., *Pinnularia*—life cycle of
PSN *Chlamydomonas*—life cycle of
N Sexual reproduction in the Chlorophyta—types of
N Asexual reproduction in the Chlorophyta—types of
SN *Pilobolus*—life cycle of
SN *Achlya*—life cycle of
S Sexual and asexual life of the Procaryota
S *Sordaria* life cycle
N Reproduction in fungi, algae, and protozoans by centripetal invagination

TAXONOMY

GENERAL TAXONOMY

PN Organism classification—broad categories used
PND Classification—procedures used in classification of organisms
PSN Taxonomic principles—systematics, classification, and nomenclature
SN Taxonomy—modern approaches to
S Classification—historical development of system
N Eucaryota—characteristics of
SN Classification, natural—characteristics of
SN Classification, phylogenetic—characteristics of
SN Classification, numerical—characteristics of
N Classification, artificial—characteristics of
SN Nomenclature—binomial system of Linnaeus
S Taxonomic structure—hierarchial basis

PLANT CLASSIFICATION

PD Algae, protozoan, and micro-crustacean classification, using a dichotomous key
P Embryophytes (non-vascular)—characteristics used for identification
P Tracheophytes—characteristics used for identification
PSN Angiosperms—characteristics used for identification
PS Life forms of terrestrial plants (Raunkaier)
P Life form (Raunkaier) identification in a woodland community
P Classification of trees, shrubs, vines, and herbs
P Gymnosperm classification using twenty evolutionary characteristics
PN Gymnosperm classification using a dichotomous key
P Tree classification using a dichotomous key for leaf characteristics
P Angiosperm classification using a dichotomous key
P Plankton and nekton classification in a pond ecosystem using Wisconsin plankton net
P Plankton classification in a lotic ecosystem using Wisconsin plankton net for collection
N Division Anthophyta—characteristics used for identification
N Division Coniferophyta—characteristics used for identification
N Class Anthocerotae—characteristics used for identification
N Tracheophytes—characteristics used for identification
N Class Musci—characteristics used for identification
N Division Bryophyta—characteristics used for identification
N Class Hepaticae—characteristics used for identification
N Labyrinthulidae—characteristics of
N Lichen classification—method of
N Phanerogamic plants—concept of
N Cryptogamic plants—concept of
N Division Pterophyta—characteristics used for identification
N Division Calamophyta—characteristics used for identification
N Division Lepidophyta—characteristics used for identification
N Division Psilophyta—characteristics used for identification
N Acrasineae—characteristics of
N Cyanomyxae—characteristics of
N Mycoplasmae—characteristics of
N Plasmodiophorae—characteristics of

ANIMAL CLASSIFICATION

P Macrofauna—classification of organisms found in soil surface and litter

P	Macrofauna—classification of organisms found below soil surface
P	Insect classification
ND	Phylum Chordata—characteristics used in identification
P	Macrofauna—classification of organisms found under logs and tree bark
P	Benthic organisms—classification of organisms in a lotic ecosystem
P	Primate classification and phylogeny
S	Trematoda—characteristics used for identification
SN	Phylum Porifera—characteristics used in classification
SN	Platyhelminthes—characteristics used for classification
SND	**Annelida—characteristics used for classification**
SND	**Arthropoda—characteristics used for classification**
S	Nematoda—characteristics used for identification
SN	Coelenterata—characteristics used for identification
N	Bony fish classification using a dichotomous key
ND	Phylum Mollusca—characteristics used in identification
N	Amphibia—classification using a dichotomous key
N	Order Squamata—characteristics used for identification
N	Phylum Echinodermata—characteristics used for identification
N	Phylum Aschelminthes—characteristics used for identification
N	Class Mammalia—characteristics used for identification
N	Phylum Hemichordata—characteristics used for identification
N	Class Aves—characteristics used for identification
N	Class Cyclostomata—characteristics used for identification

PROTIST CLASSIFICATION

P	Classification of invertebrates—classification of organisms found in a woodland community
PSN	**Protozoan classification**
P	Classification of microcrustaceans
P	Invertebrate phyla—classification
PN	Gram stain technique use in identification of bacteria
ND	Bacterial types—cocci, baccilli, and spirilla
PSN	**Plaque technique—identification of bacteriophage**
PN	Plaque morphology determined by genotype of bacteriophage
PN	Gram stain—chemical composition of the bacterial cell wall
N	Division Euglenophyta—characteristics used for identification
N	Division Mycophyta—general characteristics
N	Division Mycophyta—characteristics used for identification
N	Division Phaeophyta—characteristics used for identification
N	Division Rhodophyta—characteristics used for identification

N Division Schizophyta—characteristics used for identification
N Division Chrysophyta—characteristics used for identification
N Division Pyrrophyta—characteristics used for identification
ND Protista—characteristics of
N Protists, lower—subdivisions of
N Spirochaetes—characteristics used for identification
N Eubacteria—principal subdivisions
PND Algae classification using a dichotomous key
N Division Chlorophyta—characteristics used for identification
PD Fungi—characteristics used for identification
N Deuteromycetes—classification system used
SN Class Basidiomycetes—characteristics used for identification
N Class Phycomycetes—characteristics used for identification
ND Class Ascomycetes—characteristics used for identification
N Pigment types found in algae
N Division Cyanophyta—characteristics used for identification
N Deuteromycetes—pathogenic forms
N Myxobacteriae—characteristics of
N Actinomycetes—characteristics of
S Ciliata—characteristics used for identification
ND Phylum Protozoa—characteristics used for identification
S Mushroom identification—the spore print
S Spore print preparation using *Agaricus*
N Biochemical characterization of bacteria—methods

DEVELOPMENT

EARLY DEVELOPMENT

Cleavage

PN Cleavage patterns of the protostomia and the deuterostomia
PD Fertilized frog egg—animal and vegetal hemispheres
PD Cleavage in frog
P Cleavage and polar cap formation in the teleost embryo, *Salmo*
P Cleavage in sea urchin zygote
P Cleavage in insect eggs
PN Cleavage in starfish
PN Cleavage—holoblastic radial, bilateral, and spiral

P	Cleavage—meroblastic
PN	Cleavage—discoidal
SN	Spiral cleavage in *Urechis*
D	Cleavage stages in the perch
D	Cleavage stages in the salamander
D	Cleavage stages in the chick embryo

Blastula Formation

P	Implantation in rat—blastocyst contact with endometrium
P	Implantation in mammal—structure of the embedded blastocyst in rat
P	Implantation in the mammal—umbilical cord development in rat
PN	Implantation and trophoblast activities in the human
P	Blastodisc formation in the teleost embryo, *Salmo*
P	Early organogenesis in the teleost embryo prior to gastrulation
PND	**Blastula formation in the frog**
PN	Blastula stage in starfish
P	Morula stage in starfish embryo development
P	Germ layers and their derivatives in starfish embryo
P	Germ layer and derivatives in the frog embryo
PN	Blastopore—fate in the protostomia and deuterostomia
P	Placental types
P	Chorio-allantoic development
ND	Blastocoel formation
N	Placenta—anatomy of
N	Placenta—permeability and diffusion

Gastrulation

PS	Gastrulation—cell movement during
P	Gastrulation in the teleost embryo
P	Gastrulation in mammals
PSD	**Gastrulation, amphibian**
P	Hypoblast, epiblast, and blastocord formation in the chick
PS	Gastrulation in the sea urchin
PN	Gastrulation in the starfish
S	Gastrulation in *Urechis*
S	Gastrulation—role of grey crescent in (Curtis)
S	Yolk content effect on gastrulation

Early Development in the Chick

P	Chick embryo structure at 24 hours
P	Chick embryo structure at 48 hours

P Chick embryo structure at 72 hours
P Chick embryo structure at 96 hours

GERM LAYER DERIVATIVES AND ORGANOGENESIS

Mesoderm derivatives—Somites and Lateral Mesoderm

P Endo-mesoderm formation of the protostomia and deuterostomia
P Mesoderm derivatives in the 24-hour chick
P Somites and derivatives
P Somite formation in the 33-hour chick embryo
P Somite in 48-hour chick
P Coelom development in the chick embryo at 24 hours
P Coelom in pericardial region in the 24-hour chick
P Coelomic development in the protostomia and deuterostomia
P Lateral mesoderm—development of appendages and vertebral column
P Limb formation
PSN Muscle formation
SN Mesodermal derivatives in vertebrates

Endoderm Derivatives—Digestive Tract

P Foregut establishment in the chick embryo at 24 hours
P Foregut lengthening in the 33-hour chick embryo
P Digestive tract development in the 48-hour chick embryo
P Digestive system development of the 72-hour chick embryo
SD Endodermal derivatives shown with a dissected frog
N Epithelial tissue types derived from endoderm

Ectoderm Derivatives—Central Nervous System

PN Neural groove formation in the chick embryo at 24 hours
PD Neural groove closure in the chick embryo at 33 hours
P Neuropore formation in the 33-hour chick embryo
P Sinus rhomboidalis formation in the 33-hour chick embryo
P Neural crest formation in the 48-hour chick
P Brain region structure in the chick embryo at 33 hours
P Telencephalic region in the 48-hour chick embryo
P Telencephalic vesicles in the 72-hour chick embryo
P Nervous system development in the 72-hour chick embryo
P Spinal nerve formation in the 72-hour chick embryo
P Spinal cord formation in the 72-hour chick embryo

P	Cranial ganglia formation in the 72-hour chick embryo
PND	**Neural groove structure (late) in the frog embryo**
PD	Neural tube struct[illegible] (late) in the frog embryo
SND	**Ectodermal deri[illegible] vertebrates**

Ectoderm Deriva[illegible]—Sense Organs and Epidermis

P	Optic vesicle development in the 48-hour chick embryo
P	Eye lens development in the 48-hour chick embryo
P	Eye development in the 72-hour chick embryo
P	Ear development in the 72-hour chick embryo
P	Olfactory organ development in the 72-hour chick embryo
P[illegible]	Skin—an ectodermal derivative

Pharyngeal Arches and Derivatives

P	Pharyngeal arches—development
P	Pharyngeal pouches—development
P	Aortic arches—development
P	Respiratory system—development in the 72-hour chick embryo

Urogenital System Derivatives

P	Urinary system development in the 48-hour chick embryo
P	Urinary system development in the 72-hour chick embryo, pronephros, mesonephros, and metanephros
P	Urogenital system development and sex determination—interrelation
PS	Gonad development
P	Kidney—embryonic development in the vertebrate, especially mammal
P	Ducts—development of reproductive and urinary tract

Circulatory System Derivatives

P	Area vasculosa in the chick embryo at 24 hours
P	Area vasculosa in the 33-hour chick embryo
P	Heart and omphalomesenteric veins in the 33-hour chick
P	Heart development in the 48-hour chick
P	Aortic arches and fusion in the dorsal aortae in the 48-hour chick
P	Embryonic circulation in the 72-hour chick
P	Blood formation
P	Lymphopoiesis, thymus and spleen development
P	Circulation patterns—embryonic and adult
P	Heart formation—pattern of
P	Heart development from bilateral primordia

ANALYSIS OF DEVELOPMENT

Organization of the Egg

P	Polarity of growth—types of
PD	Polarity of egg—environmental influences on
P	Morphogenic gradients in the egg cytoplasm
P	Regulative vs. mosaic eggs
PSN	**Organization of the egg before fertilization—visible**
PD	Organization of the egg after fertilization—visible
P	Localization and organization of egg—origin of
PSND	**Nuclear role in egg development**
PS	Regulation in animal embryos
PS	Blastomeres—separation in sea urchin embryos
P	Egg organization and development
PD	Blastomeres—separation in frog embryo
S	Cytoplasmic determinants in the sea urchin egg
N	Polarity of the unfertilized egg
N	Egg development—role of extrinsic factors (CO_2 in *Hydra*)

Fate Regions in the Early Embryo

PD	Mapping of blastoderm—techniques
P	Presumptive regions of gastrula
PD	Cell movement during gastrulation—tracing methods

Morphogenic Movements

P	Morphogenic movements—chemical gradients and
P	Surface affinities
P	Carbon marking of explanted chick embryos of 18 to 20 hours (Spratt method)
PS	Contact guidance—Harrison's study on nerve growth
P	Contact guidance—Weiss' experiments on nerve regeneration
P	The culture of chick cells on an oriented surface
P	Chick removal and dissociation of chick embryo skin cells
P	Chick cell culturing on fish scale lamellae—cell movements
P	Killing, fixing and staining of chick skin cells on fish-scale lamellae
SD	Morphogenic movements—types
S	Cell recognition—concept of

Induction

PND	**Induction—Spemann and Mangold experiment**
PND	**Induction as a chemical phenomenon**

PN Inducer and induced tissues interaction
PND Organizer—dorsal lip as
PSD Induction of nervous system
P Gastrula—potency of regions
P Potency expression—dependence on relation to rest of embryo
P Potency of regions—progressively restricted in early gastrula
PS Determination—the selection of potencies
P Ectoderm flexibility in early gastrula
PD Transplant experiments
PS Induction—hypothesis of
PSD Inducing substance—nature of
P Inducers—chains of
S Nuclear determinants beyond the 32-cell stage
SD Determinants—nuclear and cytoplasmic interaction in embryo development
D Implant development—influence of host environment
D Eye lens formation—optic cup as organizer

Fields

P Embryonic fields—definitions
P Neuralizing gradients—dorsal-ventral in embryo
P Mesodermalizing gradients—anterior-posterior in embryo

Theories of Development

P Morphogenic processes
PSD Preformation
PSD Epigenesis
P Preformation, molecular—the modern view
PD Development as a chain of inhibitions
P Developmental aspects of growth
PS Development as a chain of evocations
PD Development as a change in genetic complement of nuclei
PSD Nuclear equivalence—problem of
PSN Differentiation—nuclear control, e.g., *Acetabularia* experiments
S Enucleation and renucleation studies—support of epigenesis
S Gene expression—cytoplasmic influences
S Gene expression—environmental influences
SD Cellular differentiation
S Segregation hypothesis in embryo development
SD Unidirectionality of development
SD Ontogeny concept in development
SN Neural and hormonal integration in development
SND Nucleus and cytoplasm relations in development

