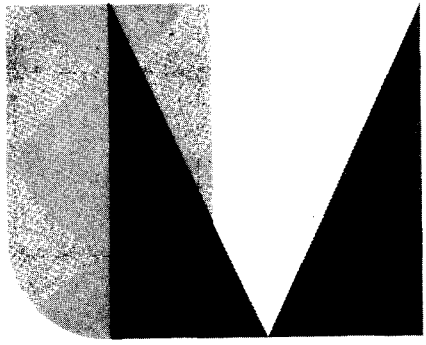


UNIVERSITY
MINNESOTA
BULLETIN



1967-69

BIOLOGICAL

HOW TO USE THIS BULLETIN

This bulletin is the basic source of information about the College of Biological Sciences. It is arranged in four general sections.

Section I, *General Information*—All students and prospective students should read this section carefully. It contains detailed information relating to the following topics:

- Organization and Objectives of College of Biological Sciences
- Degree Offerings
- Career Opportunities
- Admission Requirements
- Procedures and Practices
- Requirements for Graduation
- Student Personnel Services

Section II, *Graduate Study in Biological Sciences*

Section III, *Curricular Requirements*—This section contains the specific curricular requirements for the various fields of work.

Section IV, *Course Descriptions*—This section presents the descriptions of undergraduate and graduate courses offered in the College of Biological Sciences.

All students and prospective students also need to refer to the *Bulletin of General Information*. In addition, some will wish to refer to the following bulletins:

- Bulletin of the College of Liberal Arts
- Bulletin of the Graduate School
- Bulletin of the Medical School
- Bulletin of the Institute of Technology
- Bulletin of the College of Veterinary Medicine
- Bulletin of the School of Dentistry
- Bulletin of the College of Pharmacy
- Bulletin of the College of Agriculture
- Bulletin of the School of Forestry

All of these bulletins are available at the information booth in Morrill Hall or may be obtained by writing to the Office of Admissions and Records, University of Minnesota, Minneapolis, Minnesota 55455.

The days and hours when classes meet and the place of the meeting are contained in the *Class Schedule* published just before the registration period each quarter.

In addition to the bulletins of the other collegiate units, graduate students and candidates for graduate study should refer to the *Bulletin of the Graduate School*.

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Cell Biology

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Campus (647-3991)

Developmental Biology

Nelson T. Spratt, Program Chairman, 209 Zoology Building, Minneapolis Cam-
pus (373-3646)

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Department of Ecology and Behavioral Biology

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Herbert E. Wright, Jr., Ph.D.

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D. P. Sinniff, Ph.D.

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Frederick M. Williams, Ph.D.

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Museum of Natural History

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Robert C. Bright, *Curator of Paleontology*

Albert W. Erickson, *Curator of Mammalogy*
James C. Underhill, *Associate Curator of Fishes*
Dwain W. Warner, *Curator of Ornithology*

Contributing Faculty from Other University Units

Department of Microbiology
(College of Medical Sciences)

Professor

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Gerhard K. Brand, M.D.
Louis H. Muschel, Ph.D.
Edwin L. Schmidt, Ph.D.

Associate Professor

Robert W. Bernlohr, Ph.D.
Martin Dworkin, Ph.D.
Palmer Rogers, Ph.D.

Assistant Professor

Peter G. W. Plagemann, Ph.D.

**College of Agriculture, Forestry,
and Home Economics**

Professor

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Richard Behrens, Ph.D.
Huai-Chang Chiang, Ph.D.
Edwin F. Cook, Ph.D.
Albert J. Linck, Ph.D.

William E. Rempel, Ph.D.
A. Glenn Richards, Ph.D.

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Marion A. Brooks, Ph.D.
Richard E. Phillips, Ph.D.
Roger D. Price, Ph.D.
Theodore W. Sudia, Ph.D.
C. J. Weiser, Ph.D.

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William A. Brun, Ph.D.
Rouse S. Farnham, Ph.D.
Edward I. Sucoff, Ph.D.

College of Veterinary Medicine

Professor

Archie L. Good, Ph.D.
Clarence M. Stowe, Ph.D.

Assistant Professor

Thomas F. Fletcher, Ph.D.
Keith I. Loken, Ph.D.
Charles H. McGinnis, Ph.D.
John A. Sullivan, Ph.D.

College of Biological Sciences

Section I: GENERAL INFORMATION

ORGANIZATION AND OBJECTIVES

The excitement that now centers around the activities of biologists in universities and research institutes stems from the fact that many major problems confronting mankind are biological in nature; the well-being of all of us is intimately tied up with their solution. It is evident that the talents of our most able people must be brought to bear on these problems if they are to be resolved. This is because their resolution will require an understanding of, and ability to use, the most profound concepts in physics, chemistry, and mathematics in addition to an appreciation of organisms when viewed at the molecular, cellular, organismal, and population levels. This does not mean that the contribution of the specialist working in a circumscribed area will no longer be of value. It does mean, however, that the "integrator"—the man who has a depth of knowledge in a range of areas and who, therefore, has the capacity to work with highly complex physical-chemical reactions in the milieu of dynamic systems—will be in the forefront of biology.

During the last decade it has become apparent that knowledge of the structure and functioning of biological systems was increasing at such a rapid rate that extensive revisions were needed in both the undergraduate and graduate bio-science curriculums. In the course of discussions as to how these revisions could be effected an all-University committee, with the counsel of an expert panel from other universities, concluded that a College of Biological Sciences should be established which would serve as a focal point for course offerings and research in biology. Following the approval of the University of Minnesota Faculty Senate, the proposal to establish a new college was submitted to and approved by the Board of Regents. Thus, the first such college in the nation was administratively and budgetarily established on September 1, 1965.

Upon establishment of the College of Biological Sciences (CBS), the Botany and Zoology Departments from the College of Liberal Arts and the Biochemistry Department from the Institute of Agriculture were administratively and budgetarily transferred to CBS. In addition, a new Genetics Department was created by the voluntary transfer of some professors from the Institute of Agriculture, and from the Zoology Department to the Genetics Department.

The college has three primary commitments in helping the University maintain excellence in scholarship among the broadest possible spectrum of the student body: first, to provide bio-science courses for other collegiate units both for the purpose of general education as well as to assist in the development of majors in fields which are based on a thorough grounding in bio-science; second, to provide a substantial curriculum that leads to the

General Information

granting of bachelor of science degrees in bio-science and, finally, to provide opportunities for research and teaching at the graduate level that assures high standards and the maintenance of an excellent faculty.

DEGREE OFFERINGS

Undergraduate Programs

The bachelor of science degree is the only degree offered by the College of Biological Sciences and it can be earned with honors if the student attains a high level of excellence and satisfies other specified requirements. It is possible to obtain the degree with a major in biology, biochemistry, botany, microbiology, or zoology. Irrespective of the major, however, each student must complete the same core sequence of courses in biology, the physical sciences, and mathematics. Students with a grade point average of 2.50 or above may take advantage of the opportunity to carry out a research problem during 1 or more quarters of the senior year, under the guidance of a research adviser.

The core sequence was designed in recognition of the following facts: (1) that there is an underlying similarity in the functioning of all biological systems when viewed at the molecular and cellular levels; (2) that to train students for careers as biologists, great emphasis must be given to training in the physical sciences; and (3) that to maintain student interest, core courses must be taught so that they emphasize physical science methodologies in the solution of biologically important problems.

CAREER OPPORTUNITIES

The bachelor of science degree was designed to provide a student with a background in the physical, mathematical, and biological sciences that would give him a thorough basis on which to build if he chose to pursue a graduate degree in bio-science or to enter the fields of medicine, veterinary medicine, or education. Should a student choose to end his formal education with the Bachelor's degree, he would have a sufficient level of sophistication in bio-sciences and a liberal enough education to assume any one of a variety of office, laboratory, or field positions with governmental agencies and industry. For the student who achieves the Master's or Ph.D. degree, the opportunities are plentiful for employment in universities, junior colleges, high schools, federal agencies, state agencies, and industry.

ADMISSION REQUIREMENTS

General

At the undergraduate level, the College of Biological Sciences will serve primarily as an Upper Division unit; that is, students will normally enter the CBS at the beginning of their junior year. Nevertheless, students with an interest in a major in biology are urged to contact the college offices at 307 Zoology Building or 123 Snyder Hall at once in order to receive appropri-

ate advice. Course work in the biological sciences will be based on a sound preparation in the mathematical and physical sciences as well as a broadly based preparation in the liberal arts. Students may appropriately register in the College of Liberal Arts or the College of Agriculture, Forestry, and Home Economics during their freshman and sophomore years and, with the advice and counsel of a member of the biology faculty, take courses that will provide the most adequate preparation for their Upper Division registration in the College of Biological Sciences. Students should refer to the *Bulletin of the College of Liberal Arts*, the *Bulletin of the College of Agriculture*, the *Bulletin of the School of Forestry*, and the *Bulletin of the School of Home Economics* for information regarding admission criteria, etc.

A typical program for the freshman and sophomore years is as follows:

Fall		Winter		Spring	
Engl A or 2B	4-5	Engl B or 2B	4-5	Engl C or 3B	4-5
Math 15	5	Math 42	5	Math 43	5
GeCh 4	5	GeCh 5	5	GeCh 6	4
Electives	0-3	Electives	0-3	Biol 49	3
	14-18		14-18		16-17
Math 44	5	OrCh 62	5	Biol 60	4
OrCh 61	5	Biol 51	5	Biol 52	4
Biol 50	5	Ger 1	5	Ger 2	5
Electives	0-3	Electives	0-3	Electives	3
	15-18		15-18		16

PROCEDURES AND PRACTICES

Admission Procedures

Requirements for Admission—Students will normally enter the College of Biological Sciences at the beginning of their junior year. Specific requirements are:

1. Satisfactory completion of the equivalent of 75 quarter credits with at least a 2.00 grade point average.
2. The completion of 30 credits in mathematics, physical and/or biological sciences with at least a 2.50 grade point average in biological science courses.

Transfer from Other Colleges Within the University—Obtain a "Transfer of College Within the University" form from an Office of Admissions and Records. Transfer application deadlines of September 1, December 1, and March 1 have been set for the fall, winter, and spring terms, respectively.

Admission from Outside the University with Advanced Standing—Apply to the St. Paul Campus Office of Admissions and Records. Ordinarily applications can be acted on before the transcript with the current quarter's grades has been submitted. Thus if an application is made by May 1, the

General Information

student should be informed of the action before June 1 of the same year. The student will be admitted, subject to the satisfactory completion of his current registration.

Adult Special Status

Adult special registration provides the opportunity for men and women to undertake work in individual courses or groups of courses to meet special and individual needs without wishing to apply this course work to a degree. However, subsequent admission to a degree program is possible on recommendation of the college. In such case, credit earned as an adult special will be applied when possible. Only 1 quarter of work as an adult special may be used toward a Graduate School degree. Admission is completed through the Office of Admissions and Records. Restrictions on admission of nonresident undergraduate students apply to admission of adult students. Applications should be filed well in advance of the quarter of entrance.

Maximum and Minimum Credits per Quarter

Most students take about 15 credits of work each quarter. To take less than 12 you must secure permission of your adviser and of the college office. If you hold a job requiring more than 20 hours of work a week you are advised to take no more than 12 credits, and if you must work 30 hours or more you should take less. In general it is unwise to work more than 15 to 20 hours a week while going to college.

The maximum number of credits for which you may register is ordinarily 17. After 1 quarter of residence you may register for 18 credits provided you have a scholarship average of 2.50 for the quarter before registration and no failure for the quarter immediately preceding registration. Registration for credits in excess of these limits must be approved by the college office.

Credits in Graduate School

If you are lacking not more than 9 credits for graduation, you may, upon petition, get graduate credits for a limited amount of work taken as an undergraduate. No graduate credit will be given unless you have made previous arrangements with the Graduate School. Courses taken for graduate credit will not carry credit toward the Bachelor's degree.

With the permission of the college office, an undergraduate lacking not more than 6 credits for graduation may be registered in the Graduate School while completing requirements for the Bachelor's degree.

Courses Without Credit

Under certain circumstances, you may register for a course without credit with the permission of the instructor and the college office. This will entitle you to participate in class activities to an extent agreed upon in advance with the instructor. The usual arrangement, when permission is granted, is

for full participation with a final grade recorded on the permanent record, but the credits and grade points do not count in computing the grade point averages in the college. The procedure is particularly useful for returning students who may wish to repeat a course for review.

