



College of NATURAL SCIENCE

George E. Leroi, DEAN

We have entered a new and exciting era of scientific understanding that has taken concepts like genetic engineering and biotechnology out of the realm of science fiction and into everyday life. New applications of science will continue to have profound effects. Thus, graduates with training in any of the biological, mathematical, or physical sciences offered in the College of Natural Science are finding new employment opportunities with industries on the cutting edge of high technology, as well as in teaching, communications, professional and environmental fields, and many other areas.

The mission of the College of Natural Science closely parallels the mission of the University itself: a three-fold commitment to research, education, and service. The College of Natural Science is one of the largest colleges within the University, overseeing academic programs in the departments of Biochemistry and Molecular Biology, Chemistry, Geological Sciences, Mathematics, Microbiology and Molecular Genetics, Physics and Astronomy, Physiology, Plant Biology, Statistics and Probability, and Zoology. It also administers the Medical Technology Program; Lyman Briggs School, a residential option for undergraduate science majors; and the W. K. Kellogg Biological Station, a world-class biological research center. All departments within the College offer both undergraduate and graduate students experience conducting research in laboratories. Students in the College of Natural Science have access to a range of research and laboratory facilities on campus, in addition to unique research opportunities in facilities like the MSU/DOE Plant Research Laboratory, the National Superconducting Cyclotron Laboratory, the Center for Integrated Plant Systems, and the W. K. Kellogg Biological Station. A special on-site research and science teaching program for both undergraduate and graduate students is offered at the Station during the summer session. Graduate students may also choose to enter one of the College's interdisciplinary research

programs in Genetics; Cell and Molecular Biology; Neuroscience; or Ecology, Evolutionary Biology and Behavior; or in the Center for Fundamental Materials Research; or the Center for Sensor Materials.

Promoting science literacy—opening up the world of science to our youth—is the key to comprehending the total impact of new scientific developments in our lives. Already our environment is threatened by such things as insecticides, food additives, and toxic wastes. Our future leaders must have an appreciation of the sciences in order to make informed decisions regarding the preservation of our environment. To that end, the College of Natural Science offers credit courses in communities throughout Michigan in cooperation with University Outreach programs.

UNDERGRADUATE PROGRAMS

Undergraduate students in the College of Natural Science may opt for either a Bachelor of Science or a Bachelor of Arts degree program.

The College offers programs of study culminating in a bachelor's degree with either a departmental or an interdepartmental major. All programs are liberal in character and involve a specified minimum of nonscience credits in addition to those needed to meet integrative studies requirements. Electives in both major and nonmajor areas make it possible to mold a program of interest and challenge for each student.

The **departmental major** features study in a single discipline and is generally considered the proper choice for concentrated study in a limited area. A departmental major consists of not fewer than 27 nor more than 79 credits in courses recognized by the College as applicable to the major. Specific major require-

ments are given in the sections that follow. Departmental majors are available through Lyman Briggs School as coordinate majors.

The **interdepartmental major** features study in several disciplines with no single discipline being dominant and is generally considered the proper choice if breadth of background in several fields of the natural sciences is desired. The College offers interdepartmental majors: biological science–interdepartmental, earth science–interdepartmental, human biology, and physical science. In addition, the College of Education, in cooperation with the College of Natural Science, offers an integrated teaching major in General Science for students accepted in elementary education. For further information, refer to the *Department of Teacher Education* section of the catalog. The interdepartmental major consists of a minimum of 45 credits (biological science) or 36 credits (earth science and physical science) and not more than 67 credits in courses recognized by the College as applicable toward the major. Interdepartmental majors are available through Lyman Briggs School as coordinate majors. Interdisciplinary fields of concentration are also available through Lyman Briggs School.

Major Preference Students

Students who meet the general requirements for admission to the University shown in the *Undergraduate Education* section of this catalog and who are not enrolled in Lyman Briggs School are enrolled in the Undergraduate University Division but may declare a major preference in the College of Natural Science and be assigned an academic adviser in this College. All programs in the biological sciences, physical sciences, and mathematics presume a minimum of two and one-half entrance units in mathematics (one and one-half units of algebra and one unit of geometry).

Admission as a Freshman to Lyman Briggs School

Any student who meets the general requirements for admission to the University as shown in the *Undergraduate Education* section of this catalog may enroll in Lyman Briggs School, pending available space. Of the sixteen units of high school work required, a minimum of three units should be in mathematics and two units should be in the natural sciences.

Admission as a Junior to the College of Natural Science

1. Completion of at least 56 credits acceptable to the College with an academic record which at least meets the requirements of Academic Standing of Undergraduate Students.
2. Acceptance as a major in one of the academic programs of the College.

Graduation Requirements

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog.

Students who are enrolled in majors leading to Bachelor of Science and Bachelor of Arts degrees in the College of Natural Science may complete an alternative track to Integrative Studies in Biological and Physical Sciences that consists of:

- a. One course in Biological Science, Entomology, Microbiology, Physiology, Plant Biology, or Zoology.
- b. Chemistry 141 or 151 or 181H.
- c. Two credits of laboratory experience in biological or physical science.

Credits earned in courses in the alternative track may also be counted toward College and major requirements for Bachelor of Science and Bachelor of Arts degrees.

2. The requirements of the College of Natural Science for the **Bachelor of Science** and **Bachelor of Arts** degrees that are listed below:
 - a. The requirements for either a **departmental** major or an **interdepartmental** major of 27 to 79 credits. For specific requirements, see the sections that follow.
 - b. A minimum grade–point average of 2.00 in courses in the student's major; i.e., in all courses that are required for the major and that are not counted toward College and University requirements.
 - c. The following credit distribution requirements:
 - (1) A minimum of 30 credits in courses numbered 300 and above.
 - (2) A maximum of 67 credits in courses offered in a single curriculum division of the College; i.e., Biological Science or Mathematical Science or Physical Science.
 - d. Only credits in courses graded on the numerical or Pass–No Grade system may be counted toward College and major requirements for Bachelor of Science and Bachelor of Arts degrees in the College of Natural Science. College of Natural Science students may not enroll in courses that are to be counted toward College and major requirements, including courses in other colleges, on a Credit–No Credit basis.
3. The requirements of the College of Natural Science for **either** the Bachelor of Science degree **or** the Bachelor of Arts degree that are listed below:
 - a. Requirements for the **Bachelor of Science** degree:
 - (1) One semester of calculus.
 - (2) A second semester of calculus or one semester of statistics and probability.
 - (3) Two semesters of chemistry including at least one laboratory experience.
 - (4) Two semesters of physics.
 - (5) One semester of biological science.
 - (6) **For students who are admitted to Michigan State University as new freshmen and new transfer students beginning Fall 1993 there is no foreign language or alternative requirement. For students who were admitted as new freshmen and new transfer students prior to Fall 1993 only:**
 - First year competency in a foreign language.
 - or
 - Eight credits in courses offered by the College of Natural Science outside the major area **in addition** to the credits that count toward requirements 3.a.(1) through (5) above. For students majoring in the biological sciences, the credits must be in the mathematical and physical sciences. For students majoring in the mathematical or physical sciences, the credits must be in the biological sciences.
 - or
 - A minimum of 8 credits in courses in the arts and humanities or the social, behavioral, and economic sciences beyond the credits that are counted toward the University's Integrative Studies requirement. At least one course in logic at the 300 or 400 level or one course in the philosophy of science must be included. At least 4 of the 8 credits must be in courses offered by a single department.
 - or

NATURAL SCIENCE Undergraduate Programs

For students who have been admitted to the teacher certification program, a minimum of 8 credits in **Professional Education Courses**.

- b. Requirements for the **Bachelor of Arts** degree:
- (1) One semester of calculus.
 - (2) A second semester of calculus or one semester of statistics and probability.
 - (3) One semester **each** of biological science, chemistry, and physics including at least one laboratory experience.
 - (4) Six credits in courses in the arts and humanities or the social, behavioral, and economic sciences beyond the credits that are counted toward the University's Integrative Studies requirement.
 - (5) **For students who are admitted to Michigan State University as new freshmen and new transfer students beginning Fall 1993 there is no foreign language or alternative requirement. For students who were admitted as new freshmen and new transfer students prior to Fall 1993 only:**

Second year competency in a foreign language.

or

First year competency in a foreign language plus a minimum of 6 credits in one of the following fields other than the student's major field: philosophy or mathematical sciences or biological sciences or physical sciences.

or

For students who have been admitted to the teacher certification program, first year competency in a foreign language plus a minimum of 6 credits in **Professional Education Courses**.

Many major programs which lead to a Bachelor of Science degree require a proficiency greater than the College established minimum in one, or more, of the following fields: chemistry, physics, and mathematics. Also, for either the Bachelor of Arts or the Bachelor of Science degree, when two or more options exist for the fulfillment of any College— established requirement, one of the options may be specified as a major requirement. The specific requirements for each major program are given in the sections that follow.

Chemistry and mathematics requirements should be completed to the fullest extent possible during the freshman and sophomore years. Bachelor of Science candidates with a major in a physical science should complete the physics requirement during the sophomore year. Students with a major in a biological science may postpone completion of the physics requirement until the junior year, but should complete Biological Science 110, 111 by the end of the sophomore year. The biology courses should be completed during the freshman year because they are prerequisites to most of the courses offered by the departments in the biological sciences. All students should complete the University's Tier I writing requirement during the freshman year.

Honors Study

The College of Natural Science encourages honors students to develop distinctive undergraduate programs in their chosen fields. All qualified students in the College, including Lyman Briggs School students, may also be members of the Honors College. A member of the faculty is selected to serve as adviser to Honors College students in each major field, and it is the adviser's responsibility to help the student plan a rigorous and balanced

program which will also reflect the student's special interests and competencies.

The departments of the College annually offer numerous honors opportunities at both introductory and advanced levels. At the introductory level these consist chiefly of regularly offered honors courses. Honors options are also available in many other courses. At the advanced level honors students are encouraged to undertake faculty-guided independent research in their fields of specialization. These honors experiences are provided mainly, but not exclusively, for Honors College students. In addition, honors undergraduates are encouraged, when appropriate, to undertake work at the graduate level.

In addition to the disciplinary honors courses, the College offers an honors course intended primarily for non-science majors. Students may reenroll in this course, which is conducted as a seminar and involves topics at the forefront of current scientific interest.

Charles Drew Science Enrichment Laboratory

The Charles Drew Science Enrichment Laboratory was created to help students from minority and other groups currently underrepresented in the sciences to achieve the best preparations for science education possible. The program is designed to: a) assist students with the transition from high school to college and b) to expose them to the vast number of career opportunities in the sciences.

These goals are attained, in part, through problem-solving courses, specially designed courses in mathematics, and designated sections of biology and chemistry courses. In addition, tutoring is available and students are exposed to minority role models in the sciences.

The purpose of this program is, through advising and focused academic support, to help interested and motivated students develop the foundation for successful careers in science. Students are encouraged to contact the College of Natural Science for additional information about this program.

Preprofessional Programs

All professional colleges have established minimum requirements in selected areas of knowledge for admission (hereafter referred to as admission requirements). Although fulfilling these requirements does not in itself guarantee admission, their fulfillment is a necessary first step for those who aspire to enter a professional college.

At Michigan State University students may select programs of study which help to prepare them for enrollment in professional colleges. Since the admission requirements of various professional colleges vary, it is not feasible to establish a single program that satisfies the admission requirements of all colleges in a given profession. However, in the fields of dentistry, allopathic and osteopathic medicine, podiatry, and optometry, the College of Natural Science does have suggested programs of study. These programs satisfy the minimum admission requirements of most professional colleges. It is the student's responsibility to determine whether or not the proposed program meets the minimum admission requirements of a particular professional college.

There are a number of programs of study which may be completed in the normal four years and which provide both the academic preparation for admission to a professional school and fulfill the requirements for a bachelor's degree. The preprofessional programs as outlined do not in themselves lead to a bachelor's degree.

PREDENTAL PROGRAM:

Students who meet the requirements for admission to the University as freshmen and sophomores, as shown in the *Undergraduate Education* section of this catalog, may select the preidental program in the College of Natural Science as their major preference. Students who are enrolled in the preidental program are enrolled in the Undergraduate University Division, but receive academic advising through the College.

University regulations require that a student who has arrived at junior standing must select a major leading to a baccalaureate degree. The College of Natural Science does **not** offer a bachelor's degree program for preidental students. Therefore, upon reaching junior standing, students who have been enrolled in the preidental program must be admitted to a major in either the College of Natural Science or in another college in order to complete the requirements for a bachelor's degree, regardless of whether they have completed the requirements for the preidental program.

Requirements for the Preidental Program

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| | CREDITS |
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1. A total of 60 credits in courses in the natural sciences, mathematics, social sciences, humanities, and writing, including courses that are used to satisfy the University requirements and the courses that are listed below: 60
 - a. All of the following courses (30 credits):

BS 110	Organisms and Populations	4
BS 111	Cells and Molecules	3
BS 111L	Cell and Molecular Biology Laboratory	2
CEM 141	General Chemistry	4
CEM 161	Chemistry Laboratory I	1
CEM 251	Organic Chemistry I	3
CEM 252	Organic Chemistry II	3
CEM 255	Organic Chemistry Laboratory	2
PHY 231	Introductory Physics I	3
PHY 232	Introductory Physics II	3
PHY 251	Introductory Physics Laboratory I	1
PHY 252	Introductory Physics Laboratory II	1

Some dental colleges do not require Chemistry 252.
 - b. 3 additional credits in general chemistry selected from the following courses: Chemistry 142, 152, and 162.
 - c. 3 credits in a biological science course in addition to Biological Science 110, 111, and 111L.
 2. Students who are enrolled in the preidental program should complete the University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog.