PN Environmental influence on differentiation
N Greode concept in differentiation
N Plasmagenes—role in differentiation
N Fern ontogeny
S Nuclear determinant segregation—Weismann's hypothesis
S De-differentiation—concept of
S Differentiation and ability to undergo mitosis
D Differential gene action—concept in development
N Developmental patterns in the metazoa
D Recapitulation theory of Haeckel
D Mosaic theory of development—Roux's

Experimental Techniques

P Incubation of chicken eggs for embryonic studies
P Chick embryo removal from the egg—techniques of
P Chick embryo culturing on an artificial medium (Spratt technique)
S Egg extraction from *Urechis* for developmental studies
N Tissue culture methods of Weismann
S Isolation of specific recognition material from vertebrate tissue
PS Nuclear clones—use in study of differentiation
D Nuclear transplantation—Briggs and King experiments
D Eye anlage transplantation in *Drosophila* larvae

MORPHOGENESIS IN OTHER FORMS

Slime Molds

P Morphogenesis in the cellular slime mold *Dictyostelium discoideum*
P Slime mold culturing method
P Myxamoeba aggregation patterns in the cellular slime mold *Dictyostelium discoideum*
P Morphogenesis in a cellular slime mold—dissection of slug and its effect on morphogenesis
P Morphogenesis—homogeneity of slug cells in *Dictyostelium discoideum*
P Slime molds—general characteristics

Insect Metamorphosis

P Hemimetabolous types in insect metamorphosis
PSN Homometabolous types in insect metamorphosis

Amphibian Metamorphosis

P Metamorphic changes in the frog
P Ammonotelism to urotelism in amphibians
P Hemoglobin synthesis during metamorphosis in amphibians
S Amphibian physiological adaptations

Hormone Control

PD Molting—hormone control in insect metamorphosis
P Thyroid gland—accelerated activity during metamorphosis
P Thyroxin effect on amphibian metamorphosis (pellets of thyroxin + cholesterol)
PD Thyroxin effect on amphibian metamorphosis (dilute solution)
S Pheromones
D Hormone control of molting in Crustacea
D Hormone control of molting in arthropods

REGENERATION

Hormonal Effects on Regeneration Competency

PSN **Regeneration in *Planaria*—regeneration of short transverse pieces**
PS Regeneration in *Planaria*—regeneration from oblique surfaces
PS Regeneration in *Planaria*—lateral regeneration
P Regenerative powers—whole plant from single cell
S Regeneration of amphibian limbs—developmental integration
S Regeneration of amphibian limbs—source of blastema cells
S Regeneration of amphibian limbs—role of epithelium
S Regeneration of amphibian limbs—thyroid and adrenocortical hormone effect
S Regeneration of amphibian limbs—innervation effects on regeneration competency
S Regeneration of differentiated structures, using *Blepharisma*
S Regeneration in *Physarum polycephalum*—hormonal effects on regeneration competency
N Regeneration and autotomy of crayfish

PLANT GROWTH AND DEVELOPMENT

Germination

PS Seed growth—epigaeous germination

P Seed growth—hypogaeous germination
PSN Seed germination—the effect of red and far-red light on germination
P Embryo growth using planted kidney bean seeds
PS Suspensor formation in angiosperms
PS Gametophyte development, fertilization, and development of the embryo in Gymnosperms
D Plant morphogenesis—techniques of study
PSD Seed formation in the Gymnosperms—ovule development
P Endosporic development of the gametophyte of *Isoetes*
PS Endosporic development of the gametophyte of *Selaginella*
S Phytochromes—conversion of P735 to P660 in darkness
S Concept of vernalization in plant growth
N Dormancy in plant seeds
N Differentiation of the plant zygote and embryo formation
N Seed production in plants—advantages of
ND Seed evolution
N Seed formation—general
S Embryo development in Angiosperms
D Plant morphogenesis—embryo growth outside of archegonium
ND Dormancy as an inhibition to growth
ND Seed germination—factors influencing
N Seeds, dormant—survival periods
N Dormancy—biological advantages of
N Seed dormancy—effect of embryo maturity
N Seed dormancy—environmental effects of
D Radiation effects on seedling growth from seeds
N Seed germination—viability tests

Apical Growth

PSD Apical growth and dominance in plants
PN Polarized growth
PN Polarity of plant embryo—established by first division
P Polarity of axis in plants—determination of
PSND Apical meristems
PN Shoot apex
P Plant growth measurement
PN Embryo growth, using wet and dry weight and length measurement
P Structure of the bean root in relation to root growth using charts and models
PN Root apex
PSN Pericycle origin of lateral roots
SN Root growth—identification of growth areas using India ink markings

PN	Embryonic potential of plant retained through adult life
SND	**Leaf development from primordia**
S	Apical cell growth—concept of
SN	Leaf— growth of
S	Leaf trace—differentiation of vascular tissue
D	Leaf development
D	Apical meristem—the functional center location hypothesis
D	Apical meristems—mapping of physiological fields in leaf growth
D	Polarity of plant embryo—developmental and metabolic consequences
D	Organ culture of pea roots
N	Plant growth—thermoperiodicity
N	Plant growth—temperature effects on chemical reactions
N	Plant growth rate—temperature effects
N	Plant growth—optimum temperature ranges
N	Stem growth rate—the sigmoid curve
N	Plant growth—methods of measuring environmental influence
N	Plant growth and Liebig's law of the minimum
N	Plant growth—environmental factors affecting
D	Seasonal growth in plants—annuals, biennials, and perennials

Lateral Growth

P	Differential growth
PSN	**The lateral cambia**
PD	Lateral growth in plants—meristematic region function
SND	**Growth ring formation in secondary xylem**
SND	**Cork cambium—structure and function in bark formation**
S	Woody stem—differentiation of the vascular cambium

Bud Development

P	Morphogenesis in *Epibolium*—isolation of leaf primordia from shoot apex
PD	Morphogenesis at the apex of *Epibolium*
N	Bud dormancy—chemical inhibition and day length
N	Bud dormancy—growth inhibitors
N	Bud dormancy—environmental factors responsible for
D	Leaf position—function of meristem

PLANT HORMONES

Auxin

PD	Auxins and tropisms
PSND	**Auxin concept**

PSND	**Auxin (IAA) relation to negative geotropism in the stem and positive geotropism in the root**
N	Hormones, plant—types and functions
PSD	**Auxin (IAA)—coleoptile sensitivity to concentration**
PSN	**Auxin and light relationship in hypocotyl elongation**
PN	Auxin (IAA)—root sensitivity to concentration
PSN	**Auxin (IAA) effects on stem and petiole growth in *Coleus***
PSN	**Auxin (IAA) effects on leaf abscission, using *Coleus***
PSND	**Auxin and relationship to phototropism**
SN	Auxin (IAA) effect on plant cell elongation
SN	Auxin (IAA) induction of root formation
SD	Auxins and apical dominance
S	Auxin—structure of the IAA molecule
S	Auxins—sites of synthesis
S	Auxins—techniques used to isolate
SN	Polarity influence on auxin (IAA) transport
S	Auxin and kinetin—interaction in seedling
SD	Auxin effect on xylem differentiation
N	Auxin—directional transport
N	Auxin—history of discovery
N	Auxin—neutralization of coconut milk inhibitor in cell division
N	Auxin—effect on cell permeability
N	Herbicides—physiological effects
N	Herbicides—selective toxicity
N	Bioassay for 2,4-D—inhibition of root elongation

Kinetin

PS	Plant tissue culture—the effect of kinetin on growth of *Nicotiana* tumor
P	Plant tissue culture—the effect of kinetin on growth of *Nicotiana* pith, using White's medium
PN	Kinetin in plant development
N	Kinetin—molecular structure
N	Cell division—stimulation by coconut milk constituents
D	Growth factors—coconut endosperm effect on carrot tissue (Steward)

Gibberellin

PSN	**Gibberellins in plant development**
ND	Gibberellic acid effects on bean plant growth
PN	Gibberellic acid effects on a dwarf corn mutant and wild type corn
S	Gibberellin effect on vernalization requirements in flowering plants

ND Gibberellin—history and effect on plant growth
N Gibberellins—economic uses in plant growth

Flowering Hormone

PND Flowering in "short day" plants
PN Flowering hormones
SD Phytochromes—role in periodicity
SND Photoperiodism—florigen hypothesis
SN Photoperiod responses in flowering plants

Other Hormones

P X-factor produced by roots, needed by shoots
PS B-vitamins in plant development
PN Growth inhibitors and seed dormancy

GROWTH

In Relation to Biosynthesis

PSND Factors influencing growth
PSND Growth as synthesis of protoplasm
PS The component processes of growth
PS Relation of RNA synthesis to growth
PS RNA-protein, RNA-DNA ratios in "fast-" and "slow-growing" cultures of *E. coli*
PS Protein assay in "fast-" and "slow-growing" cultures of *E. coli*
PS RNA assay in "fast-" and "slow-growing" cultures of *E. coli*
PS DNA assay in *E. coli* "fast-" and "slow-growing" cultures
N Bacterial growth—control by DNA nucleoid

Of Cells

PSND Cell division—an aspect of growth
S Cellular growth control
N Aging and death of cells
S Thermal resistance of dormant cells
PN Latent period in phage replication—determination of
N Bacteria—relative insensitivity to pH
S Cell growth in plants—environmental influences

Of Organisms

N Human growth and life span

SN Heat resistance and heat death
SN Cold resistance and cold death
SD Pressure effects on growth
PS Temperature and salinity effects on hatching of *Artemia* eggs

Of Populations

PSN Autocatalytic process of bacteria growth
PS Bacteriophage replication
N Colony formation by bacteria—implications and characteristics
ND Generation time concept in population growth
S Population dynamics—types of
S Population distribution
N Human population size—regulatory factors
S Natality—definition of
S Balanced and unbalanced growth—concept of
P Incubation and temperature effect on specific growth rate
PN Medium composition effect on specific growth rate
P Genetic constitution effect on specific growth rate
N Growth, bacterial—temperature effects
N Mesophilic microorganisms—characteristics of
N Psychrophilic microorganisms—characteristics of
N Thermophilic microorganisms—characteristics of

Quantitative Aspects and Techniques

PS Growth rate equations
PSND Phases of bacterial growth—lag, accelerating, exponential, decelerating and stationary phases
PND Concept of growth
PN Measuring growth of a single cell—methods
S Optimum rates of increase in population—mathematical formulae
S Litter size—mathematical model
S Natality rate—concept of
S Natality rate—mathematical expression
S Age pyramids
PS Specific growth rate of a population—concept of
PS Specific growth rate determination for *A. aerogenes*—total protein and RNA content methods
PS Specific growth rate determination for *A. aerogenes* by cell count methods
PS Specific growth rate of *A. aerogenes*, using turbidity
PN Specific growth rate calculation—generation time
PND Population growth—quantitative methods of measurement
PN Viable count technique for bacteria cultures

P	Growth rate of *E. coli* using serial dilution counting method
PSN	**Turbidity as a measurement of growth in microorganisms**
PS	Dry weight calculation of a bacterial cell
SN	Asepsis
PSN	**Sterilization methods and techniques**
PN	Sterile technique principles in the handling of bacteria
PSN	**Agar slants—preparation for culturing microorganisms**
PSN	**Media preparation for bacteria culturing**
PN	Serial dilution, and plating—methods and techniques for bacteriophage culturing
PS	Multiplicity of bacteriophage infection—determination of
PN	Bacteriophage presence—the plaque
PSN	**Burst size determination in T4 phage replication**
PS	Mammalian cell (HeLa) culturing techniques
PS	Plating efficiency of cultured mammalian cells (HeLa)—determination of
S	Determination of total unabsorbed phage
S	Growth curve of a phage
N	Selective media concept in growth of microorganisms
N	Petri dish—history and use in microbiology
N	Culture media—history of development
N	Pasteurization—method
S	Single cell growth in plants—methods of culturing
D	Sterile technique—method of spore inoculation
N	Anaerobic culture methods
N	Soil microbes—methods of isolation
N	*Chlorella*—culture development in light and dark
N	Mold cultures—the slide culture technique
N	Bacteriological filters—types of
N	Microbe susceptibility to antibiotics—the disc-plate technique
PN	Pure culture technique for the study of microorganisms
PN	Micromanipulation—isolation and culturing of bacterial cells
SN	Plating of bacteria on solid medium
PSN	**Serial dilution techniques in isolation and culturing of bacterial cells**
PN	Enrichment culture technique in isolation of pure bacterial cultures
PN	Streak plate method of bacteria isolation
N	Dilution shake cultures—isolation of anaerobic bacteria
PD	Replica plating—method of
PD	Isolation of *Neurospora* asci
P	Centrifugation—use in concentrating bacterial suspensions
SD	Logistics—application to human populations
PS	The logistic curve of population growth

SD Logistic curve—assumptions in the use of
PS Logistic curve—experimental models
PN Exponential growth of bacteria
PN Culture media types—synthetic and complex
N Culture maintenance techniques
N Culture media—oxygen concentration control methods

MISCELLANEOUS

PROBABILITY, STATISTICS, AND BIOMATHEMATICS

P Statistical operations—definition and use by biometricians
P Frequency distributions in biological studies, a tally of categorical observations
PS Histogram—a graphic representation of the frequency distribution
PN Central tendency measurement—mean, median, and mode
PN Dispersion in populations—range, standard deviation, and coefficient of variation
PD Probability and probability distributions—binomial distribution, Poisson distribution, and normal distribution
PD Statistical inference and confidence intervals—Chi square, Student's t-test and variance ratio tests
P Mensuration and treatment of numerical data using four species of *Paramecium* and Student's *t*-test
P Logistic curve—mathematical expression
PN Normal Gaussian distribution
P Poisson distribution
PND Binomial distribution
P Sampling techniques in populations
P Frequency distributions
PN Probability distributions
P Variables of populations—events or measurements
ND Probability (p) value—definition of
N Standard error—definition of
ND Chi square—definition and uses of
D Probability—genotypic ratio determination
D Population dynamics—mathematical models
D Probability—basic theorems
P Statistics in population studies—significance of