Audited Courses

Auditing a course differs from taking it without credit in that the student may not normally participate in the activities of the class or take the final examination, and no grade is recorded. Moreover, you may not later take for credit a course that you have audited. If you wish to audit, you must obtain the approval of the college office. The course will count as part of the academic load for fee purposes but not for determining credit load.

Repeating a Course

You may, without special permission, repeat a course which you have failed; both the old and new grades will then stand on the record. You need not repeat a failed course, however, unless it is prerequisite to other courses you wish to take or is required for graduation.

You may not, without permission from the college office, repeat a course for which you have already received credit. When permission is given, the college will determine how the second grade shall be counted in the grade point average. Usually it does not count.

Credit for Courses Prerequisite to Courses Accredited

If, by some mistake, you take a course without fulfilling a prerequisite, you may not later take this prerequisite course for credit except by permission of the college office.

Canceling Out of College

If you should need to cancel out of college during a quarter or plan not to return in the succeeding quarter, you should report to the St. Paul Campus Admissions and Records Office (Coffey Hall) to check on your financial status, cancel courses for the current or succeeding quarter, and discuss your academic standing and possibilities of return or transfer, grades to be awarded, wisdom of the decision to cancel, financial needs, job placement, or other topics.

REQUIREMENTS FOR GRADUATION

Each of the undergraduate degree offerings of the College of Biological Sciences is based on the undergraduate core curriculum. Students in each of these degree programs must fulfill the all-College requirements listed on page 10. In addition, they must complete a major which must include at least 20 Upper Division science and mathematics credits.

General Information

Candidates will be recommended for graduation following:

1. Completion of the basic core curriculum requirements.
2. Completion of a total of not less than 180 credits.
3. Completion of a minimum of 45 credits in residence in the College of Biological Sciences plus 2 quarters (30 credits) of the senior year in residence.
4. A grade point average of at least 2.00 (C) computed in each of the following ways: (a) in all work presented from the University and *in toto*, and (b) in all work done while in CBS.

Liberal Education Requirements:

As stated in the University Senate *Minutes* of June 1965: "The University of Minnesota believes that all of its students, whatever their area of specialization or their vocational goals, should hold in common the search for a liberal education. In the broadest sense a liberal education is one which frees us from the limitations placed by ignorance on our powers of judgment and choice. More specifically, a liberal education asks of us that we seek control over the general intellectual instruments for acquiring and communicating knowledge, primarily the instruments of language and number; that we seek understanding of the ways in which scientists contribute to man's knowledge of himself and his environment; that we seek historical and philosophic perspective on the nature of our own lives and the world in which we live; and that we seek appreciation of the creative insights into life and nature provided by literature and the arts." To help students achieve the goals of liberal education, the College of Biological Sciences expects each student to distribute some part of his course work in areas of study other than those most closely linked to his specialized or vocational interests.

A. Communication, Language, Symbolic Systems

1. English Communication Skills—Completion of 9 credits of English or exemption
2. Foreign Language—Completion of 15 credits preferably in one of the following languages: French, German, or Russian, or demonstration of equivalent proficiency as determined by the appropriate language department
3. Mathematics—Through Math 44 (Analytic Geometry and Calculus III)

B. Physical and Biological Sciences

1. The Physical Universe

GeCh 4-5—General Principles of Chemistry (10)	OrCh 61-62—Elementary Organic Chemistry (10)
GeCh 6—Principles of Solution Chemistry (10)	Phys 7-8-9—General Physics (15)

2. The Biological Universe

Biol 1-2—General Biology (10)
(or) Biol 49—Principles of Biology (3)
Biol 50—Animal Biology (5)
Biol 51—Plant Biology (5)
Biol 52—Microbiology (4)
Biol 60—Biochemistry (4)

Biol 70—Genetics (3)
Biol 80—Ecology (3)
Biol 82—Field Biology (1)
Biol 110—General Physiology (3)
Biol 120—Developmental Biology (3)
Laboratory in three biology courses (4-6)

C. Man and Society—Completion of 18 credits from the following areas:

1. The analysis of human behavior
2. The analysis of social, economic, and political institutions
3. The development of civilization: historical and philosophical studies

D. Artistic Expression—Completion of 12 credits in the following areas:

1. Literature
2. The arts

Graduation with Honors

In order to graduate with honors a student must meet the following requirements: (1) he must earn at least 60 credits in Upper Division courses in the University of Minnesota; (2) he must elect at least two College Honors Seminars in either the College of Biological Sciences or the College of Liberal Arts; and (3) he must complete satisfactorily at least 1 quarter of research within the major. The minimum grade point averages required for graduation with honors are: *cum laude*, 3.00; *magna cum laude*, 3.25; and *summa cum laude*, 3.40. These averages must be based on the following:

1. All work completed for the degree at the University of Minnesota.
2. All work completed in the College of Biological Sciences.
3. All work in the courses in the major.

Candidates for the degree *summa cum laude* must present an acceptable thesis, completed under the guidance of a research adviser.

STUDENT PERSONNEL SERVICES

Faculty Advisers—Each student in the College of Biological Sciences will be assigned a faculty adviser. The student is encouraged to consult frequently with his adviser regarding curricular planning and progress in specific courses as well as any other matters which relate to his University experience.

Before seeing the adviser regarding curricular planning, the student should study the relevant bulletins carefully and be prepared to present a tentative program as well as a current copy of the transcript of credit already earned at the University or elsewhere. If a student should wish to change his

General Information

adviser, this can be arranged through the college office, 123 Synder Hall, St. Paul Campus.

College Office—A student should always feel welcome to discuss any questions or problems he may have with a member of the staff of the college office. The college will try to assist students with such problems as the location of meaningful employment, etc.

All-University Personnel Services—Several specialized personnel services are provided by the University for all students. Some of these are:

For professional help on a personal problem or vocational choice, go to the Student Counseling Bureau, 101 Eddy Hall.

To learn about student activities, visit the Student Activities Bureau at 4 TNM, the Coffman Union Program Office in 229 Coffman Memorial Union, or the St. Paul Student Center.

For financial help, apply at the Bureau of Student Loans and Scholarships, 107 Armory Building.

For a part-time job on or off campus, apply at the Student Employment Bureau, 30 Wulling Hall.

For help in improving reading or other study skills, use the Reading and Study Skills Clinic, 101 Eddy Hall.

For aid with speech difficulties, consult the Speech and Hearing Clinic, 225 Shevlin Hall.

For questions concerning veterans' benefits, go to 102 Morrill Hall.

For help in finding a room or apartment, see the Student Housing Bureau, 209 Eddy Hall; for married students, 100 Wesbrook Hall.

For assistance and advice as a foreign student, contact the Office of the Foreign Student Adviser, 302 Eddy Hall.

For assistance with health problems, go to the University Health Service Building or the St. Paul Campus Health Service.

For assistance with legal problems, consult the Legal Aid Clinic, 133 Fraser Hall.

Section II: GRADUATE STUDY

Graduate study at the University of Minnesota is co-ordinated and administered by the Graduate School through the members of the various graduate faculties, the Graduate Group Committees, and the Executive Committee of the Graduate School. In this way, members of departments, schools, and colleges throughout the University co-operate in the offering of advanced study and training in a wide range of academic fields. The faculty of the College of Biological Sciences plays a major role in offering graduate degrees in biological science areas. A student should refer to the *Bulletin of the Graduate School* for details relating to general policies regarding admission requirements, registration procedures, general requirements for graduate degrees, general opportunities for financial aid, etc.

GRADUATE STUDY IN BIOCHEMISTRY

The M.S. degree (Plan A) and Ph.D. degrees are offered jointly through the faculty in the Departments of Biochemistry in the College of Biological Sciences and the College of Medical Sciences. The program is administered under the direction of a subcommittee for biochemistry which functions under the Group Committees for Medical Sciences and Biological Sciences.

The major aim of the graduate program is to prepare candidates for careers in research and/or teaching in biochemistry and related sciences. The program has been designed to encourage the development of independent thought, research potential, and technical skills. A series of courses and informal seminars provides the stimulus, but the thesis research is a major component of the degree program. Areas of research interest represented by the graduate faculty in biochemistry include chemistry and biochemistry of carbohydrates, proteins, and lipids, microbial metabolism, enzyme catalysis (kinetics, mechanism and active site determination), phage metabolism and genetics, amino acid metabolism, immunochemistry, physical biochemistry, biochemical genetics, evolutionary and comparative biochemistry.

For course descriptions, check the listings of courses in the Department of Biochemistry on page 27. For further details, see the *Bulletin of the Graduate School*.

GRADUATE STUDY IN BIOLOGY

The master of science (Plan A and B) and the Ph.D. degrees in biology accommodate students in areas of biological specialization which are interdepartmental in nature. Students should refer to the interdepartmental programs outlined below. Members of the graduate faculty are drawn from areas of biological, agricultural, and medical sciences.

Students who wish to earn an advanced degree in biology must demonstrate competence in the field as a whole at approximately the level of the undergraduate core curriculum program as well as complete a field of specialization or a special program designed for the student's interest.

The master of science degree has only recently been instituted and since details are not available in the present *Bulletin of the Graduate School*, a brief summary of requirements is included here. In addition to fulfilling the requirement of passing a comprehensive examination on the subject matter covered in the undergraduate core curriculum, a student pursuing the master of science (Plan A) must take 18 credits of biological sciences, at least 9 of which must be within a single department or program. Nine credits are required for the minor which may be either outside the biological sciences or from a department or program within the biological sciences from which no courses are used for the major. A thesis and final oral examination complete the requirements for this plan.

The master of science (Plan B) requires 45 credits. The student can offer a minimum of 21 credits in the biological sciences and 18 in two related fields. The student must take at least 6 credits in a field to have it accepted as a related field. If a student prefers, he may fulfill the requirements by taking 9 credits in each of four biological science departments or programs. Three papers representing the quality but not the range of a thesis shall be prepared. In the case of the student choosing the 9-credit sequence, the papers must come from at least two departments or programs. A final oral examination completes the requirements.

Admission requests can be made to a specific program or to the general admissions committee whose membership is determined by the Biological Group Committee of the Graduate School.

Interdepartmental Programs in Biology

Behavioral Biology—Frank McKinney, Program Chairman. The field of behavioral biology is growing rapidly and a need for additional well-trained graduates is apparent. The broad aims of the program are to provide the opportunity for graduate training in all aspects of animal behavior, but the primary role of the faculty will be to represent the biological approach to behavioral problems.

The field is well represented at the University of Minnesota by 17 faculty members from the Departments of Anthropology, Ecology and Behavioral Biology, Psychology, and Zoology. They represent the following research areas: behavior genetics, animal learning, ethology, neural mechanisms of behavior, motivation, communication, activity rhythms, behavioral pharmacology, telemetry, and animal movements.

Cell Biology—Murray Rosenberg, Program Chairman. A prime concern of this program is to challenge the student with study and research of breadth and versatility to enable him to carry out independent research and to meet the challenge of new discovery and knowledge during his professional career. To accomplish these aims, the student will be given the opportunity to obtain a broad interdisciplinary background. In addition to numerous courses in physics, chemistry, mathematics, engineering, and biology offered by various departments of the University, six specialized core courses on advanced topics in cell biology and laboratory techniques are offered. Source material for these courses is drawn from the research literature. Specialized laboratory problems have been designed to familiarize students with much of the

instrumentation and experimental methodology required in cell biology ranging among tissue culture techniques, microcinematography, electron microscopy, surface chemistry, isolation and analysis of subcellular fractions, and metabolic methods.

During their first year of study, students will be encouraged to participate in ongoing research with faculty members to become acquainted with the types of research carried out by advisers in cell biology. By the end of his second year, a student will be ready to select a research problem and adviser. A large number of research problems in cell biology are now being carried out in well equipped laboratories by members of the faculty of the College of Biological Sciences. These include topics such as cell growth, cell ultrastructure and electron microscopy, mitochondrial structure and function, metabolism of neural cells, cell respiration, transport mechanisms, contractile processes, cell membranes, protoplasmic streaming, synchrony of cells, model membranes and interfaces, cell population dynamics, nuclear control of protein synthesis in cells, lipid metabolism, etc. A special instrumentation laboratory is being equipped so that graduate students will also have access to a pool of equipment and biological material required for the conduct of their research.

For course descriptions, check the listings of graduate courses in the Department of Genetics and Cell Biology, beginning on page 37.

Developmental Biology—Nelson T. Spratt, Program Chairman. The program in developmental biology promises to be an unusual one in that the study of differentiation and morphogenesis at all levels from subcellular organelles to whole plants, animals, and microorganisms will be included. The aim of the program will be to train students to recognize the important problems in developmental biology while learning enough about many types of organisms to be able to choose one in order to attack a particular problem.