Students who are enrolled in the Preidental Program in the College of Natural Science may complete an alternative track to Integrative Studies in Biological and Physical Sciences that consists of the following courses: Biological Science 110, 111, and 111L and Chemistry 141. The completion of Biological Science 110 and 111L satisfies the laboratory requirement. Biological Science 110, 111, and 111L and Chemistry 141 may be counted toward both the alternative track and the requirements for the preidental program referenced in item 1. a. above.

A Tier I writing course is included in the University requirements. Students who are enrolled in the preidental program are required to meet the Tier II writing requirement approved for the student's major leading to the bachelor's degree.

PREMEDICAL (including Pre–Osteopathy and Pre–Podiatry) PROGRAM:

Students who meet the requirements for admission to the University as freshmen and sophomores, as shown in the *Undergraduate Education* section of the catalog, may select the premedical program in the College of Natural Science as their major preference. Students who are enrolled in the premedical program are enrolled in the Undergraduate University Division, but receive academic advising through the College.

University regulations require that a student who has arrived at junior standing must select a major leading to a baccalaureate degree. The College of Natural Science does **not** offer a bachelor's degree program for premedical students. Therefore, upon reaching junior standing, students who have been enrolled in the premedical program must be admitted to a major in either the College of Natural Science or in another college in order to complete the requirements for a bachelor's degree, regardless of whether

they have completed the requirements for the premedical program.

Requirements for the Premedical (including Pre–Osteopathy and Pre–Podiatry) Program

- | | |
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| | CREDITS |
|--|---------|
1. A total of 90 credits in courses in the natural sciences, mathematics, social sciences, humanities, and writing, including courses that are used to satisfy the University requirements and the courses that are listed below: 90
 - a. All of the following courses (30 credits):

BS 110	Organisms and Populations	4
BS 111	Cells and Molecules	3
BS 111L	Cell and Molecular Biology Laboratory	2
CEM 141	General Chemistry	4
CEM 161	Chemistry Laboratory I	1
CEM 251	Organic Chemistry I	3
CEM 252	Organic Chemistry II	3
CEM 255	Organic Chemistry Laboratory	2
PHY 231	Introductory Physics I	3
PHY 232	Introductory Physics II	3
PHY 251	Introductory Physics Laboratory I	1
PHY 252	Introductory Physics Laboratory II	1
 - b. 3 additional credits in general chemistry selected from the following courses: Chemistry 142, 152, and 162.
 - c. One 300–400 level course in biology with laboratory (3 credits) and another course in biology (3 credits).
 - d. One additional course in biology, chemistry, or physics (3 credits).

NOTE: Higher level equivalent biological science, chemistry, and physics course sequences may be substituted for the sequences listed above. Courses in biochemistry and genetics are highly recommended.
 2. Students who are enrolled in the premedical program should complete the University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog.

Students who are enrolled in the Premedical (including Pre–Osteopathy and Pre–Podiatry) Program in the College of Natural Science may complete an alternative track to Integrative Studies in Biological and Physical Sciences that consists of the following courses: Biological Science 110, 111, and 111L and Chemistry 141. The completion of Biological Science 110 and 111L satisfies the laboratory requirement. Biological Science 110, 111, and 111L and Chemistry 141 may be counted toward both the alternative track and the requirements for the premedical program referenced in item 1. a. above.

A Tier I writing course is included in the University requirements. Students who are enrolled in the premedical program are required to meet the Tier II writing requirement approved for the student's major leading to the bachelor's degree.

PREOPTOMETRY PROGRAM:

Students who meet the requirements for admission to the University as freshmen and sophomores, as shown in the *Undergraduate Education* section of this catalog, may select the preoptometry program in the College of Natural Science as their major preference. Students who are enrolled in the preoptometry program are enrolled in the Undergraduate University Division, but receive academic advising through the College.

University regulations require that a student who has arrived at junior standing must select a major leading to a baccalaureate degree. The College of Natural Science does **not** offer a bachelor's degree program for preoptometry students. Therefore, upon reaching junior standing, students who have been enrolled in the preoptometry program must be admitted to a major in either the College of Natural Science or in another college in order to complete the requirements for a bachelor's degree, regardless of whether they have completed the requirements for the preoptometry program.

Requirements for the Preoptometry Program

1. Specific courses are not listed since admission requirements of the colleges of optometry vary greatly and can be met in several ways. The common pattern of admission requirements is a total of 90 semester credits of which 6 to 8 credits are elected from each of the following areas: English, physics, mathematics, biological science, chemistry, psychology, and social science. Courses that are used to satisfy University, college, and major requirements may be counted toward the admission requirements of colleges of optometry.
2. Students who are enrolled in the preoptometry program should complete the University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog.

NATURAL SCIENCE Undergraduate Programs

A Tier I writing course is included in the University requirements. Students who are enrolled in the preoptometry program are required to meet the Tier II writing requirement approved for the student's major leading to the bachelor's degree.

TEACHER CERTIFICATION OPTIONS

The following disciplinary majors leading to bachelor's degrees in the College of Natural Science are available for teacher certification: biological science–interdepartmental, chemistry, earth science–interdepartmental, mathematics, physical science–interdepartmental, and physics.

The following disciplinary minors in the College of Natural Science are also available for teacher certification: biological science, chemistry, earth science, mathematics, and physics.

Students who elect the biological science–interdepartmental or the physical science–interdepartmental disciplinary major, or the biological science disciplinary minor, must contact the Division of Science Education of the College of Natural Science.

Students who elect a chemistry disciplinary major or the chemistry disciplinary minor must contact the Department of Chemistry.

Students who elect the earth science–interdepartmental disciplinary major or the earth science disciplinary minor must contact the Department of Geological Sciences.

Students who elect a mathematics disciplinary major or the mathematics disciplinary minor must contact the Department of Mathematics.

Students who elect a physics disciplinary major or the physics disciplinary minor must contact the Department of Physics and Astronomy.

For additional information, refer to the statements on the disciplinary majors referenced above and to the statement on *TEACHER CERTIFICATION* in the *Department of Teacher Education* section of this catalog.

College of Natural Science Dual Degree Program: Bachelor of Science and Master of Science

The dual degree program provides an opportunity for academically talented undergraduate students who are enrolled in Bachelor of Science degree programs in the College of Natural Science to enroll in graduate courses and conduct research toward the Master of Science degree while completing the last two years of their bachelor's degree programs.

All of the Bachelor of Science and Master of Science degree programs in the College of Natural Science are available for inclusion in the dual degree program. Although most of the Bachelor of Science and Master of Science degree programs are administered by departments and schools within the College, a few such programs are administered by the College. During the second semester of the sophomore year, the student should contact the unit or units that administer the Bachelor of Science and Master of Science degree programs that the student plans to pursue while enrolled in the dual degree program and apply for admission to those programs.

A student who is accepted into the dual degree program can be admitted to both the Bachelor of Science degree program and the Master of Science degree program as early as the beginning of the junior year. Upon completion of the requirements for both the Bachelor of Science degree and the Master of Science degree, both degrees are awarded simultaneously. The Master of Science degree will **not** be awarded until the student has completed the requirements for the Bachelor of Science degree.

To be admitted to the dual degree program, an applicant must:

1. Have a grade–point average of 3.00 or higher in all undergraduate course work.

2. Have a grade–point average of 3.00 or higher in all courses in the College of Natural Science.
3. Be accepted for admission by the graduate admissions committee of the College or department or school.

Departments and schools may specify additional requirements for admission to the dual degree program. The student should contact the appropriate department or school for additional information.

Within the first semester of enrollment in the dual degree program, the student's master's adviser must be identified and the student's master's guidance committee must be established. The adviser and the committee assist the student in developing a program of study for the Master of Science degree.

The student's program of study must be approved by the committee.

A student who is admitted to the dual degree program must:

1. Satisfy all of the requirements for the Bachelor of Science degree program to which the student was admitted.

Although a minimum of 120 credits is required for the Bachelor of Science degree, more than 120 credits may be required for a given degree program.

2. Satisfy all of the requirements for the Master of Science degree program to which the student was admitted **after** being admitted to that program.

Although a minimum of 30 credits is required for the Master of Science degree, more than 30 credits may be required for a given degree program.

The credits and courses that are used to satisfy the requirements for the Bachelor of Science degree may *not* be used to satisfy the requirements for the Master of Science degree.

Departments and schools may specify additional requirements for the dual degree program. The student should contact the appropriate department or school for additional information.

GRADUATE STUDY

The graduate programs of the College of Natural Science provide for advanced study with emphasis either in a single discipline or in the multidisciplinary areas of the biological sciences and the physical sciences. The graduate programs are designed to develop independent effort, encourage creative thinking, and educate the student in the fundamentals of basic research.

The programs of study lead to one of the following degrees: Master of Arts, Master of Science, Master of Arts for Teachers, and Doctor of Philosophy. The specific degrees available and the programs leading to them for each discipline are given in the departmental or program listing.

Each student's program of study is arranged to suit individual needs, the only restriction being that the final program must conform to one of the general patterns approved by the faculty. The general University requirements for these degrees are given in the *Graduate Education* section of this catalog. A department or college may specify additional requirements. Most of the departments in the College require participation in teaching during the course of the graduate program.

Students who are enrolled in Master of Science degree programs in the departments of Entomology, Microbiology and Molecular Genetics, and Plant Pathology may elect a Specialization in Food Safety. For additional information, refer to the statement on the specialization in the *College of Veterinary Medicine* section of this catalog.

Master of Arts for Teachers

The Master of Arts for Teachers degree is designed to provide an enriching educational experience for teachers who are interested in a program of graduate study with less specialization in a science area than is common in most master's degree programs. The degree is for teachers who wish to take graduate work in a subject-matter area but who do not anticipate continuation of graduate study beyond the master's level. However, the student who holds the Master of Arts for Teachers degree may, upon the satisfactory completion of additional work as recommended by the appropriate academic unit, become eligible for admission to a doctoral program.

The degree may be earned with a major in chemistry, general science, geological sciences, or mathematics.

In addition to meeting the requirements of the University as described in the *Graduate Education* section of this catalog, students must meet the requirements specified below.

Admission

An applicant for admission to the Master of Arts for Teachers program must be a senior in or a graduate of an institution having substantially the same requirements for the bachelor's degree as Michigan State University, and possess, or be a candidate for, a teacher's certificate. Admission is recommended by the director of the program in which admission is sought, with approval of the Dean of the College of Natural Science.

Requirements for the Master of Arts for Teachers Degree

An appropriate course of study is planned with the candidate by an adviser from the academic unit in the College of Natural Science to which the candidate has been admitted. The minimum number of credits required for the degree is 30, in addition to any credits which must be taken to complete requirements for provisional teacher certification. A comprehensive written or oral examination may be required. A thesis is usually not required, but should one be required, a maximum of 10 semester credits may be allotted for it. The student must complete the requirements for provisional teacher certification before the degree may be granted.

Academic Standards

The minimum standard is a 3.00 grade-point average. Standards may be set higher than the minimum by the academic unit responsible for the degree program. The accumulation of grades below 3.0 in more than three courses of 3 or more credits each, or deferrals in more than three courses of 3 or more credits each at any given time, or a combination of the above in excess of four courses may remove the student from candidacy for the degree. A student who fails to meet the academic standards for any program may, on recommendation of the director, be required by the dean to withdraw at the end of the semester.

Residence

The minimum residence requirement is 8 credits on campus. Some programs may require more.

Time Limit

The time limit for the completion of the Master of Arts for Teachers degree is six years from the beginning of the first semester in which credit was earned toward the degree.

Master of Science and Master of Arts

The Master of Science is the conventional degree for all majors in the College of Natural Science. The Master of Arts may be conferred upon student request and College approval in the Department of Statistics and Probability.

In addition to meeting the requirements of the University as described in the *Graduate Education* section of this catalog, students must meet the requirements specified below.

Admission

Admission to provisional status may be used to indicate incomplete records, incomplete interpretation of available records, a grade-point average below 3.00 but with other evidence of good capacity, or minor deficiencies in subject matter.

Students may be transferred from one classification to another at any time by the dean, normally upon the recommendation of the department.

The College as a whole does not require an entrance examination. However, all departments expect students to provide Graduate Record Examination General Test scores.

Requirements for the Master of Science or Master of Arts Degree

For Plan A, a maximum of 10 credits of master's thesis research may be permitted. An exception is chemistry in which up to 15 credits of thesis research are allowed under Plan A.

Academic Standards

The minimum standard is a 3.00 grade-point average. Standards may be set higher than the minimum by the academic unit responsible for the degree program. The accumulation of grades below 3.0 in more than three courses of 3 or more credits each, or deferrals in more than three courses of 3 or more credits each at any given time, or a combination of the above in excess of four courses automatically removes the student from candidacy for the degree. A student who fails to meet the academic standards for any program may, on recommendation of the director, be required by the dean to withdraw at the end of any semester.

Residence

The minimum residence requirement is 8 credits on campus. A program may require more.

Time Limit

The time limit for completion of the master's degree is six years from the beginning of the first semester in which credit was earned toward the degree.

Doctor of Philosophy

The Doctor of Philosophy degree is awarded for an original contribution to scientific knowledge and high attainment of scholarship in the mathematical or natural sciences. This degree, with its emphasis on research in the frontiers of science, is the traditional terminal degree in the College of Natural Science.

In addition to meeting the requirements of the University as described in the *Graduate Education* section of this catalog, students must meet the requirements specified below.

Admission

Admission may be granted to a student who has a record of high scholastic attainment and demonstrated research potential acceptable to the department or program and to the College. A master's degree in an appropriate subject-matter field may be required, but the completion of a master's degree is not a guarantee of admission. Most programs require the applicant to submit Graduate Record Examination General Test scores; many also require the Graduate Record Examination Subject Test in the area of specialization.