OTHER MISCELLANEOUS

PSN	Photosynthesis—historical development
PS	Organism—definition of
N	Cell origin from pre-existing cells
PD	Life—a definition of
S	Life, characterized by replication, metabolic turnover and regulation of energy flow
N	Living matter—characteristics of
N	Living systems—characteristics of
S	Attributes and characteristics of the living organism
N	Biological systems—common features
N	Characteristic differences between animals and plants
S	Common denominators of all forms of life
S	Approaches to molecular biology—biophysical, biochemical and genetic
PS	Critical historical developments in molecular biology
N	Disciplines of botanical study
S	Life on earth—matter in a highly aggregated and organized state
N	Algae—economic importance
N	Bacteria—use in genetic studies
SD	The relation of cell physiology to the fields of animal, plant and comparative physiology
SD	The literature of cell physiology
S	Formation of the sun's planets—spinning-disc condensate theory
S	Dessication—problems of
S	Centrifuge—operational techniques
S	Balance, Mettler—operational techniques
S	Agitation equipment—operational techniques
SD	Effect of physiological state
S	Cultural bias in biological interpretation
S	Anthropocentrism in biological interpretations
S	Mortality—concept of
PN	Physiology—general concept and scope
P	Biology—aims of a course in structural biology
P	Organism—a definition of
P	Biology—aims of a course in cell biology
P	Agricultural revolution
P	Life—molecular insights into
P	The levels of biological organization
S	Nutritional and chemotherapeutic biotechnology
SND	Vitalistic and mechanistic interpretations of life activities
SND	Life activities—types and problems of

S	Individuals of a population—genetic definition
PS	Larval types of the protostomia and deutcrostomia
N	Metabolism—gross energy balance
N	Compensation point in plants
PS	Larval stages of the crustacean

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APPENDIX

Catalogue Descriptions of Core Courses

The following are the catalogue descriptions of the core courses in biology within the four institutions. The supplementary reading materials accompanying each course are indicated. While an analysis of textbooks and supplementary materials was not a part of this report, it is of interest to see the sort of reading materials to which the students were exposed. In perusing this list, however, the reader should keep in mind that it **represents only those reading materials in use during the academic year encompassed by this report** (1965-66). Since that time, the core programs at the four institutions have undergone (and are still undergoing) considerable revision. Textbooks have been changed, some supplementary readings have been dropped and others added. Thus, the list in use *today* would differ significantly from the one presented here, and will undoubtedly differ from any in the future.

PURDUE UNIVERSITY

Principles of Biology (Biology 103-104)

Semesters 1 and 2. Lectures-2; Laboratories-2 (1 hour); credits-3.
The nature of the living state, and experimental approaches in studying it.

Reading Materials:

Weisz, P. 1959. *The Science of Biology.* McGraw-Hill, New York.

Scientific American Readings in the Life Sciences.

Brachet, J. 1961. *The Living Cell.* Scientific American reprint, W. H. Freeman, San Francisco.

Chiscon, N. 1965. *The Laboratory Experience, A Principles of Biology Manual.* Burgess, Minneapolis.

Structural Biology (Biology 260)

Semester 1 and 2. Lectures-2; credits-2.
Prerequisites: Principles of Biology 104 or equivalent.
Structure of plants and animals, with emphasis on function and phylogenetic relationships.

Laboratory in Structural Biology (Biology 261)

Semesters 1 and 2. Lectures-2; credits-2.
Prerequisites or corequisites: Structural Biology.

Reading Materials:

Romer, A. 1961. *The Vertebrate Body.* W. B. Saunders, Philadelphia.

Montagna, W. 1959. *Comparative Anatomy.* John Wiley & Sons, New York.

Scientific American Readings in the Life Sciences.

Bold, H. 1957. *Morphology of Plants.* Harper and Row, New York.

Environmental Biology (Biology 285)

Semesters 1 and 2. Lectures-2; credits-2.
Prerequisites: Structural Biology and a year of general chemistry.

Adaptation and competition, and the relationship of organisms to their physical environment. Natural selection and other aspects of evolution; origin and integration of species and communities; ecosystems.

Laboratory in Environmental Biology (Biology 286)

Semesters 1 and 2. Laboratories- 1(3 hour); credits-1.

Prerequisites or corequisite: Environmental Biology, unless by consent of instructor.

Reading Materials:

Ehrlich, P. and R. Holm. 1963. *The Process of Evolution.* McGraw-Hill, New York.

Smith, J. M. 1959. *The Theory of Evolution.* Penguin Books, Middlesex, England.

Stebbins, G. L. 1966. *The Process of Organic Evolution.* Prentice-Hall, Englewood Cliffs, New Jersey.

Odum, E. P. 1959. *Fundamentals of Ecology.* 2nd. ed. W. B. Saunders, Philadelphia.

Cell Biology (Biology 520)

Semesters 1 and 2. Lectures-2; credits-2.

Prerequisites: A semester of a life science and a semester of organic chemistry; corequisite: Laboratory in Cell Biology, unless by consent of instructor.

Composition, structure, heredity, and growth of cells. Analysis of the cell concept in biochemical terms.

Laboratory in Cell Biology (Biology 521)

Semesters 1 and 2. Laboratories-2 (2 hour); credits-2.

Prerequisite or corequisite: Cell Biology.

Reading Materials:

Loewy, A. and P. Siekevitz. 1963. *Cell Structure and Function.* Holt, Rinehart and Winston, New York.

Stanier, R., M. Doudoroff and E. A. Adelberg. 1963. *The Microbial World.* Prentice-Hall, Englewood Cliffs, New Jersey.

Neidhardt, F. C. and A. Boyd. 1965. *Cell Biology, a Laboratory Text.* Burgess, Minneapolis.

De Robertis, E. D. P., W. W. Nawinsky and F. Saez. 1960. *General Cytology.* W. B. Saunders, Philadelphia.

Giese, A. 1962. *Cell Physiology.* W. B. Saunders, Philadelphia.

Hartman, P. and S. Suskind. 1965. *Gene Action.* Prentice-Hall, Englewood Cliffs, New Jersey.

Sistrom, W. 1962. *Microbial Life.* Rinehart and Winston, New York.

Wilson, G. and J. Morrison. 1966. *Cytology.* Reinhold, New York.

Steiner, R. and H. Edelbach. 1965. *Molecules and Life.* D. Van Nostrand, New York.

Developmental Biology (Biology 566)

Semesters 1 and 2. Lectures-2; credits-2.
Prerequisite or corequisite: Structural Biology, unless by consent of instructor.
Principles of development of plants and animals; the formation of organ systems.

Laboratory in Developmental Biology (Biology 567)

Semesters 1 and 2. Laboratories-2 (2 hour); credits-2.
Prerequisite or corequisite: Developmental Biology.
Descriptive and experimental study of the development of plants and animals.

Reading Materials:

Balinsky, B. I. 1960. *An Introduction to Embryology.* W. B. Saunders, Philadelphia.

Wardlow, C. W. 1952. *Morphogenesis in Plants.* John Wiley & Sons, New York.

Patten, B. 1951. *Early Embryology in the Chick.* Blakiston, Philadelphia.

Vanable, J. W. 1964-65. *Laboratory Manual for Developmental Biology.* Purdue University, Lafayette, Indiana.

Genetic Biology (Biology 541)

Semesters 1 and 2. Lectures-2, Recitations-1; credits-3.
Prerequisites: Cell Biology and a course in biochemistry or equivalent; Corequisite: Laboratory in Genetic Biology, unless by consent of instructor.

Laboratory in Genetic Biology (Biology 542)

Semesters 1 and 2. Laboratories-2 (2 hour); credits-1.
Prerequisite or corequisite: Genetic Biology, unless by consent of instructor.

Reading Materials:

Herskowitz, I. 1965. *Genetics.* Little, Brown and Co., Boston & Toronto.

STANFORD UNIVERSITY

Fundamentals of Biology (Biology 1[illegible])

Readings, lecture, and discussion-demonstrations-5; credits-5.

Prerequisite: General Chemistry.

A concentrated introduction to biology for those intending to major in the subject and take Plants as Organisms through Population Biology. Emphasis on fundamental facts, concepts and questions which underlie late more detailed consideration in the core curriculum.

Reading Materials:

Barth, L. G. 1964. *Development, Selected Topics.* Addison-Wesley, Reading, Massachusetts.

Grobstein, C. 1965. *Strategy of Life.* W. H. Freeman, San Francisco.

Levine, R. 1963. *Genetics.* Holt, Rinehart and Winston, New York.

Loewy, A. and P. Siekevitz. 1963. *Cell Structure and Function.* Holt, Rinehart and Winston, New York.

McElroy, W. 1964. *Cell Physiology and Biochemistry.* Prentice-Hall, Englewood Cliffs, New Jersey.

Odum, E. 1963. *Ecology.* Holt, Rinehart and Winston, New York.

Sussman, M. 1964. *Animal Growth and Development.* Prentice-Hall, Englewood Cliffs, New Jersey.

Swanson, C. 1964. *The Cell.* Prentice-Hall, Englewood Cliffs, New Jersey.

Plants as Organisms (Biology 11)

Lectures-3, Laboratories-2; credits-5.

Prerequisites: Fundamentals of Biology.

Structure and functions of plants at the organism level.

Reading Materials:

Robbins, W. W., Wier and Stocking. 1964. *Botany: An Introduction to Plant Science*. John Wiley & Sons, New York.

Scientific American articles.

Page, R. *Laboratory Outline for Plants as Organisms*. Stanford University, Stanford, California.

Ray, P. M. 1964. *The Living Plant*. Holt, Rinehart and Winston, New York.

Animals as Organisms (Biology 12)

Lectures-3, Laboratories-2; credits-5.

Prerequisite: Plants as Organisms.

Basic functions of organisms as carried on by animals.

Reading Materials:

Villee, C., W. F. Walker and F. E. Smith. 1963. *General Zoology*. 2nd. ed., W. B. Saunders, Philadelphia.

Telfer, W. and D. Kennedy. 1965. *Biology of Organisms*. John Wiley & Sons, New York.

Molecular Biology (Biology 113)

Lectures-3, Laboratories-2; credits-5.

Prerequisites: Fundamentals of Biology and Organic Chemistry.

The synthesis, function, interactions of the various molecular components of cells, with emphasis on molecular genetics.

Reading Materials:

Hayes, W. 1964. *The Genetics of Bacteria and Their Viruses*. John Wiley & Sons, New York.

Watson, J. 1963. *Molecular Biology of the Gene*. Benjamin, New York.

Steiner, R. 1965. *The Chemical Foundation of Molecular Biology.* D. Van Nostrand, Princeton, New Jersey.

Perutz, M. 1962. *Proteins and Nucleic Acids.* Elsevier, Amsterdam, New York.

Srb, A., R. Owen and R. Edgar. 1964. *General Genetics.* W. H. Freeman, San Francisco.

Lehninger, A. 1965. *Bioenergetics.* Benjamin, New York.

Stanier, R., M. Doudoroff and E. A. Adelberg. 1963. *The Microbial World.* Prentice-Hall, Englewood Cliffs, New Jersey.

Stahl, F. 1964. *The Mechanics of Inheritance.* Prentice-Hall, Englewood Cliffs, New Jersey.

Jacob, F. and E. Wollman. 1961. *Sexuality and the Genetics of Bacteria.* Academic Press, New York.

Hartman, P. and S. Sigmund. 1965. *Gene Action.* Prentice-Hall, Englewood Cliffs, New Jersey.

Cell Physiology (Biology 114)

Lectures-3, Laboratories-2; credits-5.

Prerequisite: Molecular Biology

Structure and function of plant and animal cells.

Reading Materials:

Giese, A. 1962. *Cell Physiology.* W. B. Saunders, Philadelphia.

Giese, A. 1962. *Cell Physiology Laboratory Manual.* W. B. Saunders, Philadelphia.

Kennedy, D. (Ed.) 1960. *The Living Cell* (Scientific American articles). W. H. Freeman, San Francisco.

Population Biology (Biology 115)

Lectures-3; credits-3.

Prerequisite: Cell Physiology.

Introduction to the properties of aggregations of organisms

Reading Materials:

Ehrlich, P. and R. Holm. 1963. *The Process of Evolution.* McGraw-Hill, New York.

NORTH CAROLINA STATE UNIVERSITY

General Biology (Biological Science 100)

Lectures-3, Laboratories-2; credits-4.

A course designed to emphasize the unity of biology through study of the following concepts: 1) protoplasmic and cellular organization, 2) growth and differentiation, 3) genetic and ecological control and 4) current and past evolution.

Reading Materials:

Beal, E. O. and G. C. Miller. *Living Systems*. To be published.

Beal, E. O. and G. C. Miller. *Laboratory Manual for General Biology*. To be published.

Swanson, C. 1964. *The Cell*. Prentice-Hall, Englewood Cliffs, New Jersey.

Hanson, E. 1964. *Animal Diversity*. Prentice-Hall, Englewood Cliffs, New Jersey.

Bold, H. 1964. *The Plant Kingdom*. Prentice-Hall, Englewood Cliffs, New Jersey.

Bonner, D. M. and S. E. Mills. 1964. *Heredity*. Prentice-Hall, Englewood Cliffs, New Jersey.

Sussman, M. 1964. *Growth and Development*. Prentice-Hall, Englewood Cliffs, New Jersey.

Galston, A. 1961. *Life of the Green Plant*. Prentice-Hall, Englewood Cliffs, New Jersey.