Year-long sequences in biochemistry and physical chemistry will be required, as will advanced genetics. Since the fundamental unit of development is the cell, students will be expected to gain competence in cytology and cell biology. Rather than requiring a large number of courses in developmental biology, students will complete at least 2 quarters of an advanced topics course which will consist of reading assignments from the research literature, lectures, and seminars. This will be taught by numerous faculty members, each covering his area of special competence. The kind of topics which will be covered include morphogenesis and developmental anatomy of protists, animals, and plants; cell differentiation, morphogenesis, and homeostasis; cell-environmental interactions including cell-cell interactions; and the molecular control of development. Students will begin work in a research laboratory during their first year.

Evolutionary and Systematic Biology—Robert Jenness, Program Chairman. Students should have some preparation in the taxonomy of groups of organisms which hold a special interest for them. In addition to competence in biochemistry, genetics, biostatistics, and in the systematics of one or more of the major groups of organisms, students must develop a high level of competence in at least one of the following areas: (1) comparative biochemistry; (2) genetics of speciation, cytogenetics including cytotaxonomy, and experimental taxonomy; (3) phylogeny and taxonomy of living and extinct groups of

Graduate Study

organisms as seen from the viewpoint of comparative anatomy and morphology; (4) comparative physiology.

Field Biology—William Marshall, Program Chairman. The field biology program provides a focal point for the development of research projects and teaching programs dealing with field aspects of environmental and behavioral biology. Students interested in courses which provide extensive field work in ecology, behavior, or systematics will find that the Lake Itasca Biology Sessions offer many opportunities during the summer months in an environmental setting of great potential. The newly developed winterized facilities also provide a base for research workers to study the wide range of aquatic and terrestrial habitats with flora and fauna of northern, western, and southern affinities in the Itasca State Park region. Year-round research programs involving field studies may also be based at the Cedar Creek Natural History Area. The latter, which is only 32 miles from the Twin Cities campuses, is a 5,000-acre area dedicated to the study and preservation of natural habitats.

Limnology—Herbert E. Wright, Program Chairman. Narrowly defined, limnology, as its roots imply, is the study of lakes. However, a broader and more widely accepted definition is the study of all freshwaters so that it includes the study of ponds, streams, and rivers in addition to lakes. Thus, limnology is the freshwater counterpart of oceanology. It is a synthetic science comprising chemical, physical, biological, hydrogeological, and economic-sociological aspects which relate to the structure and functioning of inland aquatic ecosystems. These aspects are intimately related and interwoven one to the other, and it is the reaching of some understanding of their complex interplay that must be the theme of any modern training program in limnology. Basically our aim is to train students who will be capable of entering teaching and research positions in limnology in university or governmental research facilities such as the newly established Water Quality Laboratory at Duluth. To this end, the students must be broadly trained, and it is the intention, therefore, to provide only a few formal courses in basic limnology using seminars and discussions to show the relations of such fields as geochemistry, microbiology, etc., to limnology.

Terrestrial Ecology—Alan J. Brook, Program Chairman. A large scale effort is currently in progress to train students to determine and evaluate the influence of environment on vertebrate behavior in natural ecosystems through use of recently developed techniques such as biotelemetry, radionuclide tagging, and time-motion analysis of filmed behavior sequences. Excellent facilities for this training are already in existence in the College of Biological Sciences.

Recent advances, most of which were made at the University of Minnesota, in the use of biotelemetry to study animal behavior and movements have stimulated hundreds of scientists throughout the world to consider using this technique. However, lack of scientists trained to function in this interdisciplinary field is seriously hindering behavioral and ecological research. To our knowledge, the automatic radio tracking system developed by the James Ford Bell Museum of Natural History is the most advanced facility of this type in the world.

The training stresses the use of these new techniques and advanced methods of data processing and analysis. Participants are instructed in using biomathematical approaches such as model construction and systems analysis to investigate situations in which many interrelated environmental factors function in an integrated manner on individual organisms and populations.

GRADUATE STUDY IN BOTANY

Botany is that science which is directed toward a better understanding of plant function and structure at all levels of organization as well as the interaction of plants with other organisms and the environment. The graduate faculty of the Department of Botany offers instruction directed toward educating career plant biologists for research, teaching, and public service. Excellent opportunities exist for research at the molecular, cellular, organismal, developmental, taxonomic, and environmental levels. For further details, see the *Bulletin of the Graduate School*.

GRADUATE STUDY IN GENETICS

The master of science and Ph.D. degrees are offered jointly through the faculty of the Department of Genetics in the College of Biological Sciences and the faculties of the Medical School, College of Veterinary Medicine, and College of Agriculture, Forestry, and Home Economics. The program is administered by the Subcommittee of Genetics in the Graduate School. For further details, see page 37 of this bulletin; also refer to the *Bulletin of the Graduate School*.

Financial support for graduate study in genetics is available in the form of teaching assistantships, research assistantships, and fellowships. Applications for such support should be addressed to the Director of the Genetics Center, 125 Peters Hall, University of Minnesota, St. Paul, Minnesota 55101.

GRADUATE STUDY IN ZOOLOGY

The Department of Zoology offers graduate work toward the M.S. and Ph.D. degrees. Its faculty are carrying out active research programs in the areas of biophysics, cell metabolism, cytology, ecology, embryology, parasitology, physiology, and protozoology.

Well-equipped research facilities are available, including an animal room, an aquarium room, culture rooms and equipment, biochemical and histological facilities, an electron microscope, electro-physiology equipment, and a complete machine and woodworking shop.

Excellent opportunities for field study and research are afforded by the Lake Itasca Forestry and Biological Station located in an area of many lakes, streams, virgin coniferous and deciduous forests. The 5,000-acre Cedar Creek Natural History Area offers a variety of habitats and a modern field laboratory only 32 miles from the campus.

Teaching assistantships and fellowships are available for well-qualified graduate students.

For additional information, consult the *Bulletin of the Graduate School*.

Section III: CURRICULAR REQUIREMENTS

BIOCHEMISTRY

Faculty Advisers: Professors Kirkwood, Warner, Gander, Liener, Henderson

A major in biochemistry is designed for students who contemplate graduate study in biochemistry or the biochemical aspects of biological, medical, or agricultural sciences. It also will provide the courses which prepare the chemist for a biochemical position in industry at the bachelor of science level. The curriculum differs from that leading to the bachelor of chemistry degree largely in that substantial training in the biological sciences is included at the expense of additional courses in analytical, inorganic, and physical chemistry. The program is a carefully planned sequence of required courses with a small number of free electives.

In addition to the general requirements for graduation from the College of Biological Sciences, the bachelor of science degree in biochemistry requires:

- Biometrics—4 credits
- Physical Chemistry—14 credits
- Analytical Chemistry—8 credits
- Additional Organic Chemistry—6 credits
- Biochemistry**—8 credits

SAMPLE CURRICULUM: BIOCHEMISTRY MAJOR

FIRST YEAR					
Fall		Winter		Spring	
Engl A or 1B	4-5	Engl B or 2B	4-5	Engl C or 3B	4-5
Math 15	5	Math 42**	5	Math 43	5
GeCh 24 (or 4)	5	GeCh 25	3	Electives (or GeCh 6)	4
Electives	3	(or) GeCh 5 (5 cr)		Biol 49	3
		Electives	3		
	<hr/>		<hr/>		<hr/>
	17-18		15-18		16-17
SECOND YEAR					
Math 44	5	OrCh 62	5	Biol 60††	4
OrCh 61	5	Biol 51	5	Biol 61†††	1
Biol 50	5	Ger 1	5	Biol 52	4
Electives	3	Electives	0-3	Ger 2	5
				OrCh 63	3
	<hr/>		<hr/>		<hr/>
	18		15-18		17

** Students who expect to undertake a graduate program in biochemistry should enroll in BioC 141, 142, 145, and 146 (12 cr) instead of BioC 51 and 52 (8 cr). Students with a grade of A or B in Biol 60 and 61 are exempted from BioC 51.

†† Transfer students may elect to take BioC 51 and 52 instead of Biol 60 and 61.

THIRD YEAR

<i>Fall</i>		<i>Winter</i>		<i>Spring</i>	
OrCh 65	4	AnCh 46	3	AnCh 47	5
Phys 7	5	Phys 8	5	Phys 9	5
Ger 3	5	Biol 80	3	Biol 82	1
Biol 70	3	Electives	5	Electives	5
	<hr/> 17		<hr/> 16		<hr/> 16

FOURTH YEAR

PhCh 101	4	PhCh 102	4	PhCh 104	4
Biom 100	4	BioC 51	4	PhCh 105A	2
Electives	7	Biol 110 (or equiv)	3	Biol 120	3
		Biol 111 (or equiv)	2	BioC 52	4
		Electives	3	Electives	2
	<hr/> 15		<hr/> 16		<hr/> 15

BIOLOGY

Major Advisers for the College of Education: Professors Olson, Jenness, Snustad, Soulen
 Major Advisers for College of Biological Sciences: May be selected from among CBS faculty

The bachelor of science degree in biology is designed to provide the student with the opportunity to obtain a broadly-based but thorough undergraduate education in the biological sciences. For graduation, in addition to the basic course requirements for graduation, the biology major must complete 20 additional Upper Division credits in the mathematical, biological, and physical sciences. The distribution of these credits is determined by the student in consultation with his adviser. The college provides for all students with a grade point average of 2.50 or above the opportunity to carry out a research problem during 1 or more quarters of the senior year, under the guidance of a research adviser. Students with a grade point average of 3.00 or greater who wish to become candidates for honors degrees must take advantage of this research program and in addition must participate in at least two honors seminars appropriate to their interests. It is also recommended that honors sections of physical and natural science courses be elected when appropriate.

A bachelor of arts degree with a major in biology is available through the College of Liberal Arts. The core course requirements for this degree are the same as for the B.S. degree. However, the B.A. student must fulfill the additional CLA requirements that are outlined in the CLA bulletin. A student interested in teaching biology at the secondary level should consult with the College of Education where a specialized curriculum is available or with one of the advisers noted above.

Curricular Requirements

SAMPLE CURRICULUM: BIOLOGY

FIRST YEAR

<i>Fall</i>		<i>Winter</i>		<i>Spring</i>	
Engl A or 1B	4-5	Engl B or 2B	4-5	Engl C or 2C	4-5
Math 15	5	Math 42	5	Math 43	5
GeCh 4	5	GeCh 5	5	GeCh 6	4
Electives	0-3	Electives	0-3	Biol 49	3
<hr/>		<hr/>		<hr/>	
14-18		14-18		16-17	

SECOND YEAR

Math 44	5	OrCh 62	5	Biol 60	4
OrCh 61	5	Biol 51	5	Biol 52	4
Biol 50	5	Ger 1	5	Ger 2	5
Electives	0-3	Electives	0-3	Electives	3
<hr/>		<hr/>		<hr/>	
15-18		15-18		16	

THIRD YEAR

Phys 7	5	Phys 8	5	Phys 9	5
Ger 3	5	Biol 80	3	Biol 82	1
Biol 70	3	Electives	7-8	Electives	9-11
Electives	1-5				
<hr/>		<hr/>		<hr/>	
14-18		15-16		15-17	

FOURTH YEAR

Electives	14-16	Biol 110	3	Biol 120	3
		Biol 111	2	Electives	11-13
		Electives	10		
<hr/>		<hr/>		<hr/>	
14-16		15		14-16	

NOTE—In selecting elective courses, students must fulfill the Liberal Education requirements in the categories of Artistic Expression, Man and Society, and Biology Laboratory as well as complete the 20 additional Upper Division credits in the biological, mathematical, and physical sciences required for a biology major. Students would find it most beneficial to fulfill some of the Upper Division credits by registering in courses offering training in the techniques of statistical procedures. Such courses as Biom 90, Biom 100, and Biom 101 are recommended.