Admission to provisional status may be used to indicate incomplete records, incomplete interpretation of available records, grade-point average below 3.00 but with additional evidence of good capacity, or minor deficiencies in subject matter.

Students may be transferred from one classification to another at any time by the dean, normally upon the recommendation of the department.

Academic Standards

The minimum standard is a 3.00 grade-point average. Standards may be set higher than the minimum by the academic unit responsible for the degree program. The accumulation of grades below 3.0 in more than three courses of 3 or more credits each, or deferrals in more than three courses of 3 or more credits each at any given time, or a combination of the above in excess of four courses automatically removes the student from candidacy for the degree.

A student who fails to meet the academic standards for any program may, on recommendation of the director, be required by the dean to withdraw at the end of any semester.

Residence

In some programs a student may be permitted to enter the doctoral program without taking a master's degree. In such cases 30 semester credits of approved work are considered the equivalent of the master's degree, and the minimum residence requirement for the combined program is three semesters, involving at least 4 credits of graduate work each semester.

CENTER for INTEGRATIVE STUDIES in GENERAL SCIENCE

Duncan F. Sibley, Director

Integrative Studies is Michigan State University's unique approach to liberal general education, offering a core curriculum that complements specialized work by students in their majors. Integrative Studies courses integrate multiple ways of knowing and modes of inquiry and introduce students to important ways of thinking in the three core knowledge areas: the Arts and Humanities, the Biological and Physical Sciences, and the Social, Behavioral, and Economic Sciences. They assist students early during their study to develop as more critical thinkers. They also encourage appreciation of our humanity and creativity, human cultural diversity, the power of knowledge, and our responsibilities for ourselves and for our world.

Courses in Michigan State University's Integrative Studies Program are aimed at developing intellectual abilities, including criti-

cal thinking and interpretive skills. They help increase knowledge about other times, places, and cultures, key ideas and issues in human experience, and the scientific method and its usefulness in understanding the natural and social worlds. They are expected to enhance appreciation of the role of knowledge, and of values and ethics, in understanding human behavior and solving social problems. Finally, they help students recognize responsibilities and opportunities associated with democratic citizenship and with living in an increasingly interconnected, interdependent world.

The Center for Integrative Studies in the Arts and Humanities in the College of Arts and Letters has primary responsibility for the Arts and Humanities area of Integrative Studies at Michigan State University.

The Center for Integrative Studies in General Sciences in the College of Natural Sciences has primary responsibility for Integrative Studies courses in the Biological and Physical Sciences at Michigan State University.

The Center for Integrative Studies in the Social Sciences in the College of Social Science has primary responsibility for Integrative Studies courses in the Social, Behavioral, and Economic Sciences at Michigan State University.

INTERDEPARTMENTAL DEGREE PROGRAMS

The College of Natural Science offers interdepartmental degree programs in biological science—interdepartmental; cell and molecular biology; earth science—interdepartmental; ecology, evolutionary biology and behavior; general science; genetics; genetics—environmental toxicology; human biology; neuroscience; and physical science—interdepartmental. These programs are designed to serve students who wish to develop a broad background in the natural sciences. Students who desire academic preparation in the natural sciences with emphasis in a single discipline should enroll in a departmental major. The interdepartmental programs are not intended for this purpose.

BIOLOGICAL SCIENCE—INTERDEPARTMENTAL

UNDERGRADUATE PROGRAM

The biological science—interdepartmental major, which leads to the Bachelor of Science degree, is designed for persons who want a broad background in fields that comprise biological sciences and who want to understand the interrelationships among such fields. This major is designed primarily for persons who plan to teach biological sciences in elementary, middle, and secondary schools.

Requirements for the Bachelor of Science Degree in Biological Science—Interdepartmental

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Science degree in Biological Science—Interdepartmental.
The University's Tier II writing requirement for the Biological Sciences—Interdepartmental major is met by completing NSC 401. That course is referenced in item 3.a. below.
Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Cer-

tain courses referenced in requirement 3. below may be used to satisfy the alternative track.

2. The requirements of the College of Natural Science for the Bachelor of Science degree.

The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.

3. The following requirements for the major:

	CREDITS
a. All of the following courses:	38
BS 110 Organisms and Populations	4
BS 111 Cells and Molecules	3
BS 111L Cell and Molecular Biology Laboratory	2
CEM 251 Organic Chemistry I	3
CEM 252 Organic Chemistry II	3
CEM 255 Organic Chemistry Laboratory	2
CEM 262 Quantitative Analysis	2
NSC 401 Science Laboratories for Secondary Schools (W)	4
PSL 250 Introductory Physiology	4
ZOL 341 Fundamental Genetics	4
ZOL 355 Ecology	3
ZOL 355L Ecology Laboratory	1
ZOL 445 Evolution	3
b. One of the following groups of courses:	9 to 12
(1) CEM 141 General Chemistry	4
CEM 142 General and Inorganic Chemistry	3
CEM 161 Chemistry Laboratory I	1
CEM 162 Chemistry Laboratory II	1
(2) CEM 151 General and Descriptive Chemistry	4
CEM 152 Principles of Chemistry	3
CEM 161 Chemistry Laboratory I	1
CEM 162 Chemistry Laboratory II	1
(3) CEM 181H Honors Chemistry I	4
CEM 182H Honors Chemistry II	4
CEM 185H Honors Chemistry Laboratory I	2
CEM 186H Honors Chemistry Laboratory II	2
c. One of the following pairs of courses:	6 or 7
(1) MTH 132 Calculus I	3
MTH 133 Calculus II	4
(2) MTH 132 Calculus I	3
STT 201 Statistical Methods	4
(3) MTH 124 Survey of Calculus with Applications I	3
MTH 126 Survey of Calculus with Applications II	3
(4) MTH 124 Survey of Calculus with Applications I	3
STT 201 Statistical Methods	4
(5) MTH 152H Honors Calculus I	3
MTH 153H Honors Calculus II	3
d. One of the following pairs of courses:	6 or 8
(1) PHY 183 Physics for Scientists and Engineers I	4
PHY 184 Physics for Scientists and Engineers II	4
(2) PHY 193H Honors Physics I—Mechanics	3
PHY 294H Honors Physics II—Electromagnetism	3
(3) PHY 231 Introductory Physics I	3
PHY 232 Introductory Physics II	3
e. One of the following pairs of courses:	2
(1) PHY 191 Physics Laboratory for Scientists, I	1
PHY 192 Physics Laboratory for Scientists, II	1
(2) PHY 251 Introductory Physics Laboratory I	1
PHY 252 Introductory Physics Laboratory II	1
f. Two of the following courses:	8
BMB 401 Basic Biochemistry	4
ZOL 350 Histology	4
ZOL 482 Cytochemistry	4
g. One of the following courses:	3 or 4
BOT 301 Introductory Plant Physiology	3
BOT 405 Introductory Plant Pathology	4
BOT 418 Plant Systematics	3
BOT 434 Plant Structure and Function	4

TEACHER CERTIFICATION OPTIONS

The biological science–interdepartmental disciplinary major leading to the Bachelor of Science degree is available for teacher certification. Students who complete the requirements for this disciplinary major and the requirements for teacher certification choose whether they wish to be recommended for certification in biological science or general science.

A biological science disciplinary minor is also available for teacher certification.

Students who elect the biological science–interdepartmental disciplinary major or the biological science disciplinary minor must contact the College of Natural Science.

For additional information, refer to the statement on *TEACHER CERTIFICATION* in the *Department of Teacher Education* section of this catalog.

GRADUATE STUDY

Master of Science

The Master of Science degree program with a major in Biological Science–Interdepartmental is designed for science teachers who wish to pursue graduate study in the biological sciences. To meet the needs of practicing teachers, the courses that are required for the program are offered in the summer and on weekends. A doctoral program is not offered in general biology.

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

Requirements for admission to the master's degree program in biological science–interdepartmental include a bachelor's degree in biology, teacher certification for grades 7–12, at least 3 years of teaching experience, and current employment as a teacher of biology or related disciplines at the middle or secondary school level.

Requirements for the Master of Science Degree in Biological Science—Interdepartmental

The program is available under either Plan A (with thesis) or Plan B (without thesis). For a student under Plan A, a thesis committee that consists of the student's faculty adviser, the student's problem director, and one other faculty member must approve the student's program of study.

The student must complete at least 30 credits distributed as follows:

	CREDITS
Requirements for Both Plan A and Plan B	
1. All of the following courses (18 credits):	
NSC 850 Cell and Molecular Biology	2
NSC 851 Cell and Molecular Biology Laboratory	3
NSC 852 Interdisciplinary Seminar in Biological Science	1
NSC 855 Environmental and Behavioral Biology	3
NSC 856 Environmental and Behavioral Biology Laboratory	3
NSC 901 Frontiers in Biological Science	6
2. Two additional credits in courses approved by the student's graduate committee.	
Additional Requirements for Plan A	
1. NSC 899 Master's Thesis Research	10
Research for the thesis involves developing laboratories and demonstrations as part of a new teaching unit and teaching that unit.	
Additional Requirements for Plan B	
1. NSC 899 Research for Inservice Teachers	10
Research for inservice teachers requires a curriculum based project and implementation report.	

CELL AND MOLECULAR BIOLOGY

GRADUATE STUDY

Master of Science

This program provides theoretical and practical training in cell and molecular biology to prepare students for a variety of professional positions in academia, industry or government.

Admission

Most students enter the Master of Science degree program in cell and molecular biology with the goal of eventually obtaining a Ph.D. degree. However, students with limited research experience or specific deficiencies in their undergraduate training may be admitted to this program to obtain additional experience. Ap-

NATURAL SCIENCE
Interdepartmental Degree Programs

licants will be considered by the Cell and Molecular Biology admissions committee, and in general the criteria for admission are similar to those of the Ph.D. program (an undergraduate major in biological science, acceptable GPA and GRE scores, and letters of recommendation).

In addition to meeting the requirements of the University and the College of Natural Science, students must meet the requirements specified below.

Requirements for the Master of Science Degree in Cell and Molecular Biology

Students in the M.S. program in Cell and Molecular Biology must complete a total of 30 credits for the degree under either Plan A (with thesis) or Plan B (without thesis). These credits must include core courses in molecular biology, cell biology, and genetics. Detailed course and other requirements are specified in the cell and molecular biology graduate manual.

For a Plan A master's degree, students must complete a minimum of 4 and a maximum of 10 credits of Cell and Molecular Biology 899, Master's Research. They must also prepare a written thesis, complete a final research seminar, and pass an oral examination.

For a Plan B master's degree, student may complete a maximum of 8 credits of Cell and Molecular Biology 890, Independent Study. They must also complete a final report and pass an oral examination.

Doctor of Philosophy

The interdepartmental Doctor of Philosophy degree program with a major in cell and molecular biology is administered by the College of Natural Science. Students may elect to complete the requirements for a second major, in addition to the requirements for the Doctor of Philosophy degree in cell and molecular biology.

The educational objectives of the program are to provide doctoral students with fundamental knowledge and research skills so that they may become independent and self-educating scholars.

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

To be considered for admission to the Doctor of Philosophy degree program with a major in cell and molecular biology, an applicant must have taken the Graduate Record Examination General Test.

To be admitted to the doctoral program in cell and molecular biology, it is recommended that an applicant have:

1. Completed a Bachelor of Science or Bachelor of Arts degree with a minimum grade-point average of 3.00.
2. A broad background in biology, including courses in biochemistry, genetics, cell biology, and molecular biology.
3. Completed at least one year of study in each of the following fields: physics, inorganic chemistry, organic chemistry, and mathematics through integral calculus.
4. A grade of 3.0 or above in each science and mathematics course completed.
5. Acceptable scores on the Graduate Record Examination General Test.

Applicants with deficiencies in academic preparation may be admitted provisionally, in which case they will be required to complete collateral courses.

Requirements for the Doctor of Philosophy Degree in Cell and Molecular Biology

The student must:

	CREDITS
1. Complete all of the following courses (15 credits):	
BMB 801 Molecular Biology and Protein Structure	4
BMB 825 Cell Structure and Function	3
CMB 800 Cell and Molecular Biology Seminar	3
CMB 892 Research Forum	4
One graduate course in scientific ethics	1
2. Complete one of the following courses (3 credits):	
MMG 833 Microbial Genetics	3
MMG 835 Eukaryotic Molecular Genetics	3
3. Complete a minimum of two additional graduate courses of at least 3 credits each that are related to the student's research.	
4. Complete a 10-week research rotation in the laboratory of each of three different members of the cell and molecular biology faculty during the first year of enrollment in the program.	
5. Pass the preliminary examination given at the end of the second year of graduate study.	
6. Successfully complete a minimum of two semesters as a teaching assistant in a department represented on the cell and molecular biology faculty. The student's teaching assignment must be approved by the director of the doctoral program in cell and molecular biology.	

For additional information, contact the director of the doctoral program in cell and molecular biology, 153 Giltner Hall, Michigan State University, East Lansing, MI 48824.

**EARTH SCIENCE—
 INTERDEPARTMENTAL**

UNDERGRADUATE PROGRAM

The Department of Geological Sciences administers the earth science—interdepartmental major, which leads to the Bachelor of Science degree. The major is designed for persons who want a broad background in geology, meteorology, oceanography, and astronomy and who want to understand the interrelationships among these fields. It is designed primarily for persons who plan to teach earth science in elementary, middle, and secondary schools.

Requirements for the Bachelor of Science Degree in Earth Science—Interdepartmental

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Science degree in Earth Science—Interdepartmental.

The University's Tier II writing requirement for the Earth Science—Interdepartmental major is met by completing Geological Sciences 401. That course is referenced in item 3. a. below.

Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.