McElroy, W. D. 1961. *Cell Physiology and Biochemistry*. Prentice-Hall, Englewood Cliffs, New Jersey.

General Morphology (Botany 301)

Lectures-3, Laboratories-3; credits-4.

Prerequisite: General Biology.

A survey of the principal groups of plants from the standpoint of their structure, development and reproduction. Emphasis is placed on evolutionary relationships as revealed by comparisons in body organization and life histories of living and extinct forms. Some time is spent on general identification of the plants in their native habitats.

Reading Materials:

Cronquist, A. 1961. *Introduction to Botany.* Harper and Row, New York.

Hardin, J. W. 1965. *General Plant Morphology, A Laboratory Manual.* Technical Press, Raleigh, North Carolina.

Animal Life (Zoology 201)

Lectures-3, Laboratories-3; credits-4.

Prerequisite: General Biology.

The biology of the major animals, with emphasis on general structural plans and diversity, reproduction, development, ecology, behavior and evolution.

Reading Materials:

Storer, T. and R. Usinger. 1965. *General Zoology.* McGraw-Hill, New York.

Bookhart, C. S., W. S. Hunter and I. E. Gray. *Laboratory Directions for General Zoology.* Duke University Press, Durham, North Carolina.

Barnes, R. 1964. *Invertebrate Zoology.* W. B. Saunders, Philadelphia.

Stellar, E. and V. G. Dethier. 1964. *Animal Behavior.* Prentice-Hall, Englewood Cliffs, New Jersey.

Hanson, E. 1964. *Animal Diversity.* Prentice-Hall, Englewood Cliffs, New Jersey.

General Microbiology (Botany 412)

Lectures-3, Laboratories-2; credits-4.

Prerequisites: Principles of Chemistry II or General Chemistry II (Organic Chemistry or Introduction to Organic Chemistry recommended but not required.)

An advanced biology course dealing with bacteria and other microorganisms, their structure, development and function. Emphasis is placed on the fundamental concepts and techniques in microbiology such as isolation, cultivation, observation, morphology and the physiology and nutrition of bacteria. The applications of microbiology, the role of microbes in nature, and their role in infection and immunity are considered.

Reading Materials:

Stanier, R., M. Doudoroff and E. Adelberg. 1963. *The Microbial World.* Prentice-Hall, Englewood Cliffs, New Jersey.

Pelczar, M. 1965. *Laboratory Exercises in Microbiology.* McGraw-Hill, New York.

Plant Physiology (Botany 421)

Lectures-2, Laboratories-4; credits-4.

Prerequisites: General Biology, two courses in Chemistry.

An introductory treatment of the chemical processes occurring in higher green plants with emphasis on the mechanisms, factors affecting, correlations between processes, and biological significance.

Reading Materials:

Fogg, G. E. 1963. *The Growth of Plants.* Penguin Books, Middlesex, England.

Esau, K. 1965. *Plant Anatomy.* 2nd ed. John Wiley & Sons, New York.

Swanson, C. 1964. *The Cell.* Prentice-Hall, Englewood Cliffs, New Jersey.

The Scope Monograph on Cytology: The Cell. 1965. Upjohn Co., Kalamazoo, Mich.

Animal Physiology (Zoology 421)

Lectures-3, Laboratories-3; credits-4.

Prerequisites: Organic Chemistry, Physics, Animal Life, or permission of instructor.

Physiology of the vertebrates with emphasis on mammals. A comprehensive study of the mechanisms which operate to sustain life.

Reading Materials:

Guyton, A. C. 1965. *Textbook of Medical Physiology.* W. B. Saunders, Philadelphia.

Ruch, T. and H. D. Patten. 1965. *Physiology and Biophysics.* W. B. Saunders, Philadelphia.

Mitchell, P. H. 1956. *Textbook of General Physiology.* 5th ed., McGraw-Hill, New York.

The Principles of Genetics (Genetics 411)

Lectures-2, Laboratories-1; credits-3.

Prerequisites: General Biology.

An introductory course. The physical and chemical basis of inheritance; genes as units of structure and function; qualitative aspects of genetic variation.

Reading Materials:

Srb, A., R. Owen and R. Edgar. 1965. *General Genetics.* 2nd ed. W. H. Freeman, San Francisco.

Sinnot, E., T. Dobzhanzky and L. C. Dunn. 1958. *Principles of Genetics.* McGraw-Hill, New York.

DARTMOUTH COLLEGE

Life Science 1 and 2 (1701, 1702)

Lectures-4, Laboratories-1; credits-1*

Prerequisite: Life Science 1 is a prerequisite to Life Science 2.

An examination of the problems of information handling, energetics, adaptation, survival and development in organisms and species.

Reading Materials:

Loewy, A. and P. Siekevitz. 1963. *Cell Structure.* Holt, Rinehart and Winston, New York.

Moore, J. 1963. *Heredity and Development.* Oxford University Press, New York.

Villee, C., W. F. Walker and F. E. Smith. 1963. *General Zoology.* 2nd ed. W. B. Saunders, Philadelphia.

Wilson, C. L. and W. E. Loomis. 1962. *Botany.* 3rd ed. Holt, Rinehart and Winston, New York.

*One unit of credit is given for every course taught at Dartmouth College.

Cell Physiology (1736)

Lectures-4, Laboratories-1; credits-1

Prerequisites: Life Science 2, Organic Chemistry (which may be taken concurrently).

Nature and function of ultrastructural components and possible relationships to such cell processes as chemical energy transformation, transport of water and solutes, excitation, movement and growth. A wide range of microbial, animal and plant cell types will be used to illustrate common principles.

Reading Materials:

Giese, A. 1962. *Cell Physiology.* W. B. Saunders, Philadelphia.

Davson, H. 1964. *A Textbook of General Physiology.* Little, Brown and Co., Boston and Toronto.

De Robertis, E. D. P., W. W. Nawinsky and F. Saez. 1960. *General Cytology.* W. B. Saunders, Philadelphia.

Lehninger, A. 1965. *Bioenergetics.* Benjamin, New York.

Genetics (1738)

Lectures-4, Laboratories-1; credits-1.

Prerequisites: Life Science 2, Organic Chemistry, or permission of the instructor.

Mechanisms of heredity and variation. Topics include segregation genetics, statistical procedures, cytogenetics, mutation, the nature of genes, population genetics and contributions of genetics to the theory of evolution.

Reading Materials:

Srb, A., R. Owen and R. Edgar. 1965. *Genetics.* W. H. Freeman, San Francisco.

Herskowitz, I. 1965. *Genetics.* Little, Brown and Co., Boston & Toronto.

Hartman, P. and S. Suskind. 1965. *Gene Action.* Prentice-Hall, Englewood Cliffs, New Jersey.

Moore, J. A. 1960. *Heredity and Development.* Oxford University Press, New York.

3

APPENDIX

Sequence of Information Items Within Selected Courses of Core Programs

The following is a breakdown of a course from each of the core programs of the four institutions used in this study. Items are listed in the order of presentation during the lecture and laboratory portions of the courses. Following each of the items is a number indicating the approximate time spent on that piece of information, based on lecture units of fifty minutes each; 0.1 units equals five minutes.

PURDUE UNIVERSITY

PRINCIPLES OF BIOLOGY

Sequence of Items Presented in the Lecture	No. of Units
Concept of growth	0.2
Growth as synthesis of protoplasm	0.1
Cell division—an aspect of growth	0.1
Growth as synthesis of protoplasm	0.1
Developmental aspects of growth	0.2
Morphogenetic processes	0.2
Factors influencing growth	0.2
Lateral growth in plants—meristematic region function	0.1
Polarized growth	0.1
Growth measurement and graphing	1.0
Cleavage in starfish	0.3
Gastrulation in starfish	0.1
Cleavage in frog	0.1
Gastrulation, amphibian	0.2
Neural tube (late) structure in the frog embryo	0.2
Morphogenetic processes	0.3
Preformation	0.1
Epigenesis	0.1
Preformation, molecular—the modern view	0.1
Regulation in animal embryos	0.3
Blastomeres—separation in sea urchin embryos	0.2
Blastomeres—separation in frog embryo	0.1
Presumptive regions of gastrula	0.3
Mapping of blastoderm—techniques	0.3
Gastrula—potency of regions	0.3
Transplant experiments	0.1
Potency expression—dependence on relation to rest of embryo	0.1
Potency of regions—progressively restricted in early gastrula	0.3
Determination—the selection of potencies	0.3
Induction of nervous system	0.1
Organizer—dorsal lip as	0.1
Induction—hypothesis of	0.3
Development as a chain of evocations	0.1
Development as a chain of inhibitions	0.1
Development as a change in genetic complement of nuclei	0.1

Structure of organisms—possible approaches to study of	0.2
Structure-function concept in organism existence	0.2
Mendel's experiments	0.5
Hypothesis of genetic units—segregation and independent assortment	0.5
Linkage groups—concept	0.5
Chromosome basis of inheritance	0.5
Mitosis and cell division—phase films of Bajer and Bajer	0.6
Mitosis and cell division—essential features of	0.2
Nuclear partition—details of	0.2
Cytoplasmic partition (cytokinesis)	0.2
Chromosome number reduction in meiosis	0.1
Chromosome pairing during meiosis	0.1
Tetrad formation during meiosis	0.1
Chiasma formation during meiosis	0.1
Centromeres—separation during meiosis	0.2
Divisions of meiosis—first and second	0.1
Man—accessory reproductive structures (male)	0.1
Sperm structure and spermatogenesis in man	0.1
Sperm differentiation from primary spermatocyte in man	0.1
Egg differentiation in human oögenesis	0.1
Ovary structure and oögenesis	0.1
Fertilization—sperm penetration	0.2
Fertilization membrane	0.1
Parthenogenesis and egg activation	0.1
Fertilization—fusion of male and female pro-nuclei	0.1
Feeding—problems of ingestion and extracellular digestion	0.1
Multicellularity—problems of	0.2
Nutrition—transport problems	0.1
Exchange problems in multicellular organisms—e.g., digestion products, oxygen, and waste materials	0.1
Gas exchange problems in multicellular organisms	0.1
Multicellularity and exchange problems—surface area restrictions on diffusion	0.1
Transport from absorptive surface	0.2
Symmetry in organisms—spherical, radial and bilateral	0.1
Sessile organisms—adaptations of	0.1
Locomotion as a food-getting and escape mechanism	0.1
Locomotion—problems of	0.2
Coordination—problems of	0.1
Nervous coordination	0.2
Constancy of internal environment—examples of	0.1
Feed-back mechanisms	0.3
Kidney function—an example of a control system	0.1
Kidney structure, general	0.1

Nephron structure	0.2
Blood circulation in kidney—schematic flow system	0.1
Nephron filtration and selective reabsorption	0.2
Filtration—mechanisms of	0.2
Filtration rate—control of	0.1
Mechanisms of reabsorption in tubules	0.2
Hormone control of Na/K ion concentration in the kidney	0.2
Control of water in the body	0.1
Reproduction—maintenance of kind	0.1
Reproductive system structure in humans	0.1
Egg development in the ovary of humans	0.1
Reproductive cycle in the human female	0.1
Hormonal control of reproductive cycle—negative feedback	0.4
Hormonal control in pregnancy	0.3
Hormonal control of milk production in the mammary glands	0.1
Apical growth and dominance in plants	0.1
Auxin concept	0.4
Auxins and tropisms	0.2
Flowering in "short day" plants	0.3
Haplobiontic diplont reproductive cycles in plants	0.2
Haplobiontic haplont reproductive cycles in plants	0.3
Sources of plant essentials	0.1
Plant essentials—destination of water, CO_2, and mineral elements	0.1
Organ function in plant water movement	0.1
Xylem of stem and root—a component of the plant transport system	0.1
Phloem of stem and roots—a component of the plant transport system	0.1
Xylem vessels—structure and function	0.2
Phloem transport pathways—methods of analysis	0.3
Transpiration in plants—mechanisms of	0.2
Xylem transport—possible mechanisms	0.1
Capillary action—mechanism and inadequacy as complete explanation of water movement in plants	0.1
Root pressure	0.1
Transpiration-cohesion-tension theory of water movement in plants	0.2
Xylem transport—assessment of water movement mechanisms	0.2

Sequence of Items Presented in the Laboratory	**No. of Units**
Starch test for different starch types in normal and waxy corn kernels	0.4
Starch test in corn pollen for genetic analysis	0.4

F_1 studies in field corn kernel starch (waxy-normal)	0.4
F_1 studies in field corn pollen starch (waxy-normal)	0.4
Backcross studies—field corn kernel and pollen starch	0.4
F_2 segregation in field corn kernel starch (waxy-normal)	0.4
F_2 segregation in field corn pollen starch (waxy-normal)	0.4
Compound microscope—use and care	0.2
Focusing, observation and size measurements with the microscope	0.4
Magnification—determination of in microscope	0.2
Dissecting microscope—adjustment and variable magnification	0.2
Chick-embryo removal from the egg—techniques of	0.2
Hypoblast, epiblast, and blastocord formation in the chick	0.2
Head development in the chick embryo at 24 hours	0.4
External features of the chick embryo at 48 hours	0.4
External features of the chick embryo at 72 hours	0.4
Chick embryo structure at 96 hours	0.2
Asepsis	0.2
Microtechnique—principles of tissue preparation	0.2
Seed structure using prepared slides of *Capsella*	0.2
Seed structure, monocot, using corn	0.2
Seed growth—hypogaeous germination	0.2
Seed growth—epigaeous germination	0.2
Seed structure—dicot	0.2
Plant embryo growth	0.4
Embryo growth using wet and dry weight and length measurement	0.2
Incubation of chicken eggs for embryonic studies	0.2
Sterile technique principles in the handling of bacteria	0.2
Bacteria structure—staining with methylene blue	0.4
Cleavage in starfish	0.2
Morula stage in starfish embryo development	0.2
Blastula stage in the starfish	0.2
Gastrulation in the starfish	0.2
Germ layers and their derivatives in the starfish embryo	0.4
Ovulation, induced in a female frog using pituitary hormone	0.2
Fertilization of frog eggs with sperm removed from testis of a frog	0.4
Fertilized frog egg—animal and vegetal hemispheres	0.2
Gastrulation—amphibian	0.2
Neural groove structure (late) in the frog embryo	0.2
Germ layer and derivatives in the frog embryo	0.2
Growth rate of *E. coli* using serial dilution counting method	0.4
Serial-dilution techniques in isolation and culturing of bacterial cells	0.4
Viable count technique for bacteria cultures	0.2