BOTANY

Faculty Adviser: Professor Gorham

The bachelor of science program in botany provides the opportunity for a student to obtain a well-balanced undergraduate education in biology while achieving some degree of concentration in the botanical sciences. In addition to completing the core curriculum, students are required to take one course

Ecology and Behavioral Biology

from each of the following groups, plus one additional course of his own choosing:

- Group A (taxonomy)—Bot 52 or 116su
- Group B (anatomy or cytology)—Bot 53 or 118 or 121
- Group C (physiology)—Bot 91, 91A or 141, 141A
- Group D (plant kingdom)—Bot 104

SAMPLE CURRICULUM: BOTANY MAJOR

FIRST YEAR

<i>Fall</i>		<i>Winter</i>		<i>Spring</i>	
Engl A or 1B	4-5	Engl B or 2B	4-5	Engl C or 3B	4-5
Math 15	5	Math 42	5	Math 43	5
GeCh 4	5	GeCh 5	5	CeCh 6	4
Electives	0-3	Electives	0-3	Biol 49	3
	14-18		14-18		16-17

SECOND YEAR

Math 44	5	OrCh 62	5	Biol 60	4
OrCh 61	5	Biol 51	5	Biol 52	4
Biol 50	5	Ger 1	5	Ger 2	5
Electives	0-3	Electives	0-3	Bot 52	3
	15-18		15-18		16

THIRD YEAR

Phys 7	5	Phys 8	5	Phys 9	5
Ger 3	5	Biol 80	3	Biol 82	1
Biol 70	3	Electives	7-8	Bot 118	5
Electives	1-5			Electives	4-6
	14-18		15-16		15-17

FOURTH YEAR

Bot 104	5	Bot 110	3	Biol 120	3
Electives	9-11	Electives	12	Bot 91-91A or Bot 141-141A	5
				Electives	6-8
	14-16		15		14-16

NOTE—In selecting elective courses, students must satisfy the Liberal Education requirements in the categories of Artistic Expression, Man and Society, and Biology Laboratory.

ECOLOGY AND BEHAVIORAL BIOLOGY

Graduate students may pursue courses of study leading to a Master's or Ph.D. degree in biology with specialization in the area of ecology and/or behavioral biology. If these areas of biology are chosen, the candidate must

Curricular Requirements

select his major adviser from among the appropriately qualified members of the graduate faculty.

Because of the extremely wide variety of pursuits conceivable in ecology and the increasing demand for environmental scientists of widely different backgrounds, required course work is minimal and each candidate's program will be planned to meet his individual requirements.

Students who are preparing for graduate study in ecology and/or behavioral biology should have a good foundation in the biological sciences; mathematics through calculus; general chemistry; organic chemistry; and 1 year of college physics. They are urged to become proficient in at least one foreign language prior to entering Graduate School.

The Master's degree is offered under Plan A or Plan B. For the Ph.D. degree, students must develop a general competence in ecology and/or behavioral biology and will undertake thesis research which may be in one of the many areas of ecology. All major students will be expected to complete courses in statistics until they have attained a level of competence equivalent to Biom 100-101.

Depending on the area of ecology and/or behavioral biology in which the student has special interest, courses in the following (or other appropriate) areas, may be applied to the candidate's major: earth sciences, soil sciences, meteorology, climatology, systematics, physiology, probability theory and statistics, mathematics, theory of systems, philosophy of science, genetics, or psychology.

General Requirements

Each candidate's proficiency in general biology will be assessed by an examination which will be taken at the end of the third quarter.

For the Ph.D. degree, two languages of significance to the candidate's research program are required—or one such language and the collateral field option. For further details, see the *Bulletin of the Graduate School*.

GENETICS AND CELL BIOLOGY

The Department of Genetics and Cell Biology participates in teaching the core curriculum for undergraduates. Any student interested in these areas will take his undergraduate degree in biology.

The department emphasizes graduate training. Those department members whose major activity is in the field of genetics participate in a single co-ordinated genetics graduate program of the University. The graduate faculty in genetics and the Genetics Center are comprised of qualified geneticists from various departments and colleges of the University. The strength of the graduate training activity in genetics lies in three broad areas—those concerned with (1) problems presented by the materials of heredity and the processes by which they control the development and functions of organisms, (2) population and quantitative genetics, and (3) human genetics. General information concerning the program, curriculum, and graduate faculty is contained in the *Bulletin of the Graduate School*. Further information may be obtained from the director of the Genetics Center or the chairman of this department.

Department members whose major activity is in the field of cell biology participate in a co-ordinated graduate program in cell biology. Cell biologists from various departments and colleges of the University comprise the over-all graduate faculty in cell biology. These members provide a well co-ordinated graduate program in cell biology that furnishes the breadth and versatility necessary for students to carry out interdisciplinary research. The program and the special courses currently being taught are described in this bulletin (pages 38 and 39) as well as in the *Bulletin of the Graduate School*. Further information can be obtained from the chairman of the Cell Biology Program or the chairman of the Department of Genetics and Cell Biology.

MICROBIOLOGY

Faculty Advisers: Professors Bernlohr, Bradley, Brand, Dworkin, Rogers, Schmidt

The 4-year curriculum which leads to the degree of bachelor of science with a major in microbiology more than fulfills the requirements for a practicing microbiologist and also prepares a student for graduate work at any university.

The field of microbiology embraces a multitude of areas of fundamental and applied research. Microbiologists have in common an interest in the basic role played by microbes such as bacteria, fungi, and viruses in the world in which we live. The microbiologist may be interested in basic biological mechanisms, such as DNA replication or the regulation of protein synthesis, which are currently under study employing microorganisms. He may seek answers to fundamental problems in the human and animal diseases such as the mechanism of viral and bacteriological infection, immune mechanisms and auto-immune disease, and viral-induced cancer. Numerous aspects of agriculture are under investigation by microbiologists such as specific fungal and bacterial symbionts essential for maximal growth of some plants, and bacteria and fungi essential for maintenance and production of natural soil fertility. Microbiologists are also active in many industrial and pharmaceutical fields involving production and discovery of new antibiotics, manufacture of cheeses, beer, wine, etc., pasteurization in canning and food processing, and even decontamination of space vehicles.

In addition to the areas of research open to microbiologists, he may become a teacher and yet play a role in advancing our knowledge of science. Even if he selects a career outside of microbiology, he will find his training in this field invaluable in many related areas of biological research, industry, medicine, and public health.

In addition to completing the biology core curriculum, a student must take the following:

MicB 116, 116A, 121

Two of the following: MicB 102, 103, 110, 111, 124

At least 5 credits of AnCh 57A, B; or AnCh 46, 47

A sequence in physical chemistry is highly recommended
(i.e., PCh 101, 102, 103)

Curricular Requirements

SAMPLE CURRICULUM: MICROBIOLOGY MAJOR

FIRST YEAR

<i>Fall</i>		<i>Winter</i>		<i>Spring</i>	
Engl A or 1B	4-5	Engl B or 2B	4-5	Engl C or 3B	4-5
Math 15	5	Math 42	5	Math 43	5
GeCh 4	5	GeCh 5	5	GeCh 6	4
Electives	0-3	Electives	0-3	Biol 49	3
<hr/>		<hr/>		<hr/>	
14-18		15-18		16-17	

SECOND YEAR

Math 44	5	OrCh 62	5	Biol 60	4
OrCh 61	5	Biol 51	5	Biol 61	1
Biol 50	5	Ger 1	5	Biol 52	4
Electives	0-3	Electives	0-3	Ger 2	5
<hr/>		<hr/>		<hr/>	
15-18		15-18		14	

THIRD YEAR

Phys 7	5	Phys 8	5	Phys 9	5
Biol 70	3	Biol 80	3	Biol 110	3
Biol 71	2	MicB 121	3	Biol 111	2
AnCh 57A, B	5	Ger 3	5	Electives	5-6
Electives	0-3				
<hr/>		<hr/>		<hr/>	
15-18		16		15-16	

FOURTH YEAR

MicB 124**	3	MicB 116, 116A	5	MicB 111**	5
PhCh 101	4	Biol 120	3	Biol 82	1
Electives	7-9	PCh 102	4	PCh 103	4
		Electives	3	Electives	5-6
<hr/>		<hr/>		<hr/>	
14-16		15		15-16	

NOTE—In selecting elective courses, students must satisfy the Liberal Education requirements in the categories of Artistic Expression and Man and Society.

ZOOLOGY

Faculty Adviser: Assignment made in room 108 Zoology Building

The curriculum which leads to a degree of bachelor of science in zoology offers a broad and thoroughgoing education in biology and will also serve as

** Other microbiology courses may be substituted.

preparation for graduate work in zoology. In addition to completing the core curriculum, students are required to take a minimum of 13 credits in zoology including at least two of the following:

- Zool 53—Comparative Anatomy
- Zool 71—Principles of Invertebrate Biology
- (or) Zool 72—Natural History of Invertebrates
- Zool 91—Comparative Physiology

SAMPLE CURRICULUM: ZOOLOGY

FIRST YEAR

<i>Fall</i>		<i>Winter</i>		<i>Spring</i>	
Engl A or 1B	4-5	Engl B or 2B	4-5	Engl C or 3B	4-5
Math 15	5	Math 42	5	Math 43	5
GeCh 4	5	GeCh 5	5	GeCh 6	4
Elective	0-3	Electives	0-3	Biol 49	3
	14-18		14-18		16-17

SECOND YEAR

Math 44	5	OrCh 62	5	Biol 60	4
OrCh 61	5	Biol 51	5	Biol 62	4
Biol 50	5	Ger 1	5	Ger 2	5
Elective	0-3	Electives	0-3	Electives	3
	15-18		15-18		16

THIRD YEAR

Phys 7	5	Phys 8	5	Phys 9	5
Ger 3	5	Biol 80	3	Biol 82	1
Biol 70	3	Electives	7-8	Zool 71	5
Electives	1-5			Electives	4-6
	14-18		15-16		15-17

FOURTH YEAR

Zool 91	5	Zool 53	5	Biol 120	3
Electives	9-11	Biol 110	3	Electives	11-13
		Electives	7		
	14-16		15		14-16

NOTE—In selecting elective courses, students must fill the Liberal Education requirements in the categories of Artistic Expression, Man and Society, and Biology Laboratory as well as complete the 20 additional Upper Division credits in the biological, mathematical, and physical sciences required for a biology major.

Section IV: COURSE DESCRIPTIONS

Course Offerings and Major Requirements Explanation

Courses numbered from 1-49 are intended primarily for freshman and sophomores; courses numbered 50-99 are open to juniors and seniors; those numbered 100-199 are open to juniors, seniors, and graduate students unless otherwise indicated. Courses over 200 are for graduate students only.

A course sequence separated by hyphens (121-122-123) must be taken in the order listed unless it is specifically stated that a student may enter any quarter.

The following symbols are used throughout this bulletin and carry no page footnotes:

◦ Courses through which it is possible for graduate students to prepare Plan B papers.

† To receive credit, all courses listed before the dagger must be completed.

‡ Students may enter any quarter preceding the double dagger.

§ No credit is given if credit has been received for equivalent course listed after section mark.

¶ Concurrent registration is allowed with the course listed after paragraph symbol.

‡ Consent of Instructor is required.

△ Consent of the division, department, or school offering course is required.
f,w,s,su Fall, winter, spring, or summer quarters.

Students should consult the *Class Schedule* for each quarter to learn the hour and place of specific courses.