2. The requirements of the College of Natural Science for the Bachelor of Science degree. The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
3. The following requirements for the major:

	CREDITS
a. All of the following courses:	29
AST 207 The Science of Astronomy	3
GEO 203 Introduction to Meteorology	3
GLG 201 The Dynamic Earth	4
GLG 303 Oceanography	4
GLG 304 Physical and Biological History of the Earth	4
GLG 321 Mineralogy and Geochemistry	4
GLG 401 Plate Tectonics (W)	4
MTH 132 Calculus I	3
b. One of the following courses:	3 or 4
MTH 133 Calculus II	4
STT 200 Statistical Methods	3
STT 201 Statistical Methods	4
STT 231 Statistics for Scientists	3
STT 421 Statistics I	3
c. One of the following groups of courses:	8

(1)	CEM 141	General Chemistry	4
	CEM 142	General and Inorganic Chemistry	3
	CEM 161	Chemistry Laboratory I	1
(2)	CEM 151	General and Descriptive Chemistry	4
	CEM 152	Principles of Chemistry	3
	CEM 161	Chemistry Laboratory I	1
d.	One of the following groups of courses:		8
(1)	PHY 231	Introductory Physics I	3
	PHY 232	Introductory Physics II	3
	PHY 251	Introductory Physics Laboratory I	1
	PHY 252	Introductory Physics Laboratory II	1
(2)	PHY 183	Physics for Scientists and Engineers I	4
	PHY 184	Physics for Scientists and Engineers II	4
e.	One course of at least 3 credits in biological science, botany and plant pathology, entomology, microbiology, physiology, or zoology.		3
f.	One of the following courses:		3 or 4
	GEO 306	Environmental Geomorphology	3
	GLG 412	Glacial and Quaternary Geology	4
g.	Two of the following courses:		6 to 8
	AST 201	Astrophysics and Astronomy I	3
	BOT 335	Plants Through Time	3
	GEO 404	Synoptic Climatology	4
	GEO 424	Advanced Remote Sensing	4
	GLG 411	Hydrogeology	4
	GLG 421	Environmental Geochemistry	4
	GLG 422	Aquatic and Marine Organic Geochemistry (W)	3
	GLG 434	Evolutionary Paleobiology	4

TEACHER CERTIFICATION OPTIONS

The earth science–interdepartmental disciplinary major leading to the Bachelor of Science degree is available for teacher certification. Students who complete the requirements for this disciplinary major and the requirements for teacher certification choose whether they wish to be recommended for certification in earth science or general science.

An earth science disciplinary minor is also available for teacher certification.

Students who elect the earth science–interdepartmental disciplinary major or the earth science disciplinary minor must contact the Department of Geological Sciences.

For additional information, refer to the statement on *TEACHER CERTIFICATION* in the *Department of Teacher Education* section of this catalog.

ECOLOGY, EVOLUTIONARY BIOLOGY AND BEHAVIOR

GRADUATE STUDY

Doctor of Philosophy

The interdepartmental Doctor of Philosophy degree program with a major in ecology, evolutionary biology and behavior is administered by the College of Natural Science. The program is available only to those students who plan to complete a Ph.D. degree program that involves ecology, evolutionary biology and behavior and a major in one of the following departments that are affiliated with the interdepartmental program: Anthropology, Crop and Soil Sciences, Entomology, Fisheries and Wildlife, Forestry, Geological Sciences, Horticulture, Microbiology, Philosophy, Plant Biology, Psychology, and Zoology. The student does *not* have the option of completing a Doctor of Philosophy degree with a major in ecology, evolutionary biology and behavior alone.

The educational objectives of the interdepartmental program are to:

1. Provide an opportunity for doctoral students to obtain a comprehensive and contemporary academic experience in the field of ecology, evolutionary biology and behavior.

2. Stimulate doctoral students with an interest in ecology, evolutionary biology and behavior to become sensitive to their professional obligations and responsibilities.
3. Develop an intellectual environment which will foster the growth of research and teaching in the area of ecology, evolutionary biology and behavior.

Students who are enrolled in the doctoral degree program with a major in Ecology, Evolutionary Biology and Behavior may elect an Interdepartmental Specialization in Cognitive Science. For additional information, refer to the statement on *Interdepartmental Graduate Specializations in Cognitive Science* in the *College of Social Science* section of this catalog. For additional information, contact the College of Natural Science.

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

A student must apply for admission to the Doctor of Philosophy degree program with a major in ecology, evolutionary biology and behavior either before or after applying for admission to a major in one of the departments that are affiliated with that program. A minimum undergraduate grade-point average of 3.00 and undergraduate mathematics through calculus are required for admission to the program.

The Graduate Admissions Committee, composed of one member of the ecology, evolutionary biology and behavior faculty from each of the affiliated departments, reviews applications for admission and recommends acceptance of applicants for admission. In special cases an applicant who has deficiencies in background courses may be admitted to the program on a provisional basis.

In order to enroll in the Ph.D. degree program with a major in ecology, evolutionary biology and behavior a student must also have been admitted to a major in one of the departments that are affiliated with that program.

Guidance Committee

During the first year of enrollment in the Doctor of Philosophy degree program, the student and a member of the ecology, evolutionary biology and behavior faculty who will serve as the student's major professor will constitute a guidance committee that will assist in planning the student's program of study. At least two members of the ecology, evolutionary biology and behavior faculty shall be members of the committee. The student's program of study will involve ecology, evolutionary biology and behavior and a major in one of the departments that are affiliated with that program. The program shall be planned in accordance with the statement on *Dual Major Doctoral Degrees* in the *Graduate Education* section of this catalog.

Students in the Doctor of Philosophy degree program in ecology, evolutionary biology and behavior are encouraged to attend informal weekly seminars, to participate in the graduate student-organized research colloquium, and to organize special topics seminars to be offered by faculty members.

Requirements for the Doctor of Philosophy Degree in Ecology, Evolutionary Biology and Behavior

		CREDITS
1.	Both of the following required core courses:	6
	BOT 849 Evolutionary Biology	3
	ZOL 851 Quantitative Methods in Ecology and Evolution	3
2.	One 3-credit course in ecology at the 800-900 level from one of the departments that are affiliated with the Doctor of Philosophy degree program in ecology, evolutionary biology and behavior. A list of approved	

NATURAL SCIENCE
Interdepartmental Degree Programs

- courses is available from the director of the ecology, evolutionary biology and behavior program.
- Twenty-four credits in Doctoral Dissertation Research (course number 999) from one of the departments referenced in item 2. above.
 - Pass a comprehensive examination that will be defined by the requirements of the participating department and that will include a written examination in which the student demonstrates a knowledge of ecology, evolutionary biology and behavior as determined by the guidance committee.
 - Submit a dissertation that, in the judgment of the student's guidance committee, represents the integration of ecology, evolutionary biology and behavior and the student's departmental major.

GENERAL SCIENCE

GRADUATE STUDY

Master of Arts for Teachers

The Master of Arts for Teachers degree program with a major in general science is designed for elementary and middle school teachers who wish to pursue graduate study in the broad area of teaching science and mathematics. To meet the needs of practicing teachers, the courses that are required for the program are offered in the summer, on weekends, and after school hours.

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

The requirements for admission to the master's degree program in general science include a bachelor's degree, teacher certification for grades K–8, at least 3 years of teaching experience, and current employment as a teacher in an elementary or middle school.

Requirements for the Master of Arts for Teachers Degree in General Science

The program is available only under Plan B (without thesis). A total of 30 credits is required for the degree. The student's program of study must be approved by the student's academic adviser. The student must meet the requirements specified below.

	CREDITS
1. All of the following courses (23 credits):	
MTH 801 Current Issues in Mathematics Education	3
NSC 651 Physical Science I	2
NSC 652 Physical Science II	2
NSC 653 Earth Science I	2
NSC 654 Earth Science II	2
NSC 655 Life Science I	2
NSC 656 Life Science II	2
NSC 889 Research for Inservice Teachers	5
TE 860 Practice and Inquiry in Science Education	3
An approved project that involves either developing new science units and teaching those units or a project that is designed to transform science teaching in the student's school is required for Natural Science 889.	
2. Two of the following courses (6 credits):	
CEP 805 Learning Mathematics	3
CEP 806 Learning of Science	3
TE 825 Diverse Learners and Learning Subject Matter	3
TE 855 Teaching School Mathematics	3

GENETICS

GRADUATE STUDY

Master of Science

The primary purpose of the Master of Science in Genetics is to train students for a variety of careers in areas of genetics and genomics. The program also seeks to provide graduate students who are seeking the Ph.D. degree, state-of-the-art knowledge and skills to prepare them for careers in research and teaching.

Admission

Applicants will be considered for admission by the Genetics Admissions Committee. The criteria for admission include an undergraduate major in the biological sciences, acceptable grade-point average and GRE scores, a statement of objectives and three letters of recommendation. The Genetics Admissions Committee will also consider requests for students to transfer from the Doctor of Philosophy in Genetics to this program.

In addition to meeting the requirements of the University and the College of Natural Science, students must meet the requirements specified below.

Requirements for the Master of Science Degree in Genetics

All students in the Master of Science in Genetics must earn at least 30 credits, of which a minimum of 20 credits must consist of course work and must include the core courses specified for the Ph.D. program. Detailed course work and other requirements are specified in the *Student Handbook* of the Genetics Program. For a *Plan A* (with thesis) degree, students must complete 4 to 10 credits of Genetics 899, Master's Thesis Research, submit a written thesis, present a final research seminar and pass a final oral examination. For a *Plan B* (without thesis) degree, students must have earned at least 26 credits through course work, may receive a maximum of 4 credits for work completed in Genetics 899, Master's Thesis Research, submit a final report and pass an oral examination.

Doctor of Philosophy

The interdepartmental Doctor of Philosophy degree program with a major in genetics is administered by the College of Natural Science. The objectives of the program are (1) to prepare the student for independent research and teaching, (2) to help the student to understand the nature and significance of genetics as a whole and to gain strength in related sciences, such as molecular biology and biochemistry, and (3) to enable the student to keep in the forefront of this continuously changing field.

Students may specialize in one area of genetics, but are required to familiarize themselves with all major areas of the discipline. Students may elect to complete the requirements for a second major, such as biochemistry, in addition to the requirements for the doctoral degree in genetics.

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

For regular admission a student must have a bachelor's degree with a grade–point average of 3.30, appropriate background in the biological and physical sciences, and approval of the Genetics Program Admissions Committee. In special cases an applicant who fails to meet the grade–point average requirement, or who has deficiencies in background courses, i.e., organic chemistry, physics, calculus, or biology, may be admitted on a provisional basis. Applicants admitted on a provisional basis must remove these deficiencies within one year of admission to the genetics program.

Requirements for the Doctor of Philosophy Degree in Genetics

The program of study is planned by the student in consultation with the major professor and a guidance committee. Specific courses in genetics, as well as courses in other areas considered relevant to the student's interests and chosen research area, are included in the program. Students in the program will write and defend a research dissertation which shows original treatment of an important research problem. A detailed description of the genetics program and of the research interests of the genetics faculty may be obtained by writing the Director of the Genetics Program, Michigan State University, S–352 Plant Biology Building, East Lansing, MI 48824.

HUMAN BIOLOGY

UNDERGRADUATE PROGRAM

The human biology major, which leads to the Bachelor of Science degree, is designed for persons who want a broad background in fields that comprise biological sciences and who want to understand the interrelationships among such fields. This major is designed for persons who plan to pursue careers in the health care professions and for students who are interested in the biological sciences, but are not interested in a teaching option.

Requirements for the Bachelor of Science Degree in Human Biology

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Science degree in Human Biology.
The University's Tier II writing requirement for the Human Biology major is met by completing NSC 495. That course is referenced in item 3. a. below.
Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
2. The requirements of the College of Natural Science for the Bachelor of Science degree.
The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
3. The following requirements for the major:

CREDITS
44

a.	All of the following courses:	
	BMB 461 Biochemistry I	3
	BMB 462 Biochemistry II	3
	BS 110 Organisms and Populations	4
	BS 111 Cells and Molecules	3
	BS 111L Cell and Molecular Biology Laboratory	2
	CEM 251 Organic Chemistry I	3
	CEM 252 Organic Chemistry II	3
	CEM 255 Organic Chemistry Laboratory	2
	MMG 409 Eukaryotic Cell Biology	3
	MMG 451 Immunology	3
	NSC 495 Capstone in Human Biology (W)	2
	PSL 431 Human Physiology I	3
	PSL 432 Human Physiology II	3
	ZOL 341 Fundamental Genetics	4

b.	One of the following groups of courses:	9 to 12
(1)	CEM 141 General Chemistry	4
	CEM 142 General and Inorganic Chemistry	3
	CEM 161 Chemistry Laboratory I	1
	CEM 162 Chemistry Laboratory II	1
(2)	CEM 151 General and Descriptive Chemistry	4
	CEM 152 Principles of Chemistry	3
	CEM 161 Chemistry Laboratory I	1
	CEM 162 Chemistry Laboratory II	1
(3)	CEM 181H Honors Chemistry I	4
	CEM 182H Honors Chemistry II	4
	CEM 185H Honors Chemistry Laboratory I	2
	CEM 186H Honors Chemistry Laboratory II	2
c.	One of the following pairs of courses:	6 or 7
(1)	MTH 132 Calculus I	3
	MTH 133 Calculus II	4
(2)	MTH 132 Calculus I	3
	STT 201 Statistical Methods	4
(3)	MTH 124 Survey of Calculus with Applications I	3
	MTH 126 Survey of Calculus with Applications II	3
(4)	MTH 124 Survey of Calculus with Applications I	3
	STT 201 Statistical Methods	4
(5)	MTH 152H Honors Calculus I	3
	MTH 153H Honors Calculus II	3
d.	One of the following pairs of courses:	6 or 8
(1)	PHY 183 Physics for Scientists and Engineers I	4
	PHY 184 Physics for Scientists and Engineers II	4
(2)	PHY 193H Honors Physics I–Mechanics	3
	PHY 294H Honors Physics II–Electromagnetism	3
(3)	PHY 231 Introductory Physics I	3
	PHY 232 Introductory Physics II	3
e.	One of the following pairs of courses:	2
(1)	PHY 191 Physics Laboratory for Scientists, I	1
	PHY 192 Physics Laboratory for Scientists, II	1
(2)	PHY 251 Introductory Physics Laboratory I	1
	PHY 252 Introductory Physics Laboratory II	1
f.	At least 6 credits from the following courses:	6
	MMG 301 Introductory Microbiology	3
	MMG 302 Introductory Microbiology Laboratory	1
	MMG 413 Virology	3
	MMG 431 Microbial Genetics	3
	MMG 461 Molecular Pathogenesis	3
	MMG 463 Medical Microbiology	3
	MT 212 Fundamentals of Laboratory Analysis	3
	MT 213 Application of Clinical Laboratory Principles	1
	MT 416 Clinical Chemistry II: Pathophysiology and Body Fluid Analysis	5
	NSC 496 Directed Study in Human Biology	1 to 3
	NSC 497 Internship in Human Biology	1 to 3
	NSC 498 Research in Human Biology	1 to 3
	PHM 350 Introductory Human Pharmacology	3
	PHM 430 Drug Abuse	3
	PHM 450 Introduction to Chemical Toxicology	3
	ZOL 344 Human Genetics	3
	ZOL 402 Neurobiology	3
	ZOL 408 Histology	4
	ZOL 425 Cells and Development	4
	ZOL 450 Cancer Biology	3
	ZOL 482 Cytochemistry	4
	ZOL 483 Environmental Physiology	4
	With the approval of the director of the human biology major, credits in research or independent study courses may be used to satisfy this requirement.	
g.	One of the following courses:	3 or 4
	ANT 316 General Human Anatomy	3
	ZOL 320 Developmental Biology	4
	ZOL 328 Comparative Anatomy and Biology of Vertebrates	4