Growth rate of *E. coli* using serial dilution counting method	0.4
Auxin (IAA) effects on leaf abscission	0.2
Auxin (IAA) effects on stem and petiole growth	0.4
Auxin (IAA) relation to negative geotropism in the stem and positive geotropism in the root	0.4
Auxin relationship to phototropism	0.4
Auxin and light relationship in hypocotyl elongation	0.2
Auxin (IAA) relation to negative geotropism in the stem and positive geotropism in the root	0.4
Thyroxin effect on metabolism and oxygen uptake in the rat	0.2
Thyroxin formation—biosynthetic pathway	0.2
Thyroxin formation—the effect of thiouracil on production	0.2
Thyroxin and TSH production—a negative feedback system	0.2
Oxygen consumption measurement in the rat using a Phipps-Bird respirometer	0.2
Thyroxin effect on oxygen uptake in the rat using a Phipps-Bird respirometer	0.6
Thiouracil effect on oxygen uptake in the rat using a Phipps-Bird respirometer	0.6
Structure-function concept in organism existence	0.2
Stem tip structure of *Coleus*, using prepared slides	0.2
Stem, herbaceous—primary tissues	0.4
Stem structure—secondary tissue in a woody stem	0.2
Stem structure of a monocot—transverse and longitudinal sections	0.2
Root structure—regions of the root using diagrams	0.2
Root structure—primary tissues using *Ranunculus*	0.4
Root, lateral, formation from pericycle, using *Salix*	0.4
Leaf structure—removal and study of *Impatiens* epidermis	0.2
Leaf structure—internal structure of a dicot	0.4
Leaf structure—internal structure of a monocot (*Zea*)	0.2
Mitosis—mitotic figures using *Allium* root tip smears	0.4
Mitosis—preparation of *Allium* root tips for smears, using acetocarmine stain	0.4
Mitosis—cell division in the whitefish blastula using prepared slides	0.4
Reduction-division in *Ascaris*, using prepared slides	0.4
Alternation of generations in the plant kingdom	0.2
Chlamydomonas—life cycle of	0.2
Spirogyra—life cycle of	0.2
Liverwort—life cycle of	0.2
Marchantia—reproductive structures, sexual and asexual	0.2
Moss—life cycle of	0.2
Archegonium and antheridium structure in mosses	0.2
Moss sporophyte structure, using *Polytrichum*	0.2

Fern—life cycle of	0.2
Fern sporophyte structure using *Pteridium aquilinum*	0.2
Fern gametophyte structure using *Pteridium aquilinum*	0.2
Gymnosperm life cycle	0.2
Cone structure of *Pinus* (female)	0.4
Gametogenesis—micro and mega in gymnosperms	0.4
Flower structure	0.2
Gametogenesis—micro and mega in angiosperms	0.2
Pollen grain and pollen tube structure using prepared slides	0.2

STANFORD UNIVERSITY

MOLECULAR BIOLOGY

Sequence of Items Presented in the Lecture	No. of Units
Approaches to molecular biology—biophysical, biochemical and genetic	0.1
Common denominators of all forms of life	0.2
Critical historical developments in molecular biology	0.3
Growth rate equations	0.1
Factors influencing growth	0.1
Bacteriophage life cycle—e.g., T4	0.2
Bacteriophage reproduction—characteristics	0.1
Glucose as an energy source for heterotrophs	0.1
Factors influencing growth	0.1
Energy yield and ATP balance in respiration	0.1
Fermentation—the energy balance of	0.1
Exoenzymes—types of and function	0.3
Digestion, cellular	0.2
Bacterial cell wall—structure and chemical composition	0.1
Nuclear bodies in bacteria	0.2
Bacteria cell structure—common tenets	0.1
Adaptation in bacteria	0.2
Conjugation and recombination in bacteria	0.2
Recombination in phage—mechanism of	0.1
Transformation and recombination in bacteria	0.2
Conjugation and recombination in bacteria	0.4
Episomes	0.2

Transformation and recombination in bacteria	0.2
Bacteriophage replication—vegetative	0.2
Bacterial mutants—types	0.2
Conjugation and recombination in bacteria	1.0
Metabolic pathways—the universality of biochemical pathways	0.1
Auxotrophic mutants of bacteria—analysis of metabolic pathways	0.1
Chemical approach in study of biosynthesis	0.1
Alkaptonuria in man—example of a biochemical mutant	0.1
Coupled reactions and free energy change	0.2
Activation energy and enzymes	0.1
Metabolic pathways—the universality of biochemical pathways	0.2
Amino acids—structure, classification and properties	0.7
Primary structure of proteins	0.3
Proteins, conjugated	0.1
Proteins—general classification of	0.1
Primary structure of proteins	0.3
Secondary structure of proteins	0.3
Tertiary structure of proteins	0.1
Tertiary structure of proteins—disulfide, hydrogen, electrostatic, and hydrophobic bonds	0.1
Quaternary structure of proteins, e.g. insulin	0.1
Primary structure of proteins	0.3
Protein structure—1, 2, 3, 4 degree relationships	0.1
Protein synthesis—general description of events	0.1
Enzyme nomenclature	0.1
Proteins—importance in economy of cell as enzymes	0.1
Enzyme reactions—methods of study	0.1
Enzyme purification	0.1
Enzyme activity—reversible reactions, mass action	0.1
Methods of protein separation	0.2
Proteins—criteria of purity	0.1
Activation energy and enzymes	0.1
Denaturation of proteins	0.1
Lipoproteins—structure and function in the cell	0.1
Enzyme specificity	0.1
Catalysis, mechanism of	0.1
Enzyme kinetics—the effect of enzyme concentration on reaction rate	0.1
Enzyme inhibition—specific inhibition	0.1
Enzyme activity—influence of pH on	0.1
Enzyme reactions—effect of temperature on	0.1
Enzyme kinetics—the effect of enzyme concentration on reaction rate	0.1

Enzyme kinetics—the effect of substrate concentration on reaction rate	0.1
Enzyme kinetics—Michaelis equation	0.1
Enzyme kinetics—Lineweaver-Burke plot	0.1
Competitive inhibition of enzymes	0.1
Primary structure of proteins	0.1
Enzyme and substrate—structural relationship and catalysis	0.3
Enzyme action—identification of specific groups in active site	0.2
Enzyme action—e.g., ribonuclease and chymotrypsin	0.2
Enzyme and substrate—structural relationship and catalysis	0.2
Polynucleotide—the basic structure of DNA	0.3
DNA structure—the Watson-Crick model	0.2
DNA—single stranded of some bacteriophages	0.1
DNA—composition of	0.2
Nucleotide structure—bases and sugars	0.2
RNA, messenger—properties and structure of	0.1
DNA structure—x-ray diffraction studies	0.1
Nucleotide structure—bases and sugars	0.1
DNA and base pairing of analogs	0.1
Polynucleotide—the basic structure of DNA	0.1
DNA base ratios—nearest neighbor studies	0.1
Polynucleotide—the basic structure of DNA	0.2
Semiconservative replication of DNA—Meselson and Stahl experiments	0.4
DNA replication *in vitro*—analysis of the Kornberg system	0.4
DNA—single stranded of some bacteriophages	0.1
DNA replication *in vitro*—analysis of the Kornberg system	0.1
DNA and base pairing of analogs	0.2
DNA replication *in vitro*—analysis of the Kornberg system	0.1
DNA base ratios—nearest neighbor studies	0.2
Gene—concept of	0.4
Fine structure analysis using bacteriophage	0.4
Gene—concept of	0.2
rII region of T4 phage	0.1
Deletion mutation and P^{32} decay in bacteriophage	0.2
Tautomerization and changes in base pairing of DNA	0.5
Mutagens	0.1
Tautomerization and changes in base pairing of DNA	0.1
Deletion mutation and P^{32} decay in bacteriophage	0.3
Mutagens	0.1
DNA and base pairing of analogs	0.1
Mutagens	0.3
Biochemical mutations—effects on DNA and protein synthesis	0.1

Linkage groups—e.g., garden pea	0.1
Sex-linked genes—white eyes in *Drosophila*	0.1
Linkage groups—concept	0.1
Chiasmata and crossing over—cytological correlations of	0.1
Linkage maps	0.1
Interference and coincidence	0.1
Crossing over—recombinations of genes	0.1
Chromosome breakage	0.1
Chiasma formation and crossing over	0.1
Chiasmata and crossing over—cytological correlations of	0.1
Chromosome breakage	0.1
Chiasma formation and crossing over	0.1
Recombination in phage—mechanism of	0.1
Transformation and recombination in bacteria	0.1
Recombination in fungi	0.1
RNA, ribosomal—structure	0.1
RNA syntnesis—RNA polymerase (Weiss and Hurwitz experiments)	0.2
*m*RNA binding to ribosome	0.2
Hybridization studies of DNA and RNA (Spiegelman and Hall)	0.2
RNA synthesis—RNA polymerase (Weiss and Hurwitz experiments)	0.2
Genes and enzymes—one gene, one enzyme hypothesis of Beadle and Tatum	0.2
Genes and enzymes—one cistron, one polypeptide chain hypothesis	0.3
Genetic code	0.5
Krebs cycle	0.2
The pentose phosphate pathway	0.2
Polymerization of activated subunits in respiration	0.1
Electron transport	0.1
Phosphorylation, oxidative	0.3
Electron transport	0.2
Starch, cellulose, and glycogen—carbohydrate structure	0.2
Amylase and starch digestion using the iodine test	0.2
Glucose metabolism	0.4
Free energy—concept of	0.1
Glycolytic pathway of Embden-Myerhof	0.3
Biosynthesis—a specific use of energy	0.2
Mitochondria—structure and function	0.2
Enzyme activity—reversible reactions, mass action	0.2
Enzyme activity—obligatory coupling reactions	0.2
Co-factors of enzymes—organic and inorganic	0.2
Enzyme inhibition—specific inhibition	0.2
Enzyme induction—concept of the inductor and production of *m*RNA	0.6

Operator gene and genetic regulation	0.2
Operon and the operator gene	0.6

Sequence of Items Presented in the Laboratory	No. of Units
Serial dilution techniques in isolation and culturing of bacterial cells	0.2
Plaque technique—identification of bacteriophage	0.4
Determination of total unabsorbed phage	0.4
Growth curve of a phage	0.4
Burst size determination in T4 phage replication	0.4
Multiplicity of bacteriophage infection—determination of	0.2
Mutagens	0.4
Plaque technique—identification of bacteriophage	0.4
Recombination frequency (R.F.) in bacteriophage	0.8
Recombination in phage—mechanism of	0.4
Reversion mutations of T4 phage mutants	0.4
Recombination frequency (R.F.) in bacteriophage	0.4
Transformation and recombination in bacteria	0.4
Auxotrophic mutants of bacteria—analysis of metabolic pathways	0.2
Transformation and recombination in bacteria	0.4
Auxotrophic mutants of bacteria—analysis of metabolic pathways	0.4
Transformation and recombination in bacteria	0.4
Conjugation and recombination in bacteria	1.6
Reversion, principles of	0.2
Conjugation and recombination in bacteria	0.2
Turbidity as a measurement of growth in microorganisms	0.2
Tryptophan synthetase extraction and properties	0.4
End-product inhibition in amino acid biosynthesis	0.2
Enzyme induction—beta-D-galactosidase production in microorganisms	1.6
Enzyme induction—the repressor gene product and relief of inhibition	2.0
Agar slants—preparation for culturing microorganisms	0.4
Preparation of polyacrylamide gels for disc-electrophoresis	0.4
Spectrophotometry—use of a spectrophotometer	0.2
Tyrosinase extraction and assay from *Neurospora crassa*	0.2
Allelic tyrosinases in *Neurospora crassa*	0.2
Tyrosinase extraction and assay from *Neurospora crassa*	0.8
Allelic tyrosinases in *Neurospora crassa*	0.6
Tyrosinase extraction and assay from *Neurospora crassa*	0.2
Tryptophan synthetase molecule—structure	0.2
Tryptophan synthetase extraction and properties	1.8
Mutagens	2.0

Conjugation and recombination in bacteria	2.0
Fermentation—reduction of pyruvic acid by NADH—end-product formation	0.4
LDH isozymes, properties and preparation	1.6
Beta-D-galactosidase extraction from *Neurospora*	1.4
Preparation of an anion column for enzyme isolation	0.6
Co-repressors—control of ornithine transcarbamylase synthesis in *E. coli* by arginine	0.2
Enzyme induction—beta-D-galactosidase production in microorganisms	0.4
Enzyme induction—beta-D-galactosidase formation in *E. coli* assay by hydrolization of ONPG to galactose and o-nitrophenol	0.4
Beta-D-galactosidase extraction from *Neurospora*	1.2
Auxotrophs and prototrophs—concept of	0.2
Auxotrophic mutant isolation—methods	0.4
Analysis of biosynthetic pathways using auxotrophic mutants	0.4
Auxotrophic mutants of bacteria—analysis of metabolic pathways	0.4
Biosynthesis of tryptophan in *Neurospora*	0.2
Biosynthetic pathway of prodigiosin production in *S. marcescens*	0.8
Enzyme induction—beta-D-galactosidase production in microorganisms	0.4
Co-repressors—control of ornithine transcarbamylase synthesis in *E. coli* by arginine	0.6
Enzyme induction—beta-D-galactosidase formation in *E. coli* assay by hydrolization of ONPG to galactose and o-nitrophenol	1.2
Autotrophic mutant isolation—methods	1.0
Mutagens	0.2
Auxotrophic mutant isolation—methods	0.8
Spectrophotometry—use of a spectrophotometer	0.4
Temperature control equipment—operational techniques	0.4
Agitation equipment—operational techniques	0.4
Direct current power supplies—operational techniques	0.4
pH meter—operational techniques	0.4
Electrophoresis—methods	1.2
Sterilization methods and techniques	0.4
Mettler balance—operational techniques	0.4
Centrifuge—operational techniques	0.4
Colorimetry—use of the Klett-Summerson photoelectric colorimeter	0.4
Media preparation for bacteria culturing	0.8
Tryptophan synthetase extraction and properties	0.4
Electrophoresis, polycrylamide disc—theory of	0.4
Electrophoresis, methods	0.4