BIOCHEMISTRY (BioC)

- 1f,s. Elementary Biochemistry I.** A survey course of organic and biochemistry comprising lectures and discussions on the chemistry of carbon compounds which occur in nature. Special emphasis will be placed on the composition, structure, and properties of the major components of plant, animal, and bacterial cells. (5 cr, §OrCh 41 or 61; prereq GeCh 5 or equiv) Glass
- 2. Elementary Biochemistry II.** Introduction to the reactions of organic compounds in the living cell. Survey of metabolic pathways, energy considerations, and biosynthetic processes with emphasis on those aspects essential to an understanding of plant and animal nutrition and physiology. (4 cr; prereq BioC 1)
- 51w, 52s. Introduction to Biochemistry.** Introduction to the fundamentals of the composition, chemical properties, reactions, and interactions of biological materials; these are illustrated in part through laboratory exercises performed by the student. (4 cr per qtr; prereq OrCh 42 or 62)
- 53f. Dairy Biochemistry.** Discussion of problems in the biosynthesis and physical and chemical properties of the constituents of milk. (3 cr; prereq ¶63 except with ‡, 52) Jenness
- Biol 60s. Biochemistry.** (See Biology listings)
- Biol 61s. Biochemistry Laboratory.** (See Biology listings)

- 63f. **Dairy Biochemistry Laboratory.** (2 cr; prereq 52, ¶53, #) Jenness
98. **Undergraduate Seminar.** Discussion and reports. (1 cr; prereq sr standing in biochemistry curriculum)
99. **Undergraduate Research.** Research problems for B.S. thesis (optional). (1-3 cr; prereq sr standing in biochemistry curriculum)
101. **Basic Biochemistry.** Offered to enable students to make up certain deficiencies in background course work. (1-3 cr; prereq Δ or #)
- 119f. **Physical Biochemistry.** Lectures and assigned reading on colloid chemistry; surface chemistry, molecular kinetics and their application to biochemical materials and processes. (3 cr; prereq OrCh 62, Phys 9) Briggs
- 141f-142w. **General Biochemistry.** Course offered jointly by Department of Biochemistry (College of Biological Sciences) and Department of Biochemistry (College of Medical Sciences). Integrated series of lectures on chemical nature, properties, and biochemical reactions of components of biological systems. (3 cr per qtr, §MdBc 141-142; prereq ¶145-146 except with Δ , 1 yr organic chemistry and cr in physical chemistry or ¶PCh 101, 107 or 90 and #) Staff
- 143s. **Metabolic Reactions.** Biochemistry of intermediary metabolism. (3 cr; prereq 142 and #)
- 145f, 146w. **General Biochemistry Laboratory.** Laboratory work paralleling and required of all who are registered in BioC 141-142 and MdBc 141-142 except with permission of department heads. (3 cr per qtr; prereq ¶141-142, 4 cr in analytical chemistry and #) Staff
- 147s. **Advanced Biochemical Techniques.** Laboratory in modern methods for study of enzymatic and metabolic reactions. (3 cr; prereq 146 or MdBc 146, ¶BioC 143 and #)
148. **General Biochemistry Laboratory.** For students in chemistry and chemical engineering. (2 cr; prereq 142, 4 cr in analytical chemistry and #)
- 151-152. **Introduction to Biochemistry.** Same as BioC 51-52 except that a term paper is required. (4 cr per qtr; prereq OrCh 42 or 62 and #)
- 153f. **Dairy Biochemistry.** Same as BioC 53 except that a term paper on a special topic is required. (3 cr; prereq ¶163 except with #, 52 or 152) Jenness
- 163f. **Dairy Biochemistry Laboratory.** (2 cr; prereq 52 or 152, ¶153, #) Jenness

For Graduate Students Only

- 204f. **Tracer Techniques.** Laboratory work on the application of radioisotopes to study of metabolic processes. (3 cr; prereq # and 143 or MdBc 144, BioC 146 or MdBc 146...MeAg 127 advised) Kirkwood
- 220w. **Advanced Protein Chemistry.** Lectures and assigned reading on composition, structure, chemical and physical properties, and biochemical functions of proteins and amino acids. (2 cr; prereq 102 or #; offered 1968-69 and alt yrs)
221. **Advanced Carbohydrate Chemistry.** Lectures and assigned reading on composition, structure, chemical and physical properties, and biochemical functions of carbohydrates. (2 cr; prereq 102 or #; offered 1967-1968 and alt yrs)
222. **Advanced Lipid Chemistry.** Lectures and assigned reading on composition, structure, chemical and physical properties, and biochemical functions of fats and fat-like compounds. (2 cr; prereq 102 or #; offered 1967-68 and alt yrs)

Course Descriptions

- 223s. Advanced Enzyme Chemistry.** Lectures and assigned reading on nature and function of enzymes. (2 cr; prereq 102 or †, PCh 102 or equiv; offered 1968-69 and alt yrs)
- 224f. Vitamins.** Lectures and reading on biochemistry of vitamins and their physiological action. (3 cr; prereq 6, 102 or †) Schultze
- 297. Special Topics in Biochemistry.** Such materials vary from term to term as staff availability and needs for the department indicate. (1-3 cr per qtr; prereq BioC 143)
- 298. Graduate Seminar.** Reports on recent development in biochemistry and on research projects in the department. Attendance required of all students. Registration optional. (1 cr; prereq Δ)
- 299. Graduate Research.** Research problems in various fields in biochemistry represented by staff interests. (2-5 cr per qtr; prereq †)

BIOLOGY (Biol)

- 1f,w,s-2f,w,s.† General Biology.** Introduction to living things both plant and animal, and to the major biological concepts. Structure, function, classification, and evolution of organisms. (5 cr per qtr)
- 1Af,w,s-2Af,w,s.† General Biology.** Introduction to living things and the major biological concepts. A terminal course primarily for nonmajors and students not pursuing a preprofessional program related to the biological sciences. (3 cr for 1A, 4 cr for 2A)
- 2Hf,w,s. Honors Course.** (5 cr; prereq grade of A or B in Biol 1)
- 49f,s. Principles of Biology.** An introduction to biology, including the cell theory, energy relations, reproduction, inheritance, and evolution. (3 cr, §Biol 2; prereq GeCh 5 or 25) Kerr, Soulen
- 50. Animal Biology.** A survey of the types of animals, with emphasis on the varied ways in which different animals have solved similar problems. (5 cr; prereq 49 or 2 and GeCh 6 or equiv) W Herman
- 51. Plant Biology.** A comparative study of growth, development, and function in plants, emphasizing the adaptations which have evolved in various groups of plants providing suitable means of support, transport of materials, nutrition, and reproduction; evolution and diversity of plant life. (5 cr; prereq 49 or 2 and GeCh 6 or equiv) Brook
- 52f. Microbiology.** Lectures and laboratory exercises in taxonomy, anatomy, physiology, biochemistry, and ecology of microbes. Emphasis is on the fundamental properties of bacteria. Lectures also include descriptions of the major groups of the bacteria as well as of the remaining protista. (4 cr, §MicB 153; prereq 49 or 2, OrCh 62) Dworkin
- 60s. Biochemistry.** Introduction to the biochemistry and biophysics of cells with emphasis on enzyme catalysis, cellular energetics, biosynthesis of cellular constituents, and cellular regulatory mechanisms. (4 cr; prereq 49 or 2, OrCh 62) Dagley
- 61s. Laboratory in Biochemistry.** (1 cr; prereq 60 or ¶60) Chapman
- 70. Genetics.** Introduction to the principles and mechanisms of heredity, with emphasis on the structure and functioning of the genetic material and its relation to breeding behavior, development, and population structure in pro-

caryotic and eucaryotic organisms. (3 cr, §Gen 66; prereq 50, 51, 52, 60; offered 1967-68 and alt yrs) Snyder

71f,w,s. Laboratory in Genetics. (2 cr; prereq 70 or Gen 66 or ¶Gen 66)

80f,w,s. Ecology. Interactions of environmental influences and individual organisms; population growth and regulation; the nature, organization, and development of ecological systems. The role of modern man in the biosphere. (3 cr; prereq Math 44 or 23 and Biol 70, or §) Staff

81w,s. Laboratory in Ecology. (1 cr; prereq 80 or ¶80) Wright, Tester

82s. Field Biology. Field trips stressing local habitat types and instruments used in ecological research. (1 cr; prereq 50 and 51) Marshall

98H. Undergraduate Seminar. Seminars will describe the principles of many different experimental techniques. The purpose of the seminars is to acquaint students with the uses, limitations, and sensitivity of physical, chemical, and biological techniques used by the biologist. (1-2 cr; prereq 2.50 GPA and §) Staff

101. Basic Biology. Offered to enable students to make up certain deficiencies in background course work. (Cr ar; prereq Δ or §) Staff

110w,s. General Physiology. A quantitative approach to the study of cell function with an emphasis upon those cellular properties which are common to all biological systems. (3 cr; prereq 50, 51, 52, 60, Math 44 or 23, Phys 9 or equiv) Rhea, Benolken

111w,s. Laboratory in General Physiology. (2 cr; prereq 110 or ¶110) Rhea, Benolken

115. Biochemical Evolution. Lectures and assigned reading on molecular evolution covering prebiotic evolution and the phylogeny of important functional molecules and biochemical systems in living organisms. (3 cr; prereq 60, 61, or equiv) Kirkwood, Jenness

120s. Developmental Biology. The study of developing systems and of the control mechanisms of development, from the molecule to the organism. (3 cr; prereq 70 and 110) Spratt

121s. Laboratory in Developmental Biology. (2 cr; prereq 120 or ¶120) Spratt

For Graduate Students Only

220f. Orientation to Research in Developmental Biology. Lectures and demonstrations describing the research programs of faculty members in the developmental biology program. (1 cr; prereq §) Staff

221. Research Training in Developmental Biology. In-service research participation in the laboratories of faculty members. The purpose is to acquaint the student with a variety of approaches in research techniques and to aid him in the choice of his final research adviser. (2-6 cr; can be taken for credit more than once; prereq §)

222, 223, 224. Advanced Topics in Developmental Biology. Morphogenesis and differentiation of protists, plants, and animals. Cell differentiation, morphogenesis, and homeostasis. Cell-environment interactions; the molecular control of development. (4 cr per qtr; prereq 121 and §)

297f,w,s. Special Topics. Treatment in depth of one or more biological topics. (Cr ar; prereq §) Staff

Course Descriptions

BOTANY (Bot)

- 10s. Minnesota Plant Life.** Nontechnical survey of all the groups of plants native to Minnesota with special reference to identification and distribution. (3 cr; suitable for nonmajors) Morley
- 12w. Plants Useful to Man.** Survey of the roles which plants have played in man's biological and cultural development. Lectures and demonstration of material. (4 cr; for majors or nonmajors) Lawrence
- 50, 50A. General Plant Ecology.** (See Biol 80 and 81)
- 51. General Plant Physiology.** (See Biol 91, 91A)
- Biol 51. Plant Biology.** (See Biology listings)
- 52f,s. Elementary Taxonomy.** Introduction to taxonomy of ferns and flowering plants, with representative material drawn largely from Minnesota spring flora. Families of plants and their relationships; floral structure and function; taxonomic terms; nomenclature; literature; methods of collection and identification; two or three field trips. (3 cr; prereq Biol 2 or 51) Morley
- 53w. Plant Anatomy.** Structure and development of plants with especial reference to vascular plants. (5 cr; prereq Biol 2 or 51) Hall
- 55f. Morphological Methods.** Introduction to techniques basic to anatomy, morphology, and cytology. (3 or 5 cr; prereq 53, and #) Abbe
- 61. Introductory Plant Physiology.** (See 91, 91A)
- 91f,s. Survey of Plant Physiology.** A study of the physiological principles underlying the processes which occur in living plants, with emphasis on higher plants. Growth and development, mineral nutrition, water relations and solute metabolism, respiration, and photosynthesis. (3 cr; prereq Biol 2 or 51, GeCh 5 or 25) Soulen, Linck, and staff
- 91Af,s. Plant Physiology Laboratory.** A laboratory course to accompany Bot 91. (2 cr; prereq 91 or 91)
- 98f,w,s. Undergraduate Proseminar.** A discussion of biological topics of current interest. (1 cr per qtr; prereq major in biological science, #) Staff
- 99f,w,s. Research Problems.** Individual research for undergraduate majors. (1-5 cr per qtr; prereq major in a biological science, #) Staff
- 101f,w,s. Basic Botany.** Individual work in some special discipline. (Cr ar; prereq Biol 2 or equiv and #) Staff
- 103f. Plant Embryology.** Early stages of somatic development with emphasis on vascular plants. (3 cr; prereq 104 or #) Abbe
- 104f. Survey of the Plant Kingdom.** A brief consideration of evolutionary relationships throughout the plant kingdom, especially as illustrated by life histories. (5 cr; prereq Biol 2 or 51) Abbe
- PIPa 105. Introduction to the Study of Fungi.** (See Agriculture bulletin)
- 106w. A Survey of Angiosperm Families.** Detailed study of the characteristics of the orders and families of flowering plants on a worldwide basis. (5 cr; prereq 52 or #; offered 1967-68 and alt yrs) Morley
- 108f. Pteridophytes.** Classification of living ferns and fern allies with special attention to temperate North America; terminology; keys; geographic distribution; distinguishing characters of families, genera, and species. (3 cr; prereq 52 or #; offered 1967-68 and alt yrs) Ownbey