NEUROSCIENCE

Several colleges and departments within Michigan State University cooperate in offering the interdepartmental Doctor of Philosophy degree program with a major in neuroscience, which is administered by the College of Natural Science. Students may elect to complete the requirements for a second major, in addition to the requirements for the Doctor of Philosophy degree in neuroscience.

Students who are enrolled in the doctoral degree program with a major in Neuroscience may also elect an Interdepartmental Specialization in Cognitive Science. For additional information, refer to the statement on *Interdepartmental Graduate Specializations in Cognitive Science* in the *College of Social Science* section of this catalog. For additional information, contact the College of Natural Science.

NATURAL SCIENCE
Interdepartmental Degree Programs

The program provides an opportunity for doctoral students to acquire both a broad and in-depth knowledge of the function of the nervous system. The program is designed to:

1. Make it possible for a doctoral student to obtain a comprehensive and contemporary academic experience in the field of neuroscience.
2. Prepare students for their future professional obligations and responsibilities as scholars.
3. Develop an intellectual environment that will foster the growth of research and teaching in the area of neuroscience.

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

To be considered for admission to the Doctor of Philosophy degree program with a major in neuroscience, an applicant should have:

1. Completed a broad spectrum of basic science courses.
2. A grade-point average of at least 3.00 in science and mathematics courses.
3. Experience in laboratory research.

To be eligible for admission to the Doctor of Philosophy degree program with a major in neuroscience, an applicant must have:

1. Completed an undergraduate degree in a biological or physical science or in a related discipline.
2. An overall grade-point average of at least 3.00.
3. Satisfactory scores on the Graduate Record Examination General Test as judged by the faculty.

Admission decisions are made by the Neuroscience Program Admissions Committee. Applicants with deficiencies in academic preparation may be admitted provisionally, with the requirement that they complete remedial science courses during the first year of study.

Requirements for the Doctor of Philosophy Degree in Neuroscience

The student must:

- | | |
|---|---------|
| | CREDITS |
| 1. Complete all of the following courses: | |
| ANT 839 Systems Neuroscience | 4 |
| BMB 825 Cell Structure and Function | 3 |
| PHM 827 Advanced Neurobiology | 4 |
| PHM 980 Problems | 6 |
| PSY 811 Advanced Behavioral Neuroscience | 3 |
| PTH 830 Concepts in Molecular Biology | 2 |
| In order for Pharmacology and Toxicology 980 to be counted toward the requirements for the degree, 3 credits must focus on neuroscience laboratory. | |
| 2. Complete a minimum of 8 credits in additional courses as follows: | |
| a. Two of the following courses: | |
| ANT 885 Vertebrate Neural Systems | 3 |
| PHM 810 Synaptic Transmission | 3 |
| PHM 817 Advanced Neurotoxicology | 3 |
| PSL 841 Advanced Endocrine Physiology and Pharmacology | 4 |
| PSY 809 Developmental Psychobiology | 3 |
| PSY 851 Neuropsychology | 4 |
| ZOL 830 Neuroendocrine Aspects of Behavior | 3 |
| b. If necessary, one additional course related to the student's research and approved by the student's guidance committee . . . | 0 to 2 |
| 3. Complete in the first year of enrollment in the program a one-semester laboratory rotation with <i>each of two</i> members of the faculty. Faculty in the departments of Anatomy, Biochemistry and Molecular Biology, Pathology, Pharmacology and Toxicology, Physiology, Psychology, and Zoology who have an interest in neuroscience are available for laboratory rotations. Each rotation is established by mutual agreement of the faculty member and the student. | |
| 4. Pass the written and oral comprehensive examinations given at the end of the second year of enrollment in the program. | |
| 5. Complete and defend a dissertation based on original research on an important problem in neuroscience. | |

The colleges and departments that are listed below cooperate in offering the interdepartmental Doctor of Philosophy degree program with a major in neuroscience:

Colleges

- Human Medicine
- Osteopathic Medicine
- Social Science
- Veterinary Medicine

Departments

- Anatomy
- Biochemistry and Molecular Biology
- Pathobiology and Diagnostic Investigation
- Pharmacology and Toxicology
- Physiology
- Psychology
- Zoology

A detailed description of the Doctor of Philosophy degree program with a major in neuroscience and of the research interests of participating faculty may be obtained upon request from the Neuroscience Program Administrative Office, 216 Psychology Research Building, Michigan State University, East Lansing, MI 48824-1317, or by visiting the web site at <http://www.msu.edu/unit/neurosci/>.

**PHYSICAL SCIENCE—
INTERDEPARTMENTAL**

UNDERGRADUATE PROGRAM

The physical science–interdepartmental major, which leads to the Bachelor of Science degree, is designed for persons who want a broad background in fields that comprise the physical sciences and who want to understand the interrelationships among such fields. This major is designed primarily for persons who plan to teach physical science in elementary, middle, and secondary schools.

Requirements for the Bachelor of Science Degree in Physical Science–Interdepartmental

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Science degree in Physical Science–Interdepartmental.
 - The University's Tier II writing requirement for the Physical Science–Interdepartmental major is met by completing Natural Science 401. That course is referenced in item 3. a. below.
 - Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
2. The requirements of the College of Natural Science for the Bachelor of Science degree.
3. The following requirements for the major:

	CREDITS
a. All of the following courses:	27
CEM 151 General and Descriptive Chemistry	4
CEM 152 Principles of Chemistry	3
CEM 161 Chemistry Laboratory I	1
MTH 132 Calculus I	3
MTH 133 Calculus II	4
NSC 401 Science Laboratories for Secondary Schools (W)	4
PHY 183 Physics for Scientists and Engineers I	4
PHY 184 Physics for Scientists and Engineers II	4
b. One of the following courses:	3 or 4
BOT 105 Plant Biology	3
BS 110 Organisms and Populations	4
ENT 205 Pests, Society and Environment	3
MMG 205 Allied Health Microbiology	3

PSL 250	Introductory Physiology	4	
ZOL 141	Introductory Human Genetics	3	
c.	Two of the following three concentrations:		33 to 41
	Chemistry Concentration (14 credits):		
(1)	All of the following courses:		
	CEM 162 Chemistry Laboratory II	1	
	CEM 251 Organic Chemistry I	3	
	CEM 252 Organic Chemistry II	3	
	CEM 255 Organic Chemistry Laboratory	2	
	CEM 262 Quantitative Analysis	2	
	CEM 383 Introductory Physical Chemistry I	3	
	Physics Concentration (19 credits):		
(1)	All of the following courses:		
	MTH 234 Multivariable Calculus	4	
	MTH 235 Differential Equations	3	
	PHY 191 Physics Laboratory for Scientists, I	1	
	PHY 192 Physics Laboratory for Scientists, II	1	
	PHY 215 Thermodynamics and Modern Physics	3	
	PHY 431 Optics I	3	
	PHY 440 Electronics	4	
	Earth Science Concentration (21 or 22 credits):		
(1)	Both of the following courses (8 credits):		
	GLG 201 The Dynamic Earth	4	
	GLG 401 Plate Tectonics (W)	4	
(2)	One of the following courses (4 credits):		
	GLG 321 Mineralogy and Geochemistry	4	
	GLG 351 Structural Geology	4	
(3)	One of the following courses (3 or 4 credits):		
	GLG 421 Environmental Geochemistry	4	
	GLG 422 Organic Geochemistry (W)	3	
(4)	Six additional credits in Geological Sciences courses approved by the student's academic adviser. Astronomy and Astrophysics 201 may be used to satisfy this requirement.		

TEACHER CERTIFICATION OPTION

The physical science–interdepartmental disciplinary major leading to the Bachelor of Science degree is available for teacher certification.

Students who elect the physical science–interdepartmental disciplinary major must contact the College of Natural Science.

For additional information, refer to the statement on *TEACHER CERTIFICATION* in the *Department of Teacher Education* section of this catalog.

GRADUATE STUDY

Master of Science

The Master of Science degree program with a major in Physical Science–Interdepartmental is designed for science teachers who wish to pursue graduate study in the physical sciences. To meet the needs of practicing teachers, the courses that are required for the program are offered in the summer and on weekends.

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

Requirements for admission to the master's degree program in physical science–interdepartmental include a bachelor's degree in physics, chemistry, earth science, or physical science; teacher certification for grades 7–12; at least 3 years of teaching experience; and current employment as a teacher of physics, chemistry, earth science, or physical science at the middle or secondary school level.

Requirements for the Master of Science Degree in Physical Science–Interdepartmental

The program is available under either Plan A (with thesis) or Plan B (without thesis). For a student under Plan A, a thesis committee that consists of the student's faculty adviser, the student's prob-

lem director, and one other faculty member must approve the student's program of study.

The student must complete at least 30 credits distributed as follows:

	CREDITS
Requirements for Both Plan A and Plan B	
1. All of the following courses (17 credits):	
NSC 860 Problem Solving Techniques in Physical Science	3
NSC 861 Chemistry for Teachers	2
NSC 862 Physics for Teachers	2
NSC 863 Earth Science for Teachers	2
NSC 864 Interdisciplinary Seminar in Physical Science	2
NSC 902 Frontiers in Physical Science	6
2. Three additional credits in courses approved by the student's graduate committee.	
Additional Requirements for Plan A	
1. NSC 899 Master's Thesis Research	10
Research for the thesis involves developing laboratories and demonstrations as part of a new teaching unit and teaching that unit.	
Additional Requirements for Plan B	
1. NSC 889 Research for Inservice Teachers	10
Research for inservice teachers requires a curriculum based project and implementation report.	

INTERDEPARTMENTAL SPECIALIZATIONS

UNDERGRADUATE

ENVIRONMENTAL STUDIES

The Specialization in Environmental Studies is available as an elective to all students who are enrolled in bachelor's degree programs in the College of Agriculture and Natural Resources, the College of Communication Arts and Sciences, the College of Engineering, the College of Natural Science, and the College of Social Science. The specialization is administered jointly by the five colleges referenced above. The College of Natural Science is the primary administrative unit.

The Specialization in Environmental Studies is designed to:

1. provide knowledge essential for understanding the physical environment that is inhabited and influenced by humans.
2. explain the way in which direct and indirect policy-making by social, economic, and political institutions affects environmental issues.

Students who elect the specialization are encouraged to complete Integrative Studies in Social, Behavioral, and Economic Sciences 225 and Transcollegiate Course 304 in partial fulfillment of the University Integrative Studies requirement. Students who elect the specialization may complete an optional environmental studies project of 1 to 3 credits during the sophomore year.

Freshmen who have either declared the intent to complete the Specialization in Environmental Studies or who have declared a major preference for one of the bachelor's degree programs that are related to environmental studies may elect the two-year Residential Option in Environmental Studies. Students who elect this option will be housed in Hubbard Hall, where several of the courses that are required for the specialization will be taught. This integrated living–learning environment will allow students from the several colleges and disciplines to develop a sense of community and will promote a team approach to solving environmental problems.