NORTH CAROLINA STATE UNIVERSITY

GENERAL BIOLOGY

Sequence of Items Presented in Lecture	No. of Units
Living Systems—characteristics of	0.1
Thermodynamics—first law of	0.1
Thermodynamics—second law of	0.1
Thermodynamic laws and living systems	0.1
Elemental composition of living systems	0.1
Chemical elements found in living matter	0.1
Constancy of internal environment—examples of	0.1
Spectroscopy—concept of the absorption spectra of a compound	0.1
Light energy in a quantum—Planck's law	0.1
Energy relations of electromagnetic waves	0.1
Free energy, concept of	0.1
Absorption of light	0.1
Radiation, natural—properties of	0.1
Diffusion—the movement of molecules	0.1
Equilibrium, dynamic, concept	0.1
Diffusion—the movement of molecules	0.1
Permeability of membranes—rate, molecular effect, and active transport	0.1
Permeability, differential, of living membranes	0.1
Hypotonic, isotonic, and hypertonic solutions	0.1
Imbibition of water by hydrophylic colloids	0.1
Osmosis—Pfeffer's membrane and water movement	0.1
Turgor changes and movement in *Mimosa* leaves	0.2
Osmotic pressure determination of cell contents	0.1
Competitive interactions in active transport	0.1
Pinocytosis—significance of	0.2
Pinocytosis—mechanism of	0.1
Cytoplasm structure and composition	0.1
Fats, phospholipids and steroid structure	0.1
Polarity of molecules	0.1
Colloids—sol, gel transformations	0.1
Plasma membrane—Robertson's unit structure	0.1
Chemical composition of the erythrocyte "ghost" or plasma membrane	0.1
Chemical properties of cell membrane—Danielli's lipid-protein layer	0.1

Endoplasmic reticulum—structure and function	0.1
Golgi apparatus—structure and function	0.1
Ribosome composition—RNA and protein structure	0.1
Enzymes in organelles of the cell—e.g. mitochondria	0.1
Lysosomes—structure and function—respiratory mechanism	0.1
Mitochondria—structure and function	0.1
Chloroplasts—double membrane structure	0.1
Centriole ultrastructure—cylindrical nature	0.1
Centrosome—function in nuclear division	0.1
Cyclosis—cytoplasmic streaming in *Elodea* leaf cells	0.1
Autotrophism—concept of	0.1
Heterotrophism—e.g., *Paramecium*	0.1
Photosynthesis—definition	0.1
Chloroplasts—substructure of lamellar systems	0.1
Chloroplast pigments—types	0.1
Electron excitation and splitting of the water molecule	0.1
Chlorophylls a and b—light absorption analysis using a hand spectrophotometer	0.1
Chlorophyll molecule—chemical composition of	0.1
Fluorescence by chlorophyll—energy release	0.1
Phosphorescence by the chlorophyll molecule—energy release	0.1
Photosynthesis—the sun as ultimate source of energy	0.1
Quantum efficiency in photosynthesis	0.1
Electron excitation and splitting of the water molecule	0.1
Light—the photon concept	0.1
Electron excitation and splitting of the water molecule	0.1
ATP molecule structure and energy relations	0.1
Photophosphorylation system bound to membranes	0.1
Carbon-reduction phase of photosynthesis	0.1
Photosynthesis as a redox reaction	0.1
Glucose synthesis	0.1
Carbohydrate digestion as a hydrolytic reaction	0.1
Starch, cellulose, and glycogen—carbohydrate structure	0.1
Glycolytic pathway of Embden-Myerhof	0.1
Mitochondria—structure and function	0.2
Krebs cycle	0.2
Electron transport	0.1
Phosphorylation, oxidative	0.1
Mitochondria—structure and function	0.1
Glucose metabolism	0.2
Glycerol synthesis from triosephosphate	0.1
Fatty acid synthesis from acetyl fragments	0.1
Lipid synthesis from fatty acids and glycerol	0.1
Fats, phospholipids and steroid structure	0.1

Fatty acid respiration	0.1
Reductive amination—glutamic acid production	0.1
Transamination—amino acid formation from glutamic acid	0.1
Peptide bonds	0.1
Amino acid pool—concept in protein synthesis	0.1
Tertiary structure of proteins—disulfide, hydrogen, electrostatic, and hydrophobic bonds	0.1
Secondary structure of proteins	0.1
Tertiary structure of proteins	0.1
Protein structure analysis—x-ray crystallography	0.1
Primary structure of proteins	0.1
Quaternary structure of proteins—e.g., insulin	0.1
Amino acid activation and binding to sRNA	0.1
Base pairing in DNA structure	0.1
Nucleotides and nucleosides in the DNA molecule	0.1
*m*RNA binding to ribosome	0.1
*m*RNA synthesis in nucleus as complement to DNA molecule	0.1
Nucleoprotein synthesis—protein complex with DNA or RNA	0.1
Proteins—importance in economy of cell as enzymes	0.1
Proteins—amphoteric properties of	0.1
Activation energy and enzymes	0.1
Denaturation of proteins	0.1
Excretion of nitrogenous wastes among vertebrates	0.1
DNA structure—the Watson-Crick model	0.1
Base pairing in DNA structure	0.1
Polynucleotide—the basic structure of DNA	0.1
DNA structure—x-ray diffraction studies	0.1
Nuclear site of ribosomal, transfer and messenger RNA synthesis	0.1
RNA and protein synthesis—Nirenberg experiments	0.1
Codon concept—a non-overlapping set of three adjacent bases specifying an amino acid	0.1
The genetic code and protein synthesis	0.1
DNA in chloroplasts—genetic significance	0.1
Concept of the chromosome	0.1
Growth as synthesis of protoplasm	0.1
Surface area, volume relationships in cells—size limitations	0.1
Reproduction—fission	0.1
Reproduction in fungi, algae, and protozoans by centripetal invagination	0.1
Reproduction by fission	0.1
Nuclear division in fungi, algae, and protozoans by karyochorisis	0.1
Replication of DNA during interphase of mitotic cycle	0.1

Cytoplasmic partition (cytokineses)	0.1
Concept of the chromosome	0.1
Cytological stages in mitosis	0.1
Characteristics of nuclear division in the prokaryota and eukaryota	0.1
Differentiation, nuclear control—e.g., *Acetabularia* experiments	0.1
Neural and hormonal integration in development	0.1
Heterotrophism—e.g., *Paramecium*	0.1
Paramecium—structure and physiology	0.2
Exchange problems in unicellular organisms—e.g., *Paramecium*	0.1
Nucleus and cytoplasm relations in development	0.1
Growth as synthesis of protoplasm	0.1
Gas exchange problems in multicellular organisms	0.1
Exoenzymes—external digestion by	0.1
Hormone influence on sex organ formation in fungi	0.1
Environmental influence on differentiation	0.1
Exchange problems in multicellular organisms—e.g., digestion products, oxygen and waste materials	0.1
Differentiation of the plant zygote, and embryo formation	0.1
Structure of the plant embryo	0.1
Dormancy in plant seeds	0.1
Imbibition—relation to breaking of seed dormancy	0.1
Heterotrophism—e.g., *Paramecium*	0.1
Structure of the plant embryo	0.1
Cell wall, primary, growth and structure	0.1
Cell wall, secondary—tracheids	0.1
Cell wall pits—structure and function	0.1
Plasmodesmata—cytoplasmic connections	0.1
Symplast concept in multicellular organisms	0.1
Epidermis and cuticle formation in plant tissue	0.1
Xylem transport—possible mechanisms	0.1
Xylem structure—cellular components	0.1
Phloem anatomy and cell types of	0.1
Root hair structure and function	0.1
Root structure—regions of the root using diagrams	0.2
Xylem structure—cellular components	0.1
Phloem anatomy and cell types of	0.1
Base exchange in mineral uptake by roots	0.1
Active absorption by roots—method	0.1
Xylem of stem and root—a component of the plant transport system	0.1
Root, lateral, formation from pericycle, using *Salix*	0.1
Stem, herbaceous—primary tissue	0.1

Leaf structure—internal structure of a dicot	0.1
Leaf development from primordia	0.1
Stomatal apparatus—structure and function of	0.1
Axillary buds—structure and function	0.1
Apical meristems	0.1
The lateral cambia	0.1
Stem structure—secondary tissue in woody stem	0.1
Vascular rays—lateral transport in plants	0.1
Cork cambium—structure and function in bark formation	0.1
Stem structure—external features	0.1
Xylem anatomy and cell types of	0.1
Growth ring formation in secondary xylem	0.1
Transpiration-cohesion-tension theory of water movement in plants	0.1
Transpiration in plants—mechanisms of	0.1
Turgor changes and movement in *Mimosa* leaves	0.1
Carbon dioxide concentration in the earth's atmosphere	0.1
Auxin concept	0.1
Polarized growth	0.1
Polarity influence on auxin (IAA) transport	0.1
Auxin (IAA) effect on plant cell elongation	0.1
Auxin (IAA) relation to negative geotropism in the stem and positive geotropism in the root	0.1
Auxin and light relationship in hypocotyl elongation	0.1
Auxin (IAA) relation to negative geotropism in the stem and positive geotropism in the root	0.1
Auxin and relationship to phototropism	0.1
Auxin (IAA) effects on leaf abscission, using *Coleus*	0.1
Auxins—(IAA) induction of root formation	0.1
Kinetin—molecular structure	0.1
Kinetin in plant development	0.1
Gibberellins in plant development	0.1
Growth inhibitors and seed dormancy	0.1
Hormones, plant—types and uses	0.1
Flowering hormones	0.1
Flowering in "short day" plants	0.1
Photoperiod responses in flowering plants	0.1
Differentiation, nuclear control—e.g., *Acetabularia* experiments	0.1
Egg structure—amphibian	0.1
Nucleus and cytoplasm relations in development	0.1
Polarity of the unfertilized egg	0.1
Cleavage patterns of the protostomia and the deuterostomia	0.1
Cleavage—holoblastic, radial, bilateral, and spiral	0.1

Cleavage, disccidal	0.1
Spiral cleavage in *Urechis*	0.1
Cleavage patterns of the protostomia and the deuterostomia	0.1
Cell divisions—synchronized in *Tetrahymena*	0.1
Organization of the egg before fertilization—visible	0.1
Blastula formation in the frog	0.1
Blastocoel formation	0.1
Blastopore—fate in the protostomia and deuterostomia	0.1
Organizer—dorsal lip as	0.1
Ectodermal derivatives in vertebrates, using a frog	0.1
Neural groove formation in the chick embryo at 24 hours	0.1
Neural groove structure (late) in the frog embryo	0.1
Plasmagenes, role differentiation	0.1
Nuclear role in egg development	0.1
Egg development—role of extrinsic factors—e.g., CO_2 and *Hydra*	0.1
Induction—Spemann and Mangold experiment	0.1
Inducer and induced tissues interaction	0.1
Induction as a chemical phenomenon	0.1
Epithelial tissue types derived from endoderm	0.1
Skin—an ectodermal derivative	0.1
Mesodermal derivatives in vertebrates, using a frog	0.1
Neuron—structure of	0.1
Muscle formation	0.1
Muscle structure, striated, using leg muscle of bee or cockroach	0.1
Cardiac muscle structure, using prepared slides	0.1
Muscle structure, smooth, using prepared slides	0.1
Connective tissue—classification of bone and connective tissue	0.1
Bone—structure of fibrous connective tissue	0.1
Connective tissue—classification of bone and connective tissue	0.1
Connective tissue, blood—components	0.1
Erythrocyte (mammalian)—cell structure and composition	0.1
Hemoglobin in mammalian red blood cells—molecular structure	0.1
Blood composition in mammals—e.g., man	0.1
Blood platelets—structure and function in blood clotting	0.1
Blood clotting mechanisms in mammals—e.g., man	0.1
Developmental patterns in the metazoa	0.1
Blood composition in mammals—e.g., man	0.1
Mesodermal derivatives in vertebrates, using a frog	0.1
Organ system types in mammals	0.1
Symmetry in organisms—spherical, radial and bilateral	0.2

Size—the lower limit of organisms	0.1
Size—the upper limit of organisms	0.1
Autotrophism—concept of	0.1
Heterotrophism—e.g., *Paramecium*	0.1
Greode concept in differentiation	0.1
Codon concept—a non-overlapping set of three adjacent bases specifying an amino acid	0.2
Vegetative reproduction—characteristics of	0.1
Chromosomes, homologous—concept of	0.1
Synapsis—problems of	0.1
Meiosis—importance and significance of	0.1
Reduction-division in *Ascaris,* using prepared slides	0.1
Diploid concept in chromosome number	0.1
Haploid concept in chromosome number	0.1
Chromosome pairing, homologous during meiosis	0.1
Chiasma formation during meiosis	0.1
Cytological analysis of meiosis	0.1
Gamete differentiation in the male animal	0.3
Egg differentiation in human oögenesis	0.1
Gametogenesis—micro- and mega- in an angiosperm	0.1
Microsporogenesis in plants	0.1
Gametogenesis—micro- and mega- in an angiosperm	0.1
Megasporogenesis in plants	0.1
Pollination—methods of pollen transfer	0.1
Fertilization in angiosperms—description of events	0.1
Copulation in animals—transfer of sperm	0.1
Allele concept in gene function	0.1
Dominance and non-dominance	0.2
Homozygosity—concept of	0.1
Heterozygosity—concept of	0.1
Monohybrid ratios—simulation by coin toss	0.1
Genotype concept	0.1
Phenotypic ratios and gene interaction	0.1
Dominance and non-dominance	0.1
Test cross—use in genetic studies	0.1
Linkage groups—concept	0.1
Crossing over—recombinations of genes	0.1
Chiasmata and crossing over—cytological correlations of	0.1
Linkage maps	0.1
Sex linkage	0.1
Y chromosome—role in man	0.1
Sex-linked genes—lethal	0.1
Recombination—function in adaptation	0.1
Tautomerization and changes in base pairing of DNA	0.1