- 110f. **Gymnosperms.** Survey of the taxonomy and phylogeny of the gymnosperms with special emphasis on living representatives. (3 cr; prereq 52 or #; offered 1968-69 and alt yrs) Ownbey
- 112su. **Aquatic Flowering Plants.** The higher plants of aquatic and marsh habitats. Identification and collection; association of species; relations to the habitat; adaptive morphology and food value to wildlife. (5 cr; prereq 52 or equiv or #; offered in Lake Itasca Biology Sessions)
- 114w. **Principles of Angiosperm Phylogeny.** Evolutionary relationships and the various means of judging them within the angiosperms. Laboratory investigation of representative and critical groups. (3 cr; prereq 52 or #; offered 1968-69 and alt yrs) Morley
- 115s. **Flora of Minnesota.** The vascular plants of the state; taxonomic and floristic relationships; geographical distribution and variation; speciation; collecting and identification; field trips. (4 cr; prereq 52 or #) Ownbey
- 116su. **Summer Flora of Minnesota.** A survey of the summer flowering plants and ferns of the state with particular reference to the local flora. Collection and identification of species; distribution in Minnesota; literature and taxonomic methods. (5 cr; prereq 52 or equiv or #; offered in Lake Itasca Biology Sessions)
- 118f,s. **General Cytology.** Introductory analysis of structure and related functions of intact cells and protoplasmic systems. The nature of cytoplasm, nuclei, and cell walls. Relationship of cytological data to life cycles, cytogenetics, cytotoxicology, and cytochemistry. (5 cr, §CB 118, §Zool 165; prereq 10 cr in biology, botany or zoology, elementary genetics or #) Ar
- 119s. **Experimental Cytology.** Discussion and experimental analysis of suitable current, specialized phases of cytology. The use of microscopical and cytochemical analytical methods to study cells *in vitro* and *in vivo*. (3 or 5 cr; prereq 118 or Zool 272) Ar
- 121w. **Developmental Plant Anatomy.** Microscopic structure of vascular plants with particular attention to development in the root, stem, and leaf. (5 cr; prereq Biol 2 or 51 or equiv) Abbe
- 125f. **Morphogenesis.** Development of form and structure in ontogeny and phylogeny; phenomena and genetical factors involved. (5 cr; prereq 10 cr in botany or biology) Abbe
- 126f. **Pre-Pleistocene Palynology.** A survey of pollen and spores primarily from Mesozoic and Tertiary deposits. Techniques of sample preparation; nomenclature and identification of fossil pollen and spores; their use in stratigraphy. (3 cr; prereq 165; offered 1968-69 and alt yrs) Hall
- 127f. **Morphology of Vascular Plants.** Vegetative and reproductive structure of living and fossil vascular plants. Their evolutionary relationships based on phylogenetic principles. (5 cr; prereq 104 or #) Abbe, Hall
- 128s. **Phyletic Paleobotany.** The morphology, anatomy, and evolution of fossil plants, especially those occurring in the late Paleozoic. (3 cr; prereq #) Hall
- 129f. **Floristic Paleobotany.** A study of fossil floras from the late Paleozoic to the present; emphasis on macrofossil remains, especially leaves, and their use in stratigraphy, paleoclimatic and paleoecologic interpretations. (3 cr; prereq #; offered 1967-68 and alt yrs) Hall
- PIPp 132. **Biology of Fungi.** (See Agriculture bulletin)

Course Descriptions

- 141s. Survey of Plant Physiology.** A critical study of the physiological processes which occur in living plants, with emphasis on higher plants. Growth and development, energy relations, mineral nutrition, water relations, respiration, photosynthesis, and nitrogen metabolism. (3 cr; prereq Biol 2 or 51, course in organic chemistry, physics) Frenkel
- 141As. Plant Physiology Laboratory.** A laboratory course to accompany Bot 141. (2 cr; prereq 141 or ¶141)
- 150f. Introduction to the Study of Algae.** Structure, reproduction, and life histories of major algal divisions. (5 cr; prereq 10 cr in botany or biology or #; offered 1968-69 and alt yrs) Brook
- 151f. Biology of Algae.** Aspects of the biology of the algae, dealing with their culture, cytology, and ecology, and their importance in limnology, fisheries, public health, and water supplies. (5 cr; prereq 150 or #; offered 1967-68 and alt yrs) Brook
- 155su. Freshwater Algae.** Morphology and taxonomy of freshwater algae; collection and identification of local algae. (5 cr; prereq 10 cr in biology or #; offered in Lake Itasca Biology Sessions)
- 157su. Bryophytes and Pteridophytes.** Field and laboratory study of the mosses and liverworts of Minnesota. (5 cr; prereq 10 cr in biology or #; offered in Lake Itasca Biology Sessions)
- 159su. Lichens.** Taxonomy, ecology, and floristics of the lichens of northern Minnesota; identification, sampling methods, microchemistry as a taxonomic tool. (5 cr; prereq 10 cr botany or zoology or #; offered in Lake Itasca Biology Sessions)
- 165w. Introduction to Pollen Analysis.** Ontogeny, comparative morphology, and identification of pollen grains; preparation of reference collections, applications of pollen analysis to allergology, ecology, and phylogeny; practice in atmospheric analysis. (3 cr; prereq 10 cr in botany or biology and #; offered 1968-69 and alt yrs) Cushing
- Phcg 165f. Basic Application of Radionuclides.** (See *Bulletin of the College of Pharmacy*)
- Phcg 166f. Basic Laboratory Course in Radionuclide Techniques.** (See *Bulletin of the College of Pharmacy*)
- Phcg 167w. Advanced Course in Radionuclides.** (See *Bulletin of the College of Pharmacy*)
- Phcg 168w. Advanced Laboratory Course in Radionuclide Techniques.** (See *Bulletin of the College of Pharmacy*)
- 166s. Introduction to Palynological Analysis.** The application of techniques of pollen-spore investigations to research analyses of atmosphere, recent and ancient deposits, systematic materials, allergology, etc. (5 cr; prereq 165 or #; offered 1967-68 and alt yrs) Ar
- PIPa 168f. Experimental Protoplasmatology.** (See Agriculture bulletin)
- 182f. Plant Physiology.** The plant cell and its organelles, metabolism, including photosynthesis, and genetic control of physiological processes, with emphasis throughout on the dynamic aspects of these processes. (3 cr; prereq Biol 60 or equiv) Soulen, Olson
- 183w. Plant Physiology.** A discussion of membrane phenomena, water relations, mineral metabolism, and translocation in plants. (3 cr; prereq Biol 2 or 51, OrCh 42 or 62, physics) Sudia and staff

- 184s. Plant Physiology.** The growth of higher plants, including regulation by hormones, light, and temperature. (3 cr; prereq Biol 2 or 51, OrCh 42 or 62, physics) Brun and staff
- 185w. Physiology of Photosynthetic Microorganisms.** Primarily a laboratory course dealing with the application of spectrophotometry, manometry, and other techniques used in the elucidation of the physiological behavior, chemical makeup, and intermediary metabolism of algae and photosynthetic bacteria. (3-5 cr; prereq #; offered 1968-69 and alt yrs) Frenkel
- 186w. Measurement of Plant-Environment Interactions.** A laboratory course dealing with measurements using intact plants, including water balance, plant-radiation interactions, and gas exchange between plants and the environment. (1-4 cr; prereq PCh 90, and #) Sucoff and staff
- 187. Methods of Plant Analysis.** In-depth experimental laboratory approach to microscopic analysis, sample preparation, fractionation, isolation, and measurement of plant compounds employing modern methods of plant physiology. (1-6 cr; enrollment limited; prereq AnCh 57, 8 cr biochemistry and #) Weiser and staff
- 188f,w,s. Research Perspectives in Plant Physiology.** A laboratory course in which the student undertakes a well-defined research problem of limited scope. (1-4 cr; prereq #) Behrens and staff

For Graduate Students Only

- BioC 204f. Tracer Techniques.** (See Biochemistry listings)
- Agro 252. Cytogenetics.** (See Agriculture bulletin)
- 280w. Radioisotope Techniques Applied to Biology.** Lecture and laboratory course on uses of radioisotopes in biological research and problems in their use and measurement. (3 cr; enrollment limited; prereq nuclear physics) Linck, Rust
- 281s. Growth and Differentiation of Plants.** Nature and characterization of plant growth, with analysis of the physiological changes which occur during the growth and differentiation of plants; hormonal control of growth processes. (3 cr; prereq 184; offered 1967-68 and alt yrs) Linck
- 282f. Advanced Topics in Plant Metabolism.** Treatment in depth of one or more topics selected from the following: respiratory pathways, including modifications; organic acid metabolism; nitrogen metabolism; sulfur metabolism. Content of course will vary with instructor and may include topics not listed. (3 cr; prereq 182; offered 1967-68 and alt yrs) Olson and Soulen
- 283w. Structural Physiology.** Discussion of the interrelationship of chemical composition, physiological activity, and ultrastructure of biological systems. (5 cr; prereq #; offered 1967-68 and alt yrs) Cunningham
- 285w. Photosynthesis.** Detailed survey of the present state of knowledge of photosynthesis. (3 cr; prereq 182; offered 1968 and alt yrs) Frenkel
- 297f,w,s. Special Topics.** Treatment in depth of one or more biological topics. (Cr ar; prereq #) Staff
- 298f,w,s. Seminar.** (1 cr per qtr) Staff
- 299f,w,s. Research Problems.** (Cr ar) Staff

ECOLOGY AND BEHAVIORAL BIOLOGY

Ecology (Ecol)

- 50w. Introduction to Ecology.** Interrelationships between environmental influences and plants and animals, including man: population growth and regulation; the nature, organization, and development of ecological systems. The role of man in the biosphere. (3 cr; prereq open to jrs and above, but not to biology majors) Brook
- 99. Research Problems.** Individual research for undergraduate majors in biology. (1-6 cr; prereq #) Staff
- 116w. Population Dynamics.** Seminars and lectures on verbal mathematical population theories; emphasis on relationship to laboratory and field data. (2 cr; prereq Biol 80 or #...Math 44 recommended; offered 1967-68 and alt yrs) Williams
- 118f. Experimental Ecology.** Experimental approach to study of environmental factors affecting animal populations. For companion laboratory course see Ecol 201. (3 cr, §Ent 118; prereq 9 cr in general biology or equiv and 3 cr in animal or plant ecology, #) Chiang
- 119su. Aquatic Ecology.** Conditions for life in the water and distribution of aquatic animals. (5 cr; prereq 15 cr incl Biol 2 or 50; offered in Lake Itasca Biology Sessions) Underhill
- 127s. Ecology of Soil Microorganisms.** Soil as a microhabitat; the nature of the microbial population of soil; interactions among microorganism in the soil ecosystem; experimental approaches and techniques in soil ecology. Lectures and laboratory. (4 cr, §Soils 127s; prereq MicB 53 or 153, or VBac 53, or Biol 52 and #) Schmidt
- 128f. Limnology.** Description and analysis of the events occurring in lakes, reservoirs, and ponds, beginning with their origins and progressing through study of their physics, chemistry, and biology. Interrelationships of these parameters, and effects of civilization on lakes. Laboratory, field trips. (4 cr, §Bot 138; prereq GeCh 26 or equiv and #) Shapiro
- 130f. Ecology of Plant Communities.** Patterns in development, structure, interrelationships, stability of plant communities. (5 cr; prereq Biol 80)
- 131w.* Structure and Function of Ecosystems.** Energy exchange and cycles of water and nutrients, in relation to biological productivity and development and regulation of ecosystems. (5 cr; prereq Biol 80, 81, introductory chemistry and physics, or #)
- 133s.* Ecological Plant Geography.** Ecological principles of plant distribution and landscape analysis, vegetation regions of North America, interpretation of regional vegetation patterns. (3 or 5 cr; prereq Biol 80 or #; offered 1967-68 and alt yrs) Lawrence, Cushing
- 135su. Ecology of the Itasca Region.** Plant communities represented; their dynamic relationships. Relationships of local communities to vegetation of Minnesota as a whole. Use of modern methods of vegetation analysis and measurement of environmental factors. (5 cr; prereq Biol 80 or #; offered in Lake Itasca Biology Sessions)
- 137s.* Ecological Life Histories of Plants.** Influence of environmental factors on each developmental stage of life cycle under natural conditions. Individual species assigned for study at Cedar Creek Natural History Area. Weekly half-

day field trips. (5 cr; prereq Biol 51, 80, 81, 91A and #; offered 1968-69 and alt yrs) Lawrence

138su. Wetland Ecology. Nature, origin, and development of lake, marsh, swamp, and bog ecosystems; environmental control and productivity. (5 cr; prereq 15 cr in biological subjects, introductory chemistry, or #...Biol 80 recommended) Gorham

139s. Paleocology. Nature of fossil evidence; problems and techniques for the reconstruction of past habitats, populations, communities, and ecosystems. Examples from various parts of the geologic column and from various groups of organisms. (3 cr; prereq 8 cr in geology, Biol 80, or #; offered 1968-69 and alt yrs) Cushing

140su. Soils and the Ecosystem. Formation and distribution of soils in relationship to vegetation, climate, and other soil-forming factors. Interrelationships of soils in the ecosystem. (3 cr; prereq Biol 80 or #) Farnham