NATURAL SCIENCE
Interdepartmental Specializations

Requirements for the Specialization in Environmental Studies:

The student must meet the requirements specified below:

1. Biological and Physical Dimensions of the Environment: 14 to 16
 - a. Both of the following courses (8 credits):
 - GLG 201 The Dynamic Earth 4
 - ISS 310 People and Environment (I) 4
 Integrative Studies in Social, Behavioral, and Economic Sciences 310 may be used to satisfy both the requirements for the Specialization in Environmental Studies and University requirements.
 - b. One of the following courses (3 or 4 credits):
 - BS 110 Organisms and Populations 4
 - FW 203 Resource Ecology 3
 - c. One of the following two options (3 or 4 credits):
 - (1) Both of the following courses:
 - ZOL 355 Ecology 3
 - ZOL 355L Ecology Laboratory 1
 - (2) One of the following courses:
 - CE 280 Introduction to Environmental Engineering . . . 3
 - CSS 210 Fundamentals of Soil and Landscape Science 3
 - CSS 455 Pollutants in the Soil Environment 3
 - FOR 404 Forest and Agricultural Ecology 4
 - FW 207 Great Lakes: Biology and Management 3
 - FW 364 Ecosystem Processes 3
 - FW 444 Conservation Biology 3
 - GEO 203 Introduction to Meteorology 3
 - GEO 206 Physical Geography 3
 - GLG 421 Environmental Geochemistry 4
 - RD 324 Water Resource Development 3
2. Social-Environmental Interactions: 6 or 7
 - a. One of the following courses (3 credits):
 - ANP 470 Food, Hunger and Society 3
 - EOP 260 World Food, Population and Poverty 3
 - EOP 320 Public Policy Analysis Methods 3
 - FOR 464 Natural Resource Economics and Social Science (W) 3
 - JRN 408 Topics in Specialized Reporting and Writing 3
 - PKG 370 Packaging and the Environment 3
 - PLS 342 Comparative Political Economy 3
 - PRR 302 Environmental Attitudes and Concepts 3
 - RD 201 Environmental and Natural Resources 3
 - RD 336 State Environmental Law 3
 - RD 430 Law and Resources 3
 - RD 460 Resource and Environmental Economics 3
 - SOC 452 Environment and Society 3
 - UP 323 Land and Environmental Planning 3
 - ZOL 446 Environmental Issues and Public Policy 3
 Journalism 408 may be used to satisfy requirement 2.a. only when the topic deals with environmental journalism.
 - b. One of the following courses (3 or 4 credits):
 - PLS 301 American State Government 3
 - PLS 310 Public Bureaucracy in the Policy Process 3
 - PLS 313 Public Policy Analysis 3
 - PLS 324 American Legislative Process 3
 - PLS 331 Political Parties and Interest Groups 3
 - TC 310 Basic Telecommunication Policy 4
3. Seminar: 3
 - NSC 192 Environmental Issues Seminar 3

With the prior written approval of the associate dean of the college that administers a course in the specialization, another course may be substituted for that course. Before a student requests a substitution, the student should consult with his or her academic adviser to ensure that the substitution will not adversely affect the requirements for his or her degree program.

Upon completion of the requirements for the Specialization in Environmental Studies, the student should contact the Dean of the College of Natural Science and request certification for the completion of the specialization. After the certification is approved by the Dean of the College of Natural Science, the Office of the Registrar will enter on the student's academic record the name of the specialization and the date that it was completed. This certification will appear on the student's transcript.

ECOLOGY, EVOLUTIONARY BIOLOGY AND BEHAVIOR

The interdepartmental graduate Specialization in Ecology, Evolutionary Biology and Behavior is available for students who are enrolled in master's degree programs in the departments of Anthropology, Crop and Soil Sciences, Entomology, Fisheries and Wildlife, Forestry, Geological Sciences, Horticulture, Microbi-

ology and Molecular Genetics, Philosophy, Plant Biology, Psychology, and Zoology. The College of Natural Science administers the specialization.

The interdepartmental graduate Specialization in Ecology, Evolutionary Biology and Behavior is designed to:

1. Provide an opportunity for master's students to obtain a comprehensive and contemporary academic experience in the field of ecology, evolutionary biology and behavior.
2. Help graduate students with an interest in ecology, evolutionary biology and behavior to become sensitive to their professional obligations and responsibilities.
3. Develop an intellectual environment which will foster the growth of research and teaching in the area of ecology, evolutionary biology and behavior.

A student who is enrolled in a master's degree program in one of the twelve participating departments and who wishes to complete the requirements for the interdepartmental Graduate Specialization in Ecology, Evolutionary Biology and Behavior should have a minimum grade-point average of 3.00 and have grades of 3.0 or higher in quantitative science courses.

Requirements for the Interdepartmental Graduate Specialization in Ecology, Evolutionary Biology and Behavior

During the first year of study toward a master's degree, the student and the major professor select a guidance committee that will assist in planning the student's program of study for both the degree and the specialization. At least one member of the student's guidance committee shall be a member of the Ecology, Evolutionary Biology and Behavior faculty.

The specialization consists of the completion of the ecology, evolutionary biology and behavior required core courses listed below. Credits that are used to meet the requirements for the specialization may also be counted toward the requirements for the student's major at the discretion of the department.

Required Core Courses

	CREDITS
BOT 849 Evolutionary Biology	3
One additional 800-level course in ecology offered by the College of Natural Science or the College of Agriculture and Natural Resources	3

Upon completion of the requirements for the degree program and of the interdepartmental Graduate Specialization in Ecology, Evolutionary Biology and Behavior, the student should contact the College of Natural Science and request certification for the completion of the specialization. After the certification is approved by the Dean of the College of Natural Science, the Office of the Registrar will enter on the student's academic record the name of the specialization and the date that it was completed. This certification will appear on the student's transcript.

GRADUATE SPECIALIZATION IN ENVIRONMENTAL TOXICOLOGY

The College of Natural Science, the College of Agriculture and Natural Resources, the College of Engineering, and the College of Veterinary Medicine administer the Graduate Specialization in Environmental Toxicology. The College of Agriculture and Natural Resources is the primary administrative unit. For additional information, refer to the *Graduate Specialization in Environmental Toxicology* statement in the *College of Agriculture and Natural Resources* section of this catalog.

LYMAN BRIGGS SCHOOL

Diane Ebert-May, Director

Lyman Briggs School is a residential school within the College of Natural Science. The program in Lyman Briggs is designed to provide students with a sound education in the fundamentals of mathematics and the basic sciences. Additionally, the core program addresses some of the societal, historical, and philosophical concerns and consequences of modern science and technology. Advanced undergraduate courses are usually taken in the respective departmental units of the College of Natural Science and the University at large. A sizable number of Lyman Briggs students pursue programs leading to employment or graduate study in the natural sciences. Many others pursue preengineering programs or preprofessional programs related to medicine, dentistry, optometry, or law. Still others plan to enter careers in teaching at the secondary level, science writing, or government service.

Lyman Briggs is a residential program, with its classrooms, laboratories, and faculty and administrative offices located in Holmes Hall, the largest residence hall at MSU. Because of this residential organization, it offers students a sense of identification with and belonging to a well-defined intellectual and social community, with numerous opportunities for involvement in its many activities. These opportunities include the development of extensive personal contacts between faculty, staff, and students; individual and readily available advising; and a generally reassuring environment in which many students find support in achieving academic success and satisfaction. The school and its students also organize a number of social, preprofessional, and cultural activities during the year.

Students admitted to Michigan State University are also admissible to Lyman Briggs School. There are no additional requirements; however, it is advisable that, of the sixteen units of high school work required, a minimum of three units be in mathematics and two units be in the natural sciences.

Enrollments in the school are limited, and students are encouraged to apply early. Prospective new freshman and transfer students should notify the University's Office of Admissions and Scholarships as early as possible of their desire to enroll in the school. Currently enrolled Michigan State University students may also be eligible to transfer into the school.

Normally Lyman Briggs School students fulfill the school's core requirements in biology, chemistry, computers, mathematics, physics, and writing by enrolling in the school's courses in these areas. However, one or more of these requirements may be satisfied by completing approved courses elsewhere in the College or University.

Students who are enrolled in the environmental biology/microbiology and microbiology coordinate majors in Lyman Briggs School may elect the Specialization in Food Processing and Technology. For additional information, refer to the *Specialization in Food Processing and Technology* statement in the *Department of Food Science and Human Nutrition* statement in the *College of Agriculture and Natural Resources* section of this catalog.

Transfer Students

All students in good academic standing in Lyman Briggs School may transfer at any time to other programs at Michigan State University for which they are eligible, in order to accommodate changing academic needs and interests.

Students who wish to transfer into Lyman Briggs School should call (517) 353-6482 or go to E-30 Holmes Hall to make an appointment to consult with the Assistant to the Director.

UNDERGRADUATE PROGRAM

The Lyman Briggs School program leads to the Bachelor of Science Degree.

Requirements for the Bachelor of Science Degree in Lyman Briggs School

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this University catalog; 120 credits, including general elective credits, are required for the Bachelor of Science degree in Lyman Briggs School.

Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below are equivalent to courses in the alternative track and, therefore, may be used to satisfy the alternative track.

The completion of the Lyman Briggs School mathematics and statistics requirement [referenced in item 3.c.(4) below] may also satisfy the University mathematics requirement.

The completion of Lyman Briggs School 133 or one of the approved alternatives [referenced in requirement 3.c.(6)(a) below] may also be counted toward the University Tier I writing requirement.

The University's Tier II writing requirement for the Fields of Concentration (majors) and Coordinate Majors in Lyman Briggs School is met by completing Lyman Briggs School 492 and one of the following courses: English 483; History 425; Lyman Briggs School 332, 333, 334, 335, 336, 355. Those courses are referenced in items 3. a. (6) and 3. a. (7) below.

2. The requirements of the College of Natural Science for the Bachelor of Science degree.
The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
3. The following requirements of Lyman Briggs School for the Bachelor of Science degree:

	CREDITS
a. CORE PROGRAM	46 to 58
(1) Biology: One of the following groups of courses (8 to 10 credits):	
(a) Lyman Briggs School 144, 145.	
(b) Lyman Briggs School 148H, 149H, 158H, 159H.	
(c) Biological Science 110, 111, 111L.	
(2) Chemistry: One of the following groups of courses (8 to 10 credits):	
(a) Lyman Briggs School 165, 165L, 266, 266L.	
(b) Lyman Briggs School 165, 165L; Chemistry 143	
(c) Lyman Briggs School 165, 165L; Chemistry 251.	
(d) Chemistry 141, 142, 161.	
(e) Chemistry 141, 143, 161.	
(f) Chemistry 141, 161, 251.	
(g) Chemistry 151, 152, 161.	
(h) Chemistry 181H, 182H, 185H.	
(3) Computer Science: One of the following courses: Lyman Briggs School 125, 126, 127; Computer Science and Engineering 101, 131, 230 (3 credits). Students who pass a waiver examination for Computer Science and Engineering 101 will not be required to complete one of the following courses: Lyman Briggs School 125, 126, 127; Computer Science and Engineering 101, 131, 230.	
(4) Mathematics and Statistics: One of the following groups of courses (6 to 11 credits):	
(a) Lyman Briggs School 118, 119.	
(b) Lyman Briggs School 118; Statistics and Probability 231.	
(c) Mathematics 132, 133, 234.	
(d) Mathematics 132, 133; Statistics and Probability 231.	
(e) Mathematics 152H, 153H.	
(5) Physics: One of the following groups of courses (6 to 8 credits):	
(a) Lyman Briggs School 164, 164L, 267, 267L.	
(b) Physics 231, 232, 251, 252.	
(c) Physics 183, 184.	
(d) Physics 181B, 182B, 251, 252.	
(e) Physics 231B, 232B, 251, 252.	
(f) Physics 183B, 184B.	
(g) Physics 193H, 294H.	
(6) Science and Technology Studies: A total of 11 or 12 credits from the courses in groups (a), (b), and (c) below. In addition to completing one course from each of the three groups, the student must complete one of the following courses from group (b) or group (c): English 483; History 425; Lyman Briggs School 332, 333, 334, 335, 336, 355.	

NATURAL SCIENCE
Lyman Briggs School

- (a) One of the following courses: Lyman Briggs School 133; American Thought and Language 110, 115, 120, 125, 130, 135, 140, 145, 150, 195H.
- (b) One of the following courses: Lyman Briggs School 331, 332, 333, 334, 335, 336, 355.
- (c) One of the following courses: Lyman Briggs School 330, 331, 332, 333, 334, 335, 336, 355, 490E; English 483; History 425.

Each of the following courses may be used to meet **either** requirement 3.a.(6)(b) or requirement 3.a.(6)(c), but not both of those requirements: Lyman Briggs School 331, 332, 333, 334, 335, 355.

(7) **Senior Seminar:** Lyman Briggs School 492 (4 credits).

b. FIELD OF CONCENTRATION or COORDINATE MAJOR.

Each student must complete the requirements of a Field of Concentration or a Coordinate Major. The Field or Major must be chosen from the lists of options below. **Both** the Field or Major *and* the related courses must be approved by the student's academic adviser. With the approval of the appropriate Lyman Briggs School Curriculum Coordinator or Undergraduate Director, courses other than those that are listed as requirements for a Field or Major may be used to satisfy degree requirements.

Fields of Concentration:

- Biology
- Computer Science
- Earth Science
- Environmental Science and Management
- Physical Science
- Science and Technology Studies

Coordinate Majors:

- (1) College of Natural Science:
 - (a) Astrophysics
 - Biochemistry
 - Biochemistry/Biotechnology
 - Biological Science—Interdepartmental
 - Chemical Physics
 - Chemistry
 - Computational Chemistry
 - Computational Mathematics
 - Earth Science—Interdepartmental
 - Entomology
 - Environmental Biology/Microbiology
 - Environmental Biology/Plant Biology
 - Environmental Biology/Zoology
 - Environmental Geosciences
 - Geological Sciences
 - Human Biology
 - Mathematics
 - Medical Technology
 - Microbiology
 - Physical Science—Interdepartmental
 - Physics
 - Physiology
 - Plant Biology
 - Statistics
 - Zoology
- (2) College of Engineering:
 - (a) Computer Science
 - Students are admitted to this Coordinate Major after they have reached junior standing and have met certain other requirements specified by Lyman Briggs School.