Reciprocal translocations and translocation heterozygotes	0.1
Structural aberrations of chromosomes—consequences for homologous pairing	0.1
Mutagens	0.1
Population as the unit of evolution—the gene pool	0.1
Hardy-Weinberg law—population genetics	0.1
Mutation effects on gene frequency	0.1
Mutation and selection effect in populations	0.1
Coloration, adaptive	0.1
DDT resistance in mosquitoes	0.1
Drift (chance) effects on gene frequencies	0.1
Genetic drift and population size	0.1
Mating systems—effects on gene frequencies	0.1
Polymorphism, balanced	0.1
Reproductive barriers and speciation	0.1
Reproductive barriers and speciation—types of	0.1
Species concept (new) as population unit	0.1
Parthenogenesis and genic variability	0.1
Evolution as a diversifying process	0.1
Viruses—history of discovery	0.1
Latent viruses—e.g., Astor yellows virus	0.1
Virus structure—techniques of evaluation	0.1
Bacteriophage reproduction—characteristics	0.1
Transduction, general, in *Salmonella*	0.1
Tobacco mosaic virus structure	0.1
TMV, RNA and protein reconstitution (Fraenkel-Conrat)	0.1
Tobacco mosaic virus structure	0.1
Virus structure—adenovirus, type 5	0.1
Structure and composition of a phage (general)	0.1
Bacteriophage reproduction—characteristics	0.1
Viruses—ATP and movement of	0.1
Bacteriophage life cycle—e.g., T4	0.1
Procaryotic organisms—structural characteristics of	0.1
Bacterial types—cocci, baccilli, and spirilla	0.1
Endospores in *Bacillus megaterium*	0.1
Bacteria cell structure—common tenets	0.1
Bacterial capsule—occurrence, composition, antigenicity, and pathogenicity	0.1
Flagella, bacterial—occurrence, types, structure, and chemical composition	0.1
Eucaryota—characteristics of	0.1
Nuclear bodies in bacteria	0.1
Bacterial capsule—occurrence, composition, antigenicity and pathogenicity	0.1

Flagella—chemical composition in bacteria	0.1
Flagellar movement—changes in protein bonding patterns	0.1
Bacterial enzyme system—association with plasma membrane	0.1
Chemosynthesis in bacteria—mechanisms	0.1
Bacterial growth—control by DNA nucleoid	0.1
Bacterial replication—centripetal invagination	0.1
Exponential growth of bacteria	0.1
Endospores in *Bacillus megaterium*	0.1
Conjugation and recombination in bacteria	0.1
Transformation and recombination in bacteria	0.1
Transduction in bacteria—characteristics of	0.1
Digestion in bacteria—exoenzymes	0.1
Saprophytism in bacteria	0.1
Nitrification by bacteria	0.2
Pathogenicity and bacteria	0.1
Ammonification by bacteria and fungi	0.1
Nitrogen cycle	0.1
Denitrification by bacteria	0.1
Bacteria and the fossil record	0.1
Mycoplasmae—characteristics and structure	0.1
Plasmodium vivax—development in red blood cells	0.1
Microbiological examination of food—techniques	0.1
Myxobacteriae—characteristics of	0.1
Actinomycetes—characteristics of	0.1
Cyanomyxae—characteristics of	0.1
Acrasineae—characteristics of	0.1
Labyrinthulidae—characteristics of	0.1
Plasmodiphorae—characteristics of	0.1
Slime mold—life cycle of	0.1
Algae—forms and organization	0.1
Parthenogenesis and genic variability	0.1
Chlamydomonas—life cycle of	0.1
Diatom structure, using *Pinnularia*	0.1
Division Euglenophyta—characteristics used for identification	0.1
Division Rhodophyta—characteristics used for identification	0.1
Division Phaeophyta—characteristics used for identification	0.1
Division Chlorophyta—characteristics used for identification	0.1
Division Cyanophyta—characteristics used for identification	0.1
Alternation of generations in the plant kingdom	0.1
Class Phycomycetes—characteristics used for identification	0.1
Achlya—life cycle of	0.1
Rhizopus life cycle	0.1
Class Ascomycetes—characteristics used for identification	0.1

Yeast life cycle	0.1
Aspergillus—life cycle of	0.1
Penicillium—life cycle of	0.1
Class Basidiomycetes—characteristics used for identification	0.1
Puccinia—life cycle of	0.1
Lichen structure—algal and fungal components	0.1
Saprophytism—concept of	0.1
Parasitism—concept of	0.1
Photoautotrophism—concept of	0.1
Heterotrophism—e.g., *Paramecium*	0.1
Class Musci—characteristics used for identification	0.1
Moss sporophyte structure, using *Polytrichum*	0.1
Moss—life cycle of	0.1
Homothallism in plant reproduction	0.1
Heterothallism in plant reproduction	0.1
Marchantia—structure of a liverwort	0.1
Liverwort—life cycle of	0.1
Geological time scale	0.1
Psilotum—structure	0.1
Lycopodium sporophyte structure	0.1
Selaginella—structure of the sporophyte	0.1
Equisetum—structure	0.1
Fern—life cycle of	0.1
Fern sporophyte structure using *Pteridium aquilinum*	0.1
Pine—life cycle of	0.1
Zamia, structure of a cycad	0.1
Ginkgo—structure	0.1
Flower structure	0.1
Angiosperm—life cycle of	0.1
Seed structure—dicot, using peas and beans	0.1
Seed structure—monocot, using corn	0.1
Nomenclature—binomial system of Linnaeus	0.1
Species concept (new) as population unit	0.1
Species concept (old) as taxonomic unit	0.1
Taxonomy—modern approaches to	0.1
Taxonomic principles—systematics, classification and nomenclature	0.1
Phylum Chordata—characteristics used in identification	0.1
Frog—external morphology	0.1
Arthropoda—characteristics used for classification	0.1
Grasshopper structure—external features	0.1
Annelida—characteristics used for classification	0.1
Earthworm structure—external	0.1
Phylum Mollusca—characteristics used for identification	0.1

Mollusc structure—general	0.1
Phylum Echinodermata—characteristics used for identification	0.1
Starfish structure—general	0.1
Coelenterata—characteristics used for identification	0.1
Hydra—structure	0.1
Platyhelminthes—characteristics used for classification	0.1
Planaria—structure	0.1
Phylum Protozoa—characteristics used for identification	0.1
Paramecium—structure and physiology	0.1
The Darwinian thesis of evolution	0.2
Lamarckian thesis of evolution	0.1
Evolution as a diversifying process	0.1
Skulls, horse—an evolutionary series of	0.1
Forefoot evolution analysis in the horse	0.1
Ecosystem—concept of	0.1
Producers of the woodland community—angiosperms, algae, bryophytes and ferns	0.1
Consumers, primary of the woodland community—herbivores	0.1
Consumers, secondary, of the woodland community—predators	0.1
Marine ecology	0.1
Lakes, thermal properties of	0.1
Terrestrial habitat—characteristics of	0.1
Biome—definition of	0.1
Phylogeny of plant kingdom	0.1
Origin of life—spontaneous generation concept	0.3
Life origin—hypotheses	0.2

Sequence of Items Presented in the Laboratory	**No. of Units**
Magnification—determination of in microscope	0.2
Brownian movement, using colloidal particles of white ink	0.2
Cyclosis—cytoplasmic streaming in *Elodea* leaf cells	0.2
Compound microscope—use and care	0.2
Electron microscope—fundamentals of	0.2
Electron microscope—use in study of cell structure	0.2
Resolution in cell structure	0.2
Diffusion—the movement of molecules	0.6
Diffusion gradients	0.2
Osmosis—use of an osmometer	0.2
Osmosis effect on cell size (mass) using potato sticks	0.2
Permeability, differential, of living membranes	0.2
Imbibition of water by hydrophylic colloids	0.2
Cyclosis—cytoplasmic streaming in *Elodea* leaf cells	0.2

Active transport—examples of	0.2
Chloroplast pigment separation using paper chromatography	0.2
Chlorophylls a and b—light absorption analysis using hand spectrophotometer	0.2
Chlorophyll—fluorescence using U.V. light	0.2
Carbon dioxide fixation—*Elodea* in phenol red solution	0.2
Iodine test for presence of starch	0.2
Malt diastase and starch digestion	0.2
Digestion, cellular—observation of	0.2
Iodine test for presence of starch	0.2
Electrophoresis—methods	0.2
Electrophoretic separation of blood proteins	0.6
Carbon dioxide production by yeast during fermentation, measured with BaOH	0.2
Heat evolution during respiration—calorimetry	0.2
Life origin—hypotheses	0.2
Asexual reproduction by budding	0.2
Reproduction by fission	0.2
Asexual spore formation in fungi	0.2
Asexual reproduction by budding	0.2
Regeneration	0.2
Mitosis—mitotic figures using *Allium* root-tip smears	0.4
Absidia—structure of a fungus	0.2
Embryo structure	0.2
Root hair structure and function	0.2
Root growth—identification of growth areas using India ink markings	0.2
Phototropism (Lionel Jaffre)	0.4
Auxin (IAA) effects on stem and petiole growth in *Coleus*	0.2
Auxin (IAA) relation to negative geotropism in the stem and positive geotropism in the root	0.4
Leaf structure—internal structure of a dicot	0.2
Leaf structure—internal structure of a monocot *(Zea)*	0.4
Stem structure—secondary tissue in woody stem	0.2
Stem herbaceous—primary tissue	0.2
Cell division—an aspect of growth	0.2
Stem, herbaceous—primary tissue	0.2
The lateral cambia	0.2
Blastula stage in starfish	0.2
Cleavage in starfish	0.2
Blastula stage in starfish	0.2
Gastrulation in starfish	0.2
Epithelial tissues—types and characteristics	0.2

Cardiac muscle structure, using prepared slides	0.2
Muscle structure, smooth, using prepared slides	0.2
Muscle structure, striated, using leg muscle of bee or cockroach	0.2
Connective tissue—classification of bone and connective tissue	0.2
Neuron—structure of	0.2
Digestive tract of the mammal	0.2
Paramecium—structure and physiology	0.2
Heterotrophism, e.g., *Paramecium*	0.2
Cell organelles	0.2
Reproduction by fission	0.2
Daphnia—external morphology	0.2
Daphnia—internal morphology	0.2
Frog—external morphology	0.2
Conjugation in *Paramecium*	0.2
Respiratory system structure—frog	0.2
Capillary blood flow in the frog foot web	0.2
Chromosome staining—the Feulgen reaction for DNA	0.2
Mitosis—mitotic figures using *Allium* root-tip smears	0.2
Mitosis—preparation of *Allium* root tips for smears, using aceto-carmine stain	0.2
Cytological stages in mitosis	0.2
Meiosis in *Ascaris*	0.2
Cytological analysis of meiosis	0.4
Chromosome number reduction in meiosis	0.2
Endospores in *Bacillus megaterium*	0.2
Bacteria cell structure—common tenets	0.4
Sterile technique principles in the handling of bacteria	0.2
Yeast structure and reproduction	0.2
Rhizopus—structure	0.2
Agaricus—basidiocarp structure	0.2
Perithecium structure in *Sordaria*, with asci and ascospores	0.2
Diatom structure, using *Pinnularia*	0.2
Volvox—structure	0.2
Laminaria—structure	0.2
Lichen growth forms—crustose, foliose, and fruiticose	0.2
Polytrichum—structure	0.2
Lycopodium sporophyte structure	0.2
Fern sporophyte structure using *Pteridium aquilinum*	0.2
Fern sporangia structure	0.2
Fern gametophyte structure using *Pteridium aquilinum*	0.2
Cone structure of *Pinus* (female)	0.2
Cone structure of *Pinus* (male)	0.2

Flower structure	0.2
Annelids—characteristics used for classification	0.2
Earthworm structure—external	0.2
Earthworm internal anatomy	0.2
Earthworm structure—digestive system	0.2
Earthworm reproductive system	0.2
Earthworm circulatory system	0.2
Earthworm nervous system	0.2
Earthworm excretory system	0.2
Heartbeat in frog—preparation by pithing and dissection	0.2
Heart structure—major blood vessels leading to and from the heart in the frog	0.2
Heartbeat—temperature effects on the heartbeat of a frog	0.2
Viscera structure in a frog	0.2
Frog digestive system—structure	0.2

DARTMOUTH COLLEGE

GENETICS

Sequence of Items Presented in Lecture	No. of Units
Phenotype—concept of	0.1
Variation—genetic and environmental factors	0.4
Phenocopy—genetic and environmental influences	0.4
Phenocopy—concept of	0.1
Dominance and non-dominance	0.1
Dominance—production of functional gene product	0.1
Genes and enzymes—one gene, one enzyme hypothesis of Beadle and Tatum	0.1
Dominance—production of functional gene product	0.1
Genetic block—accumulation of precursors	0.1
Cross-reacting material (CRM)—definition of	0.1
CRM detection—immunological method of	0.2
Cross-reacting material (CRM)—definition of	0.1
Dominance—production of functional gene product	0.1
Eye pigment formation (brown) in *Drosophila*	0.1
Eye anlage transplantation in *Drosophila* larvae	0.1