152su. Ecology of Freshwater Algae. Aspects of algal ecology in lakes and ponds; phytoplankton, benthos, and periphyton; also in streams, bogs, soils, and other terrestrial habitats. Laboratory instruction in relevant research techniques. (5 cr; prereq Bot 150 or 155 or #; offered in Lake Itasca Biology Sessions) Brook

158su. Theory and Practice in Environmental Measurement. Physical factors of environment: energy budget, water budget, and microclimatic variation. Modern field instrumentation. (5 cr; prereq college physics, ecology or physiology; offered in Lake Itasca Biology Sessions)

162su.* Vertebrate Ecology. Field work on populations and their relationships to local environments; habitat analysis and ecological research methods. Individual and team research projects, field trips, and lectures. (5 cr, §Ent 162; prereq Biol 80 or equiv; offered in Lake Itasca Biology Sessions) Marshall, Tester

169w.* Quaternary Phytogeography. Historical problems in interpretation of distribution of modern plant species. Applications of Pleistocene and recent pollen and plant macro-fossil analysis; applications to phytogeography. Field and laboratory methods. (4 cr; prereq Bot 165 and Biol 80, or #; offered 1968-69 and alt yrs) Cushing

170s. Physiological Ecology. Current problems of distribution and abundance of animals in the natural environment. (4 cr; prereq Biol 110 or Zool 105 and Biol 80, ...statistics recommended) Schmid

195su. Problems in Ecology and Behavioral Biology. Advanced work on special topics suited to the needs of individual students. (Cr ar; prereq #; offered in Lake Itasca Biology Sessions) Staff

196su. Problems in Ecology and Behavioral Biology. Advanced work on special topics suited to the needs of individual students. (Cr ar; prereq #; offered in Lake Itasca Biology Sessions) Staff

197f, 198w, 199s.* Advanced Work in Ecology and Behavioral Biology. Individual work in same special aspect of the area. (Cr ar; prereq #) Staff

201w.* Experimental Ecology Laboratory. Laboratory companion course to 118. (2 cr, §Ent 201; prereq 118 or ¶118) Chiang

202s.* Insect Ecology. Dispersal, distribution, abundance, natural control, and related problems. (3 cr, §Ent 202; prereq 118 or #) Chiang

Course Descriptions

- 228w.° **Advanced Limnology.** Detailed study of selected problems in limnology using current and classical literature. Term paper required. (3 cr; prereq 128 or Bot 138 and #; offered 1967-68 and alt yrs) Shapiro
- 229.° **Research in Limnology.** (Cr ar; prereq 128 or Bot 138 and #) Shapiro
- 230.° **Methods for Analysis of Natural Waters.** Analysis and significance of the ecologically important constituents and parameters of surface and ground waters with appreciation of different approaches. Term paper. (3 cr; prereq 128 or equiv, AnCh 46 or 47 or equiv, and #; two 3-hour periods per wk; offered 1968-69 and alt yrs) Shapiro
- 284s. **Ecological Physiology.** Organization, collection, and interpretation of physiological data so that it may have ecological significance particularly at the community level. (3-5 cr; prereq #)

NOTE—Students should also consult the *Bulletin of the Graduate School* for details of the following courses which may be of significance in their ecological studies, particularly those with reference to agriculture, forestry, or conservation: Ent 248-49, 251, 273, 274, 275, 276; For 141, 148, 230; PIPa 217; Soil 105, 133, 134.

Behavioral Biology (Ecol)

- 110s. **Animal Behavior.** Survey of effector mechanisms, their nervous and endocrine control, and behavior patterns of animals. (3 cr; prereq Zool 91 or 92 or equiv and #) McKinney
- 136su. **Avian Behavior.** Field studies stressing courtship, nesting, and other facets in the breeding behavior of birds in the Itasca area. (5 cr; limited to 15 students; prereq Zool 75-76 or 135, or #; offered in Lake Itasca Biology Sessions)
- 150w. **Behavioral Physiology.** Current concepts of neurological and neurochemical bases of animal behavior, including reception, coding; transmission and storage of information; levels of integration; central control of input and output; spontaneity, development, and learning. (3 cr, §AnSc 150, §VPP 150; prereq AnSc 45 or VPP 45 or 6 cr systemic physiology, Biol 110 or #) Phillips and others

NOTE—The following is a partial listing of courses offered by other departments relevant to behavioral biology: Psy 55, 75, 101, 102, 117, 127, 128, 129, 132, 133, 148, 149, 150, 151; Zool 114.

GENETICS AND CELL BIOLOGY

Genetics (Gen)

- 66f,w,s. **Principles of Genetics.** (Replaces Agro 30 and Biol 70, Zool 66) The mechanisms of heredity, their implications for biological populations and applications to practical problems. (3 cr; prereq Biol 2 or equiv) Staff
- 68s. **Human Genetics and Social Affairs.** (Replaces Zool 68) An introduction to genetics with special attention to human heredity and with emphasis on behavior and other topics of social concern. For students in programs not directly related to the biological sciences. (3 cr; not open to students who have had Biol 2 or equiv) Anderson, Reed

Biol 70. **Principles of Genetics.** (See Biology listings)

Biol 71. **Genetics Laboratory.** (See Biology listings)

99. **Special Projects.** Individual work on selected topics or problems. (Cr ar; prereq 66 or equiv and #)
- 140f.s. **Intermediate Genetics I.** The structure and function of genetic elements at the molecular and cellular levels. Organization and replication of genetic material, mutagenesis, recombination, the genetic code and protein synthesis, episomes, suppression, complementation and regulation. (3 cr; prereq 66 and Biol 60 or equiv, ¶71) Snyder, Woodward
- 141w. **Intermediate Genetics II.** Selected topics in population and quantitative genetics, cytogenetics, immunogenetics and developmental and physiological genetics. (3 cr; prereq 66 and Biol 60 or equiv, ¶71) Enfield, Wade
- 175s. **Human Genetics.** (Replaces Zool 175) Inherited characters in man, particularly in relation to medicine, with some reference to the relation of genetics to marriage and to social conditions. (3 cr; prereq 66 or #) Reed
- 176w. **Problems and Methods in Human Genetics.** (Replaces Zool 176) Methods for research in human genetics. Importance of appropriate statistical techniques. Use of genetic concepts in exploring new problems. Individual study of current problems and group discussion. (3 cr; prereq 175 and PubH 110 or equiv and #) Anderson

For Graduate Students Only

101. **Basic Genetics.** For correction of deficiencies in background course work. (Cr ar)
- 230s. **Biochemical Genetics.** A survey of current knowledge of the molecular bases of the homo- and heterocatalytic expression of genetic material, recombination, mutation, complementation, and suppression. The genetic code, protein synthesis, and regulatory mechanisms will be emphasized. (3 cr; prereq 140 and 141 or equiv or #...MicB 110 highly recommended) Staff
- 246w.s. **Genetics Seminar.** (Replaces Agro 246) Current contributions to genetic theory. (1 cr per qtr; repeated enrollment for credit permitted) Genetics Center staff
252. **Cytogenetics.** Cytogenetic behavior of chromosomal changes. Experimental methods and possible applications. (4 cr, §Agro 252; prereq Bot 118, Gen 140 or #) Burnham
- 260f. **Population and Quantitative Genetics I.** (Replaces Agro 261) Genetic variation in quantitative traits with special attention to fitness. Causes of change of equilibria in gene frequencies, heterosis and inbreeding depression, consequences of natural and artificial selection. (3 cr; prereq 141 and Biom 101 or equiv) Enfield
- 262w. **Population and Quantitative Genetics II.** Selection with reference to population changes in quantitative characters. Information required for predicting effects of selection and related research. Emphasis is on logical analysis. (3 cr, §AnSc 204, §Agro 262; prereq 260, Biom 181 or equiv recommended) Comstock
297. **Current Topics in Genetics.** (Cr ar; repeated enrollment permitted) Staff
298. **Seminars in Genetics.** (1 cr per qtr; repeated enrollment permitted) Staff
299. **Research in Genetics.** (Cr ar; repeated enrollment permitted) Staff

Course Descriptions

Cell Biology (CB)

- 51f. Cell Biology.** Dynamic aspects of cell structure and macromolecular organization with emphasis on current research. (3 cr, §Zool 51; prereq Biol 2 or 49; GeCh 4) Hooper
- 118f. General Cytology.** Introductory analysis of structure and related functions of intact cells and protoplasmic systems. The nature of cytoplasm, nuclei, and cell walls. Relationship of cytological data to life cycles, cytogenetics, cytotoxicology, and cytochemistry. (5 cr, §Bot 118, §Zool 164; prereq 10 cr in biology, botany or zoology, elementary genetics or #) Cunningham
- 231f. Cell Biology Special Topic: Cytoplasmic and Cellular Motility.** Shuttle streaming in slime molds; rotational streaming in plant cells; theory of idealized and nonidealized fluid flow; rheological properties of materials; streaming and locomotion in protists; amoeboid motions in metazoans; cell motility in morphogenesis; movements of cellular organelles; theories of contractile mechanisms; mitotic movements; movements of cilia, flagella, and sperm tails. (3 cr; prereq #) Rhea and staff
- 232f. Cell Biology Special Topic: Cellular Regulation.** Control of the biosynthesis and function of macromolecules. Topics to be discussed will include the induction and repression of enzyme synthesis, constitutivity, the specific activation and inhibition of enzyme activity by metabolic effectors, regulation of RNA and DNA syntheses, regulation of chromosome replication, steady states of growth and transitions between steady states of growth, control of cell division, and the cycle of cell duplication. Much of the discussion will center on research with microbial systems; but where possible, work with higher organisms will be introduced. (3 cr; prereq #) Herman, Hooper
- 233w. Cell Biology Special Topic: Cellular Genetics.** Historically, genetics has addressed the question of how traits are transmitted from parents to progeny. Recently the mechanisms of heredity at the molecular level have stirred the imaginations of biologists everywhere. Now, at some point between these extreme approaches lies the area called cellular genetics, that aspect of genetics which employs the philosophy of molecular genetics but which treats the cell as a whole. The cellular system is one step removed from both organismal and molecular systems. (3 cr; prereq #) Woodward
- 234w. Cell Biology Special Topic: Cellular Growth Kinetics.** The exploration of current notions of cell growth and regulation, with emphasis on mathematical models: growth and regulation of cells and cell components; population behavior of cell systems; environmental alteration of growth patterns. (3 cr; prereq #) Williams
- 236s. Cell Biology Special Topic: Membranes and Interfaces.** The thermodynamics and statistical mechanics of interfaces; the electrical properties of interfaces; experimental methods for the study of gas/liquid and liquid/liquid interfaces; interfaces in biological systems; cell membranes; the plasma membrane; the mitochondrial membranes; special membranous systems within cells; methods for isolation of membranes; chemical reactions at interfaces; the dynamic properties of interfaces; model membrane systems; the cell surface region and cell-contact relations. (3 cr; prereq #) Rosenberg
- 237, 238, 239. Laboratory Techniques in Cell Biology.** A series of laboratory problems designed to familiarize the student with specific techniques applicable to cell biology and to develop a critical inquiring approach to experimental method. Among the techniques included are various forms of microscopy, culture methods, chromatography, fractionation, micromanipulation, spectro-

photometry, fluorometry and ellipsometry, autoradiography, etc. (3 cr per qtr; prereq #)

299. Graduate Research. Research problems in various fields in biology represented by staff interests. (Cr ar) Staff

MICROBIOLOGY (MicB)

(College of Medical Sciences)

Biol 52.** Microbiology. (See Biology listings)

53w,s.** General Microbiology. Lectures, demonstrations, and laboratory instruction in the morphology, physiology, taxonomy, and ecology of bacteria. Practical applications of fundamental principles. (5 cr; prereq soph with C avg in courses prereq to major sequence, or jr with 10 cr in chemistry and 5 cr in biological sciences, or #) Schmidt and staff

102s.** Medical Microbiology. Pathogenic bacteria, fungi, and viruses in relation to disease; principles of infection, pathogenesis, and immunity; microbiological techniques for laboratory diagnosis and antibiotic determination. (4 cr; for other than medical students; prereq 116) Johnson

103s. Soil Microbiology. Methods for enumeration and study of microflora and microfauna. Biochemical activities of soil population. (4 cr; prereq Biol 52, 60, 8 cr organic chemistry and #) Schmidt

P1Pa 109w. Physiology and Biochemistry of Fungi. (See Agriculture bulletin)