Fields of Concentration

	CREDITS
1. Biology	30
a. A minimum of 30 credits from the courses listed below including:	
(1) All of the following courses (18 credits):	
BMB 461 Biochemistry I	3
BMB 462 Biochemistry II	3
MMG 301 Introductory Microbiology	3
MMG 302 Introductory Microbiology Laboratory	1
ZOL 341 Fundamental Genetics	4
ZOL 355 Ecology	3
ZOL 355L Ecology Laboratory	1
(2) One of the following groups of courses (6 credits):	
(a) BOT 414 Plant Physiology: Metabolism	3
BOT 415 Plant Physiology: Growth, Development and the Environment	3
(b) PSL 431 Human Physiology I	3
PSL 432 Human Physiology II	3
(3) One course from group (a) and one course from group (b) below (6 to 8 credits):	
(a) Organismal and Population Biology	
(i) Students who complete Physiology 431 and 432 to satisfy requirement 1.a.(2) above must complete one of the following courses:	
BOT 418 Plant Systematics	3
BOT 423 Wetland Plants and Algae	4
BOT 434 Plant Structure and Function	4
BOT 441 Plant Ecology	3
ENT 404 Insects: Success in Biodiversity	4

- (ii) Students who complete Botany 414 and 415 to satisfy requirement 1.a.(2) above must complete one of the following courses:
 - ZOL 306 Invertebrate Biology
 - ZOL 328 Comparative Anatomy and Biology Of Vertebrates
 - ZOL 353 Marine Biology
 - ZOL 431 Comparative Limnology
 - ZOL 445 Evolution
- (b) Cellular, Molecular, and Developmental Biology
 - BOT 416 Experiments in Plant Physiology and Molecular Biology
 - LBS 347 Advances in Applied Biology
 - MMG 409 Eukaryotic Cell Biology
 - MMG 413 Virology
 - MMG 421 Prokaryotic Cell Physiology
 - MMG 431 Microbial Genetics
 - MMG 451 Immunology
 - ZOL 320 Developmental Biology
 - ZOL 421 Hormones and Development

2. Computer Science

- a. A minimum of 33 credits from the courses listed below including:
 - (1) All of the following courses (27 credits):
 - CSE 230 Algorithms and Computing
 - CSE 260 Discrete Structures in Computer Science
 - CSE 320 Computer Organization and Assembly Language Programming
 - CSE 330 Data Structures and Programming Concepts
 - CSE 360 Automata and Formal Language Theory
 - CSE 410 Operating Systems
 - LBS 220 Calculus III
 - (2) At least two of the following courses (6 to 8 credits):
 - CSE 420 Computer Architecture
 - CSE 422 Computer Networks
 - CSE 440 Artificial Intelligence and Symbolic Programming
 - CSE 450 Translation of Programming Languages
 - CSE 452 Organization of Programming Languages
 - CSE 470 Software Engineering
 - CSE 472 Computer Graphics
 - CSE 474 Vector and Parallel Programming
 - CSE 480 Database Systems

3. Earth Science

- a. A minimum of 27 credits from the courses listed below including:
 - (1) At least 14 credits in courses at the 300–400 level.
 - (2) At least 8 credits in earth science courses outside the Department of Geological Sciences.
 - (3) At least *one* course in **each** of the following 5 earth science areas (15 to 22 credits):
 - (a) Astronomy and Astrophysics
 - AST 201 Astrophysics and Astronomy I
 - AST 202 Astrophysics and Astronomy II
 - (b) Geology of the Solid Earth
 - GLG 201 The Dynamic Earth
 - GLG 321 Mineralogy and Geochemistry
 - GLG 351 Structural Geology
 - GLG 361 Petrology (W)
 - GLG 371 Plate Tectonics (W)
 - GLG 481 Reservoirs and Aquifers
 - GLG 491 Field Geology – Summer Camp (W)
 - (c) Paleobiology
 - BOT 335 Plants Through Time
 - GLG 331 Vertebrate Life of the Past
 - GLG 431 Sedimentology and Stratigraphy (W)
 - GLG 433 Vertebrate Paleontology
 - GLG 434 Evolutionary Paleobiology
 - (d) Environmental Geosciences and Meteorology
 - GEO 203 Introduction to Meteorology
 - GEO 401 Geography of Plants of North America
 - GEO 402 Agricultural Climatology
 - GEO 404 Synoptic Climatology
 - GEO 405 Applied Synoptic Climatology: Principles and Methods
 - GLG 421 Environmental Geochemistry
 - GLG 422 Organic Geochemistry (W)
 - GLG 423 Environmental Geosciences
 - (e) Geomorphology
 - CSS 470 Soil Resources
 - GEO 406 Environmental Geomorphology
 - GEO 407 Regional Geomorphology of the United States
 - GEO 408 Soil Geomorphology Field Study

4. Environmental Sciences and Management

- a. A minimum of 41 credits from the courses listed below including:
 - (1) One of the following **groups** of courses (8 or 10 credits):
 - (a) LBS 118 Calculus I
 - STT 231 Statistics for Scientists

- | | | | |
|-----|---|--|---|
| (b) | MTH 132 | Calculus I | 3 |
| | MTH 133 | Calculus II | 4 |
| | STT 231 | Statistics for Scientists | 3 |
| (2) | One course from each of the following 7 areas
(24 to 26 credits): | | |
| (a) | Ecology: | | |
| | ZOL 355 | Ecology | 3 |
| | ZOL 355L | Ecology Laboratory | 1 |
| (b) | Geology: | | |
| | GLG 201 | The Dynamic Earth | 4 |
| (c) | Taxonomy or Phylogenetic Biology: | | |
| | BOT 418 | Plant Systematics | 3 |
| | ENT 404 | Insects: Success in Biodiversity | 4 |
| | ZOL 306 | Invertebrate Biology | 4 |
| (d) | Biochemistry: | | |
| | BMB 401 | Basic Biochemistry | 4 |
| (e) | Aquatic Systems: | | |
| | BOT 423 | Wetland Plants and Algae | 4 |
| | FW 420 | Stream Ecology | 3 |
| | ZOL 431 | Comparative Limnology | 4 |
| (f) | Microbiology: | | |
| | MMG 301 | Introductory Microbiology | 3 |
| (g) | Economics: | | |
| | EC 201 | Introduction to Microeconomics | 3 |
| (3) | One course from each of the following three groups
(9 to 11 credits): | | |
| (a) | FOR 464 | Natural Resource Economics
and Social Science (W) | 3 |
| | SOC 452 | Environment and Society | 3 |
| (b) | FW 424 | Population Analysis
and Management | 4 |
| | FW 444 | Conservation Biology | 3 |
| (c) | FW 410 | Upland Ecosystem Management | 3 |
| | FW 412 | Wetland Ecosystem Management | 3 |
| | Students who elect Sociology 452L must also complete
Sociology 452L to meet requirement 4. a. (3) (a). | | |
| 5. | Physical Science 32 | | |
| a. | A minimum of 32 credits from the courses listed below including: | | |
| (1) | The following course: | | |
| | LBS 220 | Calculus III | 5 |
| (2) | At least 27 credits in chemistry courses, in physics courses,
or in chemistry and physics courses approved by the stu-
dent's academic adviser. At least 20 of the 27 credits must
be in courses at the 300 level or above, and at least 14 of the
27 credits must be in either chemistry courses or physics
courses and must meet the conditions specified below: | | |
| | For students who elect to complete at least 14 credits
in chemistry courses , at least 4 of the 14 credits must be
laboratory credits at the 300–400 level. | | |
| | For students who elect to complete at least 14 credits
in physics courses , at least 6 of the 14 credits must be in
modern physics, and at least 3 of the 14 credits must be lab-
oratory credits. | | |
| 6. | Science and Technology Studies 24 | | |
| a. | A minimum of 24 credits in 300–400 level science and technology
studies courses approved by the student's academic adviser.
Courses in the Lyman Briggs School CORE PROGRAM and
Lyman Briggs School 492 may not be used to satisfy this require-
ment. Courses outside Lyman Briggs School may be used to sat-
isfy this requirement. | | |

DEPARTMENT OF BIOCHEMISTRY and MOLECULAR BIOLOGY

William L. Smith, Chairperson

The Department of Biochemistry and Molecular Biology is administered jointly by the colleges of Natural Science, Human Medicine, and Osteopathic Medicine.

Biochemistry is the discipline that studies the chemistry of living matter. In addition to defining the chemical nature of the molecules of life, biochemists seek to understand the processes involved in their formation and degradation and how these processes are regulated. Such knowledge is a prerequisite for understanding normal biological functions and for adapting or modifying them for useful purposes. It is also fundamental to understanding abnormal functions that underlie biochemical disorders, ultimately leading to their treatment. Thus, biochemistry is a

field with significance and applications across the biological spectrum, from the microbial through the plant and animal kingdoms. The potential significance of new discoveries in biochemistry, coupled with the rapid pace of conceptual and methodological advances in the field, make modern biochemistry a most exciting area for study and research.

The Department of Biochemistry and Molecular Biology offers a program leading to the Bachelor of Science degree. The undergraduate program coexists with an extensive graduate program for students seeking the M.S. or Ph.D. degrees. Both undergraduate and graduate students have ready access to a large and diverse faculty representing expertise in the various areas of modern biochemistry.

Biochemists have many types of career opportunities open to them. These opportunities include research in industrial, academic, or government laboratories; teaching at the high school or higher levels; and marketing, management, or administrative responsibilities in enterprises where training in biochemistry is an asset.

UNDERGRADUATE PROGRAMS

BIOCHEMISTRY and MOLECULAR BIOLOGY

Bachelor of Science

The Bachelor of Science program in Biochemistry and Molecular Biology for students in the College of Natural Science combines the elements of a liberal education with thorough preparation in biochemistry and the underlying principles of biology, chemistry, physics, and mathematics. It is intended primarily for those students who wish to pursue a career in which a sound knowledge of biochemistry is necessary, or for students who plan further studies at the graduate or professional level. With suitable choice of electives, the B.S. program offers the option of merging rigorous training in biochemistry with development of writing or pedagogical skills, leading to career options in science writing or teaching.

Undergraduate students are taught by professors who are familiar with the changing directions and emphases in the field of biochemistry. Each student has as an academic adviser a professional biochemist who is aware of current problems and opportunities in the field. In addition, a departmental undergraduate student affairs office is available to provide students with up-to-date information on University curriculum changes, career opportunities, and program development. Interested undergraduates are encouraged to participate, along with graduate students and postdoctoral fellows, in the on-going research of one of the faculty members.

Students seeking admission to the program should complete the high school science or college preparatory curriculum, ensuring that their programs include courses required for admission to the University.

Requirements for the Bachelor of Science Degree in Biochemistry and Molecular Biology

- The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Science degree in Biochemistry and Molecular Biology.

The University's Tier II writing requirement for the Biochemistry major is met by completing Biochemistry and Molecular Biology 471. That course is referenced in item 3. c. (2) below.

Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.

NATURAL SCIENCE
Biochemistry and Molecular Biology

- The requirements of the College of Natural Science for the Bachelor of Science degree.
 The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
- The following requirements for the major:

	CREDITS
a. Competency in a foreign language equivalent to the completion of two 100-level courses at Michigan State University	0 to 8
b. The following courses outside the Department of Biochemistry:	62 to 65
(1) All of the following courses (34 credits):	
BS 110 Organisms and Populations	4
BS 111 Cells and Molecules	3
BS 111L Cell and Molecular Biology Laboratory	2
CEM 161 Chemistry Laboratory I	1
CEM 162 Chemistry Laboratory II	1
CEM 262 Quantitative Analysis	2
CEM 355 Organic Laboratory I	2
CEM 356 Organic Laboratory II	2
CSE 101 Computing Concepts and Competencies	3
MTH 132 Calculus I	3
MTH 133 Calculus II	4
Seven additional credits in biology courses at the 300–400 level.	
(2) One of the following pairs of courses (7 or 8 credits):	
(a) CEM 141 General Chemistry	4
CEM 142 General and Inorganic Chemistry	3
(b) CEM 151 General and Descriptive Chemistry	4
CEM 152 Principles of Chemistry	3
(c) CEM 181H Honors Chemistry I	4
CEM 182H Honors Chemistry II	4
(3) One of the following pairs of courses (6 credits):	
(a) CEM 251 Organic Chemistry I	3
CEM 252 Organic Chemistry II	3
(b) CEM 351 Organic Chemistry I	3
CEM 352 Organic Chemistry II	3
(4) One of the following courses (3 credits):	
CEM 333 Instrumental Methods	3
CEM 372 Analytical–Physical Chemistry Laboratory I	3
(5) One of the following pairs of courses (6 credits):	
(a) CEM 361 Analytical–Physical Chemistry I	3
CEM 362 Analytical–Physical Chemistry II	3
(b) CEM 383 Introductory Physical Chemistry I	3
CEM 384 Introductory Physical Chemistry II	3
(6) One of the following courses (3 or 4 credits):	
PHY 181B Basic Physics I, CBI	3
PHY 183 Physics for Scientists and Engineers I	4
(7) One of the following courses (3 or 4 credits):	
PHY 182B Basic Physics II, CBI	3
PHY 184 Physics for Scientists and Engineers II	4
c. The following courses in the Department of Biochemistry and Molecular Biology:	15
(1) One of the following courses:	1
BMB 100 Current Issues in Biochemistry	1
BMB 101 Frontiers in Biochemistry	1
(2) All of the following courses:	
BMB 461 Biochemistry I	3
BMB 462 Biochemistry II	3
BMB 471 Biochemistry Laboratory (W)	3
BMB 472 Biochemistry Laboratory	3
BMB 495 Undergraduate Seminar	2
The completion of Biochemistry and Molecular Biology 495 fulfills the department's capstone course requirement.	

BIOCHEMISTRY and MOLECULAR BIOLOGY/ BIOTECHNOLOGY

Bachelor of Science

The Bachelor of Science program in Biochemistry and Molecular Biology/Biotechnology is intended primarily for those students who plan to pursue careers in industry, veterinary medicine, or related health sciences, or for students who plan advanced study in biotechnology and molecular biology.