Implant development—influence of host environment	0.2
Genetic control of biosynthetic pathways	0.1
Genetic block—accumulation of precursors	0.1
Auxotrophic mutant isolation—methods	0.1
Genetic control of biosynthetic pathways	0.1
Genetic block—accumulation of precursors	0.1
Cross-feeding, use in detection of biochemical pathways	0.1
Cellular differentiation	0.1
Nuclear role in egg development	0.1
Nuclear transplantation—Briggs and King experiments	0.2
Nuclear role in egg development	0.1
Development as a change in genetic complement of nuclei	0.1
Determinants—nuclear and cytoplasmic interaction in embryo development	0.1
Unidirectionality of development	0.1
Differential gene action—concept in development	0.2
Colinearity of cistron and proteins	0.1
*m*RNA synthesis in nucleus as complement to DNA molecule	0.2
Stability of RNA fraction in ribosome	0.1
sRNA-AA complex binding to site on *m*RNA by base pairing	0.1
Amino acid activation and binding to sRNA	0.2
*m*RNA binding to ribosome	0.1
sRNA-AA complex binding to site on *m*RNA by base pairing	0.1
Peptide bond formation—ribosome function, *m*RNA and sRNA relationships	0.1
Codon concept—a non-overlapping set of three adjacent bases specifying an amino acid	0.3
Mutagens	0.1
Suppressor mutations—mechanisms of action	0.2
Codon concept—a non-overlapping set of three adjacent bases specifying an amino acid	0.2
Genetic code	0.1
Relationship of nucleotide combinations to incorporation of amino acids into proteins (Nirenberg and Ochoa)	0.2
Operator gene and genetic regulation	0.1
Repressor or regulator gene	0.3
Operator gene and genetic regulation	0.2
Structural gene—function of	0.1
Operon and the operator gene	0.1
Operon—definition and operation in *Salmonella* and *E. coli*	0.2
Polytene chromosomes and aberration analysis	0.2
Genes and chromosomal relationships	0.1
Chromosomal activity—Balbiani rings in *Chironomus*	0.1
Differential gene action—chromosomal puff patterns	0.6

Meiotic division, first, in the primary spermatocyte in grasshopper and formation of secondary spermatocytes	0.4
Meiotic division, second, and spermatogenesis in the grasshopper	0.1
Chiasma between 2 linked genes—genetic expectations	0.2
Recombination—possible molecular events	0.1
Synapsis—mechanism of genetic pairing	0.1
Recombination—possible molecular events	0.1
Gene interaction in phenotypic expression	0.1
Dihybrid ratios—analysis of F_1 and F_2 generations	0.2
Gene interaction—cyanide in white clover	0.3
Dominance and non-dominance	0.1
Epistatic and non-epistatic gene action	0.1
Pleiotropism	0.1
Multihybrids—F_1 and F_2 generations	0.5
Segregation—genetic (in man)	0.2
Alleles, multiple	0.3
Probability (p) value—definition of	0.2
Probability—basic theorems	0.2
Probability (p) value—definition of	0.1
Binomial distributions	0.2
Probability distributions—binomial, Poisson, and normal distribution	0.3
Chi square—definition and uses of	1.0
Multigenic or multiple-factor inheritance of quantitative traits	0.4
Quantitative inheritance—influence of dominant genes	0.6
Tetrad analysis—in *Neurospora*	0.1
Neurospora—ascus formation	0.3
Tetrad analysis—effect of first and second division segregation	0.4
Double crossing over in tetrads	0.1
Tetrad analysis—in *Neurospora*	0.1
Linkage groups—concept of	0.1
Tetrad analysis—effect of first and second division segregation	0.1
Recombination frequency—computation of	0.3
Mapping function	0.2
Linkage—parental types in linkage experiments	0.2
Recombination frequency—computation of	0.1
Linkage groups—concept	0.1
Genes—crossing-over frequency as a measure of distance between genes	0.1
Crossing-over frequency—constant for any two genes	0.1

Genes—crossing-over frequency as a measure of distance between genes	0.1
Map unit distance—definition of	0.2
Recombination frequency—relation to crossing-over	0.3
Mapping function	0.1
Interference and coincidence	0.3
Double crossing-over in tetrads	0.2
Genes—linear arrangements in three point crosses	0.5
Gene—concept of	0.1
Alleles, multiple	0.1
Pseudo alleles	0.2
Cis-trans heterozygotes and position effects	0.2
Gene—concept of	0.1
Analysis of biosynthetic pathways using auxotrophic mutants	0.2
Gene—concept of	0.1
Colinearity of cistron and proteins	0.1
Tryptophan synthetase—subunit interaction and activity	0.1
Cis-trans test—complementation of cistrons	0.1
Tryptophan synthetase—subunit interaction and activity	0.1
Biochemical mutations—effects on DNA and protein	0.1
Tryptophan synthetase—amino acid substitutions	0.1
Colinearity of cistron and proteins	0.2
Tryptophan synthetase—amino acid substitutions	0.1
Reverse mutation—consequences for protein structure	0.1
Intragenic complementation—concept of	0.1
Complementation map—*Neurospora*	0.2
Intragenic complementation—concept of	0.1
Tertiary structure of proteins	0.1
Quaternary structure—effect on protein activity	0.2
Intragenic complementation—mechanism of	0.3
Cis-trans test—complementation of cistrons	0.1
Recombination frequency in the bacteriophage T4, when crossing two phage mutants	0.3
Deletion mutation and P^{32} decay in bacteriophage	0.1
rII region of phage T4	0.1
Cistron—operational definition	0.2
Recon—operational definition	0.1
Biochemical mutations—effects on DNA and protein synthesis	0.1
Aspergillus—heterokaryon and diploid spore formation	0.3
Mitotic crossing-over—principle of	0.1
Mitotic crossing-over—mechanism of	0.1
Mitotic crossing-over—principle of	0.1
Interference and coincidence	0.1
Negative interference—mechanism of	0.2

Non-reciprocal recombination	0.1
Conjugation and recombination in bacteria	0.1
Conjugation—sexual polarity and genetic mapping	0.3
Sex factor—incorporation in bacterial chromosome	0.1
Conjugation—sexual polarity and genetic mapping	0.2
Sex factor—incorporation in bacterial chromosome	0.1
Conjugation and recombination in bacteria	0.1
Conjugation—sexual polarity and genetic mapping	0.1
Sex factor—incorporation in bacterial chromosome	0.2
Episomes	0.4
Sex factor—incorporation in bacterial chromosome	0.4
Transduction in bacteria—characteristics of	0.2
Transduction, restricted, in *E. coli*	0.3
Transduction—the genome of the transducing phage	0.1
Transduction in bacteria—characteristics of	0.1
Transduction—complete transduction and integration of transduced DNA in host	0.1
Transduction in bacteria—characteristics of	0.1
Transduction, abortive—Wollman and Jacob's experiments	0.1
Bacteriophage replication—vegetative	0.2
Phage linkage group—circular chromosome	0.2
Recombination frequency in the bacteriophage T4, when crossing two phage mutants	0.1
Phage heterozygotes—structure and characteristics of	0.3
Recombination in phage—mechanism of	0.3
Tautomerization and changes in base pairing of DNA	0.1
Tryptophan synthetase—amino acid substitutions	0.1
Genetic block—accumulation of precursors	0.1
Analysis of biosynthetic pathways using auxotrophic mutants	0.1
Genetic block—complete and leaky mutants	0.1
Genetic block—accumulation of precursors	0.1
End product inhibition in amino acid biosynthesis	0.2
Genetic control of biosynthetic pathways	0.1
Pleiotropism	0.1
DNA and base pairing of analogs	0.1
Mutagens	0.2
DNA and base pairing of analogs	0.2
Mutagens—genetic analysis of mutagenic action	0.2
Mutability spectra—concept of	0.1
Mutagen effect of acridine dyes on DNA	0.2
Chromosome breakage—single break, breakage, fusion, bridge cycle	0.2
Chromosome structure—gross morphology of	0.1
Chromosome deficiencies—cytological properties	0.1

Cytogenetic correlation—association of genetic traits with alterations in chromosomes	0.3
Cytological mapping	0.1
Chromosomal duplications—nature of	0.2
Reciprocal translocations and translocation heterozygotes	0.6
Chromosome breakage—two breaks in same chromosome	0.1
Structural aberrations of chromosomes—consequences for homologous pairing	0.1
Cross-over suppressors—effect of inversion	0.2
Concept of polyploidy	0.1
Autopolyploidy—genetic basis of	0.2
Concept of polyploidy	0.1
Autopolyploidy—phenotypic effects of	0.1
Concept of aneuploidy	0.1
Aneuploidy—monosomics and trisomics in *Drosophila*	0.2
Aneuploidy in man	0.1
Concept of aneuploidy	0.1
Race, definition of	0.2
Race differentiation—origin of species	0.1
Reproductive barriers in speciation—types of	0.1
Procaryota—evolutionary significance of	0.1
Hybridization—origin of species	0.2
Amphidiploidy—origin of	0.1
Hybridization—origin of species	0.2
Population as the unit of evolution—the gene pool	0.1
Gene frequencies in a population	0.1
Hardy-Weinberg law—population genetics	0.3
Gene frequencies in a population	0.1
Gene frequency and offspring derivation for P.T.C.	0.1
Gene frequencies in a population	0.2
Breeding systems—non-random (homozygosity)	0.1
Mutation and selection effect in populations	0.1
Mutation rates and gene frequencies	0.1
Mutational equilibrium in populations	0.1
Mutation effects on gene frequency	0.2
Genetic material—biochemical evolution of	0.1
Genetic load—definition of	0.2
Polymorphism, balanced	0.1
Mutation and selection effect in populations	0.1
Mutation and evolution	0.1
Selection effects on gene frequencies	0.1
Selection—dependence on gene frequencies	0.2
Mutation and selection effect in populations	0.2
Polymorphism, balanced	0.2

Heterosis	0.2
Pedigree analysis—use in human genetics	0.1
Cytogenetic correlation—association of genetic traits with alterations in chromosomes	0.1
Sex determination in man—role of chromosomal abnormalities	0.1
Sex chromatin—Barr body	0.1
Alkaptonuria in man—example of a biochemical mutant	0.1
Maternal, fetal incompatibility—Rh factor	0.1
Twin studies—roles of environment and genotype	0.1
Twin studies in man	0.1
Sex linkage in man—genetics of color blindness	0.1
Race differentiation in man—aspects of	0.1
Extranuclear genes—CO_2 sensitivity in *Drosophila*	0.1
DNA in chloroplasts—genetic significance	0.2
Paramecium—genetic studies of kappa particles	0.1
Conjugation in *Paramecium*—genetic consequences of	0.1
Chlamydomonas—mating types and streptomycin resistance	0.1
Mitochondria inheritance	0.2
Centrosomes and centromeres—episome relationships	0.1
Kinetosome—DNA content and centriole homology	0.1

Sequence of Items Presented in Laboratory	**No. of Units**
Drosophila—life cycle	0.2
Drosophila—phenotypic characters	0.2
Drosophila—techniques of observation	0.2
Breeding techniques—handling and crossing of *Drosophila*	0.2
Drosophila—methods of culturing	0.2
Drosophila—phenotypic characters	0.2
Drosophila—techniques of observation	0.4
Multihybrids—F_1 and F_2 generations	0.4
Epistatic and non-epistatic gene action	0.2
Analysis of biosynthetic pathways using auxotrophic mutants	0.2
Genetic block—accumulation of precursors	0.2
Cross-feeding use in detection of biochemical pathways	0.2
Neurospora—ascus formation	0.2
Complementation in *Neurospora*	0.2
Intragenic complementation—concept of	0.2
Complementation map—*Neurospora*	0.2
Neurospora—life cycle of	0.2
Sterile technique—method of spore inoculation	0.2
Auxotrophic mutant isolation—methods	0.2
Conjugation—sexual polarity and genetic mapping	0.2
Conjugation and recombination in bacteria	0.2

Conjugation sexual polarity and genetic mapping	0.4
Conjugation and recombination in bacteria	0.2
Plating of bacteria on solid medium	0.2
Replica plating—method of	0.2
Mutation, bacterial, detection using replica plating method	0.2
Recombination frequency—computation of	0.2
Mormoniella—phenotypic characters	0.2
Mormoniella—life cycle of	0.2
Mormoniella—phenotypic characters	0.2
Breeding techniques—handling and crossing of *Mormoniella*	0.6
Mormoniella—phenotypic characters	0.4
Multihybrids—F_1 and F_2 generations	0.4
Neurospora life cycle of	0.2
Neurospora—ascus formation	0.2
Tetrad analysis—effect of first and second division segregation	0.4
Recombination frequency—computation of	0.4
Neurospora—ascus formation	0.2
Sterile technique—method of spore inoculation	0.2
Isolation of *Neurospora* asci	0.2
Linkage—parental types in linkage experiments	0.2

Conjugation sexual polarity and genetic mapping	0.4
Conjugation and recombination in bacteria	0.2
Plating of bacteria on solid medium	0.2
Replica plating—method of	0.2
Mutation, bacterial, detection using replica plating method	0.2
Recombination frequency—computation of	0.2
Mormoniella—phenotypic characters	0.2
Mormoniella—life cycle of	0.2
Mormoniella—phenotypic characters	0.2
Breeding techniques—handling and crossing of *Mormoniella*	0.6
Mormoniella—phenotypic characters	0.4
Multihybrids—F_1 and F_2 generations	0.4
Neurospora life cycle of	0.2
Neurospora—ascus formation	0.2
Tetrad analysis—effect of first and second division segregation	0.4
Recombination frequency—computation of	0.4
Neurospora—ascus formation	0.2
Sterile technique—method of spore inoculation	0.2
Isolation of *Neurospora* asci	0.2
Linkage—parental types in linkage experiments	0.2