110w. Microbial Genetics. Genetic mechanisms in bacteria, bacteriophages, fungi, protozoa, and algae. Mutagenesis; selection; adaptation; cytoplasmic inheritance; patterns of genic recombination; fine structure of genetic material. (3 cr; prereq Biol 70 or #; offered 1968-69 and alt yrs) Bradley

111f.** Advanced Microbiology. Advanced laboratory in comparative morphology, taxonomy, and physiology of bacteria. For microbiology majors and others interested in biological and chemical aspects of microbes. Stresses enrichment, isolation, identification, cultivation, structure, and function of microorganisms. (4 cr; prereq 53 or 153 and 121 or #; offered 1967-68 and alt yrs) Dworkin

116w. Immunology. Host-parasite interactions; nature of antigens and antibodies; chemical basis of serologic specificity; qualitative and quantitative aspects of antigen-antibody reactions; theories of antibody production; cellular antigens and blood grouping; nature of complement and its role in immunologic phenomena; mechanisms of hypersensitivity; hypersensitivity-like states and immunologic diseases; homotransplantation and tumor immunity; mechanisms of natural and acquired immunity. (3 cr; required of all microbiology majors; prereq Biol 52 or MicB 53 or 153) Muschel

116Aw. Immunology Laboratory. (2 cr; required of all microbiology majors; prereq ¶116) Muschel

121w. Physiology of Bacteria. Chemical and physical organization of bacteria as related to function; growth; energy metabolism including oxidations and fermentations; nutritional requirements; antimicrobial agents; autotrophic mechanisms; and microbial differentiation. (3 cr; required of all microbiology majors; prereq Biol 60, 70, or ¶70, 8 cr in organic chemistry) Rogers

** Microscope required. Students may obtain use of microscope by purchasing \$3 microscope cards from the Bursar.

Course Descriptions

- 122. Physiology of Bacteria Laboratory.** Techniques employed in the study of bacterial physiology and metabolism. (3 cr; required of all grad students in microbiology; open to others by ‡; prereq 121; first summer term only) Rogers
- 124f. Biology of Viruses.** Structure, composition, and properties of bacterial and mammalian viruses; their interactions with cells and effect on host cell metabolism; biochemistry of viral replication; techniques employed in the study and diagnosis of viral infections; viral tumorigenesis. (3 cr; prereq 53 or 153 and 121) Plagemann
- 152f,w,s. Special Problems.** (Cr ar; prereq ‡) Staff
- 153f.** Biology of Microorganisms.** Lectures and laboratory exercises in taxonomy, anatomy, physiology, biochemistry, and ecology of microbes. Emphasis is on the fundamental properties of bacteria. Lectures also include descriptions of the major groups of the bacteria as well as of the remaining protista. (4 cr, §Biol 52; prereq OrCh 62, Biol 49 or 2) Dworkin

ZOOLOGY (Zool)

- 51f. Cell Biology.** Dynamic aspects of cell structure and macromolecular organization, with emphasis on current research. (3 cr, §CB 51; prereq Biol 2 or 49, GeCh 4) Hooper
- 52f. General and Comparative Embryology.** Embryological development of invertebrate forms. (5 cr; prereq Biol 2 or 50) Spratt
- 53w. Comparative Anatomy.** Comparative study of vertebrate systems, tracing the development of various structures from lowest forms to man. (5 cr; prereq soph, Biol 2 or 50) Huver
- 65f,s. Histology.** Microscopic structure of tissues and organs. (5 cr; not open to regular 3-yr premed or predent students; prereq Biol 2 or 50) Olson
- 71s. Principles of Invertebrate Biology.** The basic characteristics of the invertebrates (exclusive of insects) with emphasis on functional, adaptive, and evolutionary principles. Laboratory will include original research. (5 cr; prereq Biol 2 or 50) Williams
- 72su. Natural History of Invertebrates.** A taxonomic and ecological survey of the local fauna, including life histories and habitats. (5 cr; prereq Biol 2 or 50; offered in Lake Itasca Biology Sessions)
- 74s. Introductory Entomology.** General morphology, life histories, habits, and classification of insects. (5 cr; prereq Biol 2 or 50) Price
- 75w, 76s. Introductory Ornithology.** Laboratory and field course in structure, classification, distribution, migration, habits, habitats, and identification of birds. (3 cr per qtr; prereq Biol 2 or 50) Warner
- 77w. Mammalogy.** Distinguishing characteristics and life histories of the various mammal groups, particularly those represented in the state. (4 cr; prereq 53) Beer

** Microscope required. Students may obtain use of microscope by purchasing \$3 microscope cards from the Bursar.

- 93f. **Introduction to Animal Parasitology.** Elementary course dealing with parasitic protozoa, worms, and arthropods, and their relation to diseases of man and animals. (5 cr; prereq Biol 2 or 50) Wallace
- 96f. **Organic Evolution.** Survey of evidence for and causes of evolution. (3 cr; prereq Biol 2 or 50) Merrell
- 98f,w,s. **Senior Seminar.** A discussion of biological topics of current interest. (1 cr per qtr; prereq sr, major in biological sciences, #) Staff
- 99f,w,s. **Individual work in some special discipline.** (Cr ar; prereq Biol 2 or 50 and #) Staff
- 105f. **Comparative Animal Physiology.** An introduction to animal physiology, emphasizing functional aspects of organ systems from a comparative viewpoint. (5 cr; prereq Biol 2 or 50, OrCh 62 or #) Schmid
- 107f. **Protozoology.** Introduction to taxonomy, morphology, physiology, development and genetics of free-living protozoa. (4 cr; prereq #; offered 1967-68 and alt yrs) Kerr
- 109s. **General Endocrinology.** The physiological effects of the endocrine organs and their hormones. (3 cr; prereq AnSc 45 or VPP 45 or 6-8 cr in systemic or comparative physiology or #) Sullivan, Good, and staff
- 111f. **Reproductive Physiology.** Fundamentals of reproductive physiology including functions of the reproductive organs, fertilization, estrous cycle and its endocrine control, reproductive efficiency and problems, and principles of artificial insemination. (3 cr, §AnSc 111, §VPP 111; prereq 109 or VPP 109)
- 112w. **Advanced General Physiology.** Topics of current interest in physiology. (3 cr; prereq 91 or 92 or equiv and #) Benolken, Schmid
- 114f. **Sensory Physiology.** Survey of general properties of receptor organs with an emphasis on visual, auditory, and mechano receptor units. (3 cr; prereq Biol 110 or Zool 105 and #; offered fall 1967 and alt yrs) Benolken
- 115su. **Advanced Natural History of Invertebrates and Fishes.** Advanced taxonomic and ecological survey of local fauna, detailed and independent ecological study of several taxonomic groups. (5 cr; prereq 15 cr in Zoology; offered in Lake Itasca Biology Sessions)
- 117w. **Theoretical Biology.** A consideration of the role of semantic and mathematical theory in biology, including philosophical foundations and methodology. Detailed examples drawn from various fields of biology. (3 cr; prereq #; offered winter 1969 and alt yrs) Williams
- 120f. **Essentials of Vertebrate Development and Structure.** Principles and patterns of vertebrate anatomy, based on the development approach, for students whose interests require an understanding of functional anatomy. (5 cr, §VAna 120; prereq Biol 2 or 50 or #) Fletcher
- 121s. **Ichthyology.** Taxonomy and habits of North American fishes, especially those of upper Mississippi drainage. (3 cr; prereq 15 cr incl Biol 2 or 50) Underhill
- 125f. **Insect Morphology.** Comparative studies of external and internal anatomy and histology of insects; phylogeny and function. (5 cr; prereq 74 and #) Cook
- 126w. **Embryology and Development of Insects.** Reproductive behavior, embryology and postembryonic development of insects. (5 cr; prereq 125, OrCh 42 or 62, #) Brooks

Course Descriptions

- 127s. Insect Metabolism and Co-ordination.** Homeostasis, permeability, circulation, metabolic systems and products, properties of muscle and nerves, sensation, behavior. (5 cr; prereq 126, #...BioC 106 or MdBc 101 recommended) Richards
- 130s. Principles of Systematic Entomology.** Lectures on history of systematic entomology, the species concept and higher categories, systematic procedures, and zoological nomenclature. (2 cr; prereq 15 cr in entomology or zoology and #; offered 1968-69 and alt yrs) Cook
- 134w. Avian Physiology.** Physiology of various species of wild and domestic birds. (3 cr, §AnSc 134, §VPP 134; prereq VPP 45 or 6 cr systemic physiology and #) McGinnis
- 135su. Field Ornithology.** Field and laboratory studies of ecology and life histories of the birds in the Itasca Park region. (5 cr; prereq 15 cr in zoology; offered in Lake Itasca Biology Sessions)
- 138f,w,s. Seminar: General Physiology and Biophysics.** (Cr ar) Staff
- 143su. Animal Parasites.** Parasites of local fauna with special reference to helminths. (5 cr; prereq 15 cr incl Biol 2 or 50; offered in Lake Itasca Biology Sessions)
- 144f. Medical Entomology.** Principal arthropods noxious to man and animals. Emphasis on those that serve as vectors of the pathogenic organisms of man and animals. (3 cr; prereq 15 cr incl 74 or equiv and #) Price
- 145w. Parasitic Protozoa.** Structure, life histories, and economic relations of protozoal parasites of man and animals; laboratory diagnosis. (3 cr; prereq 15 cr incl Biol 2 or 50 and #) Wallace
- 146s. Helminthology.** Worm parasites of man and animals, their structure, life histories, and biological relationships. (3 cr; prereq 15 cr incl Biol 2 or 50 and #) Wallace
- 148w. Topics in Comparative Endocrinology.** Discussion of selected areas of current research. Specific areas to be covered will vary from year to year and will be announced in advance. (2 cr; prereq 109 or #) Herman
- 150. Behavioral Physiology.** Current concepts of neurological and neurochemical bases of animal behavior, including reception, coding, transmission, and storage of information; levels of integration; central control of input and output; spontaneity, development, and learning. (3 cr, §AnSc 150, §VPP 150; prereq 6 cr systemic physiology, Biol 110 or #) Phillips
- 155f, 156w, 157s. Biophysics.** Theoretical and experimental aspects of biology that can be studied by quantitative physical means. 155: Tissue ultrastructure (biostatics) as revealed by hypermicroscopy, birefringence, x-ray, electron and radioactive means, and by colloidal and micellar phenomena. 156: Dynamics of biophysical systems: excitatory state, contraction, secretion, synthesis. 157: Integrative biophysical systems, stability of systems, transmission of information, sensory mechanism. (3 cr per qtr; prereq 28 cr distributed between physics and biology, and #...physical chemistry and general physiology recommended) Schmitt
- 163f. Mechanisms of Drug Action.** The site and mechanisms of action of drugs, including structure-activity relationships. (3 cr; prereq systemic or comparative physiology) Stowe
- 164w. Cytology.** Principles and methods of experimentation; organization, function, and ultrastructure of cells and cell components; cell growth and cell heredity. (3 cr, §CB 118; prereq 51 or #)

- 165w. Cytology Laboratory.** Phase contrast microscopy, cytochemical methods, autoradiography; demonstration of optical equipment; individual projects. (2 cr; prereq #)
- 171w. Genetics and Speciation.** Application of genetic principles to problems of speciation and evolution. (3 cr; prereq 15 cr biology incl Biol 71) Merrell

For Graduate Students Only

- 101f,w,s. Basic Zoology.** This course number may be used to make up certain deficiencies in background course work. (Cr ar; majors must consult advisers, others consult department chairman)
- 203f. Insect Physiology.** General and comparative physiology. Organ systems and their functioning. Research methods and evaluation of data. (Cr ar; prereq #) Richards
- 220s. Adaptive Vertebrate Structure.** Relates morphological types to way of life, systemic anatomy, and functional-morphological interrelationships with environment. Laboratory consists of dissection of a primate as a generalized quadruped, and examination of significant structural adaptations in other vertebrates. (6 cr; prereq Zool 52, 53 or 120 or #) Felts
- 283f, 284f, 285f. Physiology of Development.** Organization, presentation, and evaluation of results of research in experimental embryology. 283: Chemical embryology, metabolic aspects of growth, differentiation, and morphogenesis. 284: Embryonic differentiation including neuroembryology. 285: Endocrines in development, including sex differentiation. (4 cr per qtr; prereq 182 or equiv and #; 285 offered 1967-68; 283 offered 1968-69; 284 offered 1969-70) Spratt
- 298. Graduate Seminar.**
- 299. Graduate Research.**