Students in the Biochemistry and Molecular Biology/Biotechnology program may study the biochemistry and molecular genetics of plants and animals; the metabolism and toxicology of pesticides, food additives, and other compounds in the food chain; and the development of new biotechnologies. Students must complete the requirements for one of the following three emphasis areas: plant and animal sciences, microbiology, or processing.

Requirements for the Bachelor of Science Degree in Biochemistry and Molecular Biology/Biotechnology

- The University requirements for bachelor's degrees as described in the Undergraduate Education section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Science degree in Biochemistry and Molecular Biology/Biotechnology.
 The University's Tier II writing requirement for the Biochemistry and Molecular Biology/Biotechnology major is met by completing Biochemistry and Molecular Biology 471. That course is referenced in item 3 b. below.
 Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
- The requirements of the College of Natural Science for the Bachelor of Science degree.
 The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.

	CREDITS
3. The following requirements for the major:	
a. Competency in a foreign language equivalent to the completion of two 100-level courses at Michigan State University	0 to 8
b. All of the following courses:	68
BMB 461 Biochemistry I	3
BMB 462 Biochemistry II	3
BMB 471 Biochemistry Laboratory (W)	3
BMB 495 Undergraduate Seminar	2
BS 110 Organisms and Populations	4
BS 111 Cells and Molecules	3
BS 111L Cell and Molecular Biology Laboratory	2
CEM 151 General and Descriptive Chemistry	4
CEM 152 Principles of Chemistry	3
CEM 161 Chemistry Laboratory I	1
CEM 162 Chemistry Laboratory II	1
CEM 262 Quantitative Analysis	2
CEM 351 Organic Chemistry I	3
CEM 352 Organic Chemistry II	3
CEM 355 Organic Laboratory I	2
CEM 356 Organic Laboratory II	2
CEM 383 Introductory Physical Chemistry I	3
CHE 201 Material and Energy Balances	3
CSE 101 Computing Concepts and Competencies	3
MMG 445 Basic Biotechnology	3
MTH 132 Calculus I	3
MTH 133 Calculus II	4
PHY 183 Physics for Scientists and Engineers I	4
PHY 184 Physics for Scientists and Engineers II	4
c. One of the following courses:	1
BMB 100 Current Issues in Biochemistry	1
BMB 101 Frontiers in Biochemistry	1
d. One of the following courses:	3 or 4
BMB 472 Biochemistry Laboratory	3
BOT 416 Experiments in Plant Physiology and Molecular Biology	4
CSS 451 Cellular and Molecular Principles and Techniques for Plant Sciences	4
MMG 408 Advanced Microbiology Laboratory	3
e. One of the following courses:	3 or 4
CSS 350 Introduction to Plant Genetics	3
ZOL 341 Fundamental Genetics	4
f. At least 8 credits from the following emphasis areas, at least 6 credits of which must be in one of the areas:	8
(1) Microbiology:	
FSC 440 Food Microbiology	3
FSC 441 Food Microbiology Laboratory	1
MMG 301 Introductory Microbiology	3
MMG 302 Introductory Microbiology Laboratory	1
MMG 421 Prokaryotic Cell Physiology	3
MMG 431 Microbial Genetics	3
(2) Plant and Animal Sciences:	
ANS 407 Food and Animal Toxicology	3
ANS 407L Toxicology Methods Laboratory	2
BOT 336 Useful Plants	3
BOT 405 Introductory Plant Pathology	4
BOT 415 Plant Physiology: Growth, Development and the Environment	3
CSS 441 Plant Breeding and Biotechnology	4
FOR 422 Woody Plant Genetics	3
HRT 486 Biotechnology in Agriculture: Applications and Ethical Issues	3
ZOL 342 Advanced Genetics	3
ZOL 343 Genetics Laboratory	2
(3) Processing:	
ANS 407 Food and Animal Toxicology	3
ANS 407L Toxicology Methods Laboratory	2
ENT 442 Concepts of Biological Information Systems	3
FE 329 Fundamentals of Food Engineering	3

FSC 440	Food Microbiology.....	3
FSC 441	Food Microbiology Laboratory.....	1

GRADUATE STUDY

The Department of Biochemistry and Molecular Biology is administered jointly by the colleges of Natural Science, Human Medicine, and Osteopathic Medicine. Study for the Master of Science or Doctor of Philosophy degree with a major in biochemistry and molecular biology may be administered by any one of the three colleges referenced above. Study for the Doctor of Philosophy degree with a major in biochemistry and molecular biology—environmental toxicology is administered by the College of Natural Science.

Areas of active research in the department are extensive and diverse. Such areas include biochemical genetics, plant biochemistry, biochemistry of development, biochemical instrumentation, protein structure, cell biology, eukaryotic and prokaryotic molecular biology, intermediary metabolism and metabolic regulation, membrane biochemistry and signalling mechanisms, and mechanisms of enzyme catalysis. Opportunities are also available for joint programs or research in genetics, neuroscience, toxicology, biotechnology, microbial ecology, and plant sciences.

BIOCHEMISTRY and MOLECULAR BIOLOGY

The major objectives of the graduate programs in biochemistry are to help students to develop their creative potential and to prepare them for careers in research and teaching in the biochemical sciences. Students' programs of study are designed to develop independent thought as well as broad knowledge and technical skills, through formal and informal courses, laboratory experience, seminars, individual study, and, foremost, through original research that forms the basis for the student's thesis or dissertation.

Master of Science

In addition to meeting the requirements of the University and of the College of Natural Science, Human Medicine, or Osteopathic Medicine, students must meet the requirements specified below.

Admission

Persons with bachelor's degrees in chemistry, biochemistry, or any of several biological, physical, medical, or agricultural sciences are invited to apply for admission. Undergraduate preparation should include courses in general, organic, analytical, and physical chemistry, and in physics, general biology, basic biochemistry, and mathematics through calculus. Minor deficiencies may be rectified by taking appropriate undergraduate courses concurrently with graduate courses.

Requirements for the Master of Science Degree in Biochemistry and Molecular Biology

A total of 30 credits is required for the degree under either Plan A (with thesis) or Plan B (without thesis). Most students earn the degree under Plan A. A student may pursue Plan B only with the approval of the department's Director of Graduate Studies and chairperson. Such approval is granted only in exceptional cases. The program of study is planned by the student and the major professor. Specific courses in biochemistry, as well as courses in other areas considered relevant to the student's interests and chosen research area, are included in the program.

Doctor of Philosophy

In addition to meeting the requirements of the University and of the College of Natural Science, Human Medicine, or Osteopathic Medicine, students must meet the requirements specified below.

Admission

Persons with a bachelor's or master's degree in chemistry, biochemistry, or any of several biological, physical, medical, or agricultural sciences are invited to apply for admission. Undergraduate preparation should include courses in general, organic, analytical, and physical chemistry, and in physics, general biology, basic biochemistry, and mathematics through calculus. Minor deficiencies may be rectified by taking appropriate undergraduate collateral courses concurrently with graduate courses.

Requirements for the Doctor of Philosophy Degree in Biochemistry and Molecular Biology

The program of study is planned by the student in consultation with the major professor and a guidance committee. Specific courses in biochemistry, as well as courses in other areas considered relevant to the student's interests and chosen research area, are included in the program.

It is expected that the dissertation will show original treatment of an important research problem, will give evidence of independent thought, and will be clearly, logically, and carefully written. It is also expected that the research on which the dissertation is based will be published in the scientific literature.

BIOCHEMISTRY and MOLECULAR BIOLOGY —ENVIRONMENTAL TOXICOLOGY

Doctor of Philosophy

For information about the Doctor of Philosophy degree program in biochemistry and molecular biology—environmental toxicology, refer to the statement on *Multidepartmental Doctoral Programs in Environmental Toxicology* in the *Graduate Education* section of this catalog.

DEPARTMENT of CHEMISTRY

Katherine C. Hunt, Chairperson

Chemistry is the science concerned with substances—their properties, composition and reactions. Four principal areas may be defined: analytical, inorganic, organic and physical chemistry. Chemists are employed in such diverse industries as rubber, leather, dye, explosives, drugs, plastics, adhesives, paint, metals, glass, cement, insecticides, textiles, petroleum, soap, paper, semi-conductors and cosmetics. Synthesis of new organic and inorganic chemicals is of basic importance to all chemistry. Sales of most drug and plastic companies, for example, are concentrated in substances unknown ten years ago. The development of adequate methods for analysis of these new materials requires constant research on instrumental and chemical methods of analysis. An understanding of the rates and equilibria of chemical reactions, thermodynamics and molecular structure is essential for the development of new fuels and new industrial processes as

well as for the understanding of many phenomena in nature. Every educated person should have some knowledge of chemistry, and many interesting and rewarding careers require varying amounts of training in this field.

UNDERGRADUATE PROGRAMS

CHEMISTRY

Bachelor of Science

The degree Bachelor of Science with a major in chemistry is designed to provide a thorough foundation in the various fields of chemistry and the related sciences, as well as a proper educational balance in the liberal arts. The program is for students planning careers in the chemical industries or in governmental laboratories and for those planning graduate study in chemistry. The Bachelor of Science degree program in chemistry has been accredited by the American Chemical Society.

The completion of one or more semesters of independent research (Chemistry 400H or 420) is strongly recommended for students in this program.

A detailed description of this program may be obtained from the department.

Requirements for the Bachelor of Science Degree in Chemistry

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Science degree in Chemistry.

The University's Tier II writing requirement for the Chemistry major is met by completing Chemistry 355, 395, 415, and 435. Those courses are referenced in items 3. c. (3) and 3. c. (4) below.

Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.

2. The requirements of the College of Natural Science for the Bachelor of Science degree.

The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.

For students who were admitted to Michigan State University as new freshmen and new transfer students prior to Fall 1993, the completion of the foreign language requirement referenced in item 3. below also satisfies the College foreign language requirement.

3. The following requirements for the major:

CREDITS

- a. First-year competency in a foreign language selected from a list approved by the Department of Chemistry (0 to 8 credits).
- b. The following courses outside the Department of Chemistry: 30 to 32
 - (1) One of the following courses (3 or 4 credits):
 - BOT 105 Plant Biology 3
 - BS 110 Organisms and Populations 4
 - BS 111 Cells and Molecules 3
 - ENT 205 Pests, Society and Environment 3
 - MMG 205 Allied Health Microbiology 3
 - PSL 250 Introductory Physiology 4
 - ZOL 141 Introductory Human Genetics 3
 - (2) All of the following courses (24 credits):
 - MTH 132 Calculus I 3
 - MTH 133 Calculus II 4
 - MTH 234 Multivariable Calculus I 4
 - MTH 235 Multivariable Calculus II and Differential Equations 3
 - PHY 183 Physics for Scientists and Engineers I 4
 - PHY 184 Physics for Scientists and Engineers II 4
 - PHY 191 Physics Laboratory for Scientists, I 1
 - PHY 192 Physics Laboratory for Scientists, II 1
 - (3) One of the following courses (4 or 6 credits):
 - BMB 401 Basic Biochemistry 4
 - Or
 - BMB 461 Biochemistry I 3
 - And
 - BMB 462 Biochemistry II 3
- c. The following courses in the Department of Chemistry: 43 or 44
 - (1) One of the following pairs of courses (7 or 8 credits):

- (a) CEM 151 General and Descriptive Chemistry 4
- CEM 152 Principles of Chemistry 3
- (b) CEM 181H Honors Chemistry I 4
- CEM 182H Honors Chemistry II 4
- (2) One of the following pairs of courses (4 credits):
 - (a) CEM 162 Chemistry Laboratory II 1
 - CEM 262 Quantitative Analysis 3
 - (b) CEM 185H Honors Chemistry Laboratory I 2
 - CEM 186H Honors Chemistry Laboratory II 2
- (3) All of the following courses (29 credits):
 - CEM 351 Organic Chemistry I 3
 - CEM 352 Organic Chemistry II 3
 - CEM 355 Organic Laboratory I 2
 - CEM 356 Organic Laboratory II 2
 - CEM 391 Molecular Thermodynamics 3
 - CEM 392 Quantum Chemistry 3
 - CEM 395 Analytical/Physical Chemistry 2
 - CEM 411 Inorganic Chemistry 4
 - CEM 434 Advanced Analytical Chemistry 3
 - CEM 435 Analytical Chemistry Laboratory 2
 - CEM 495 Molecular Spectroscopy 2
- (4) The following capstone course (3 credits):
 - CEM 415 Advanced Synthesis Laboratory 3

Bachelor of Arts

Many occupations require a moderate training in chemistry combined with training in one or more other areas. Accordingly, the Bachelor of Arts degree is intended for the students desiring a lesser degree of specialization than required for the Bachelor of Science degree. Students who desire chemistry as a major in the programs of premedicine, pre dentistry and prelaw, or as training for many professional or industrial positions, may elect this program. Ample opportunity in the choice of electives is provided for students who are planning to obtain positions such as the following: technical secretaries, technical librarians, technical sales personnel, chemical patent lawyers, and criminologists. Additional collateral work may be necessary if this program is presented for admission to a school of graduate studies. A more detailed statement may be obtained from the Department of Chemistry.

Requirements for the Bachelor of Arts Degree in Chemistry

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Arts degree in Chemistry.

The University's Tier II writing requirement for the Chemistry major is met by completing Chemistry 333 and 410. Those courses are referenced in items 3. c. (3) and 3. c. (4) below.

Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.

2. The requirements of the College of Natural Science for the Bachelor of Arts degree. The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.

For students who were admitted to Michigan State University as new freshmen and new transfer students prior to Fall 1993, the completion of the foreign language requirement referenced in item 3. below also satisfies the College foreign language requirement.

3. The following requirements for the major:

CREDITS

- a. First-year competency in a foreign language selected from a list approved by the Department of Chemistry (0 to 8 credits).
- b. The following courses outside the Department of Chemistry: 19 or 20
 - (1) One of the following courses (3 or 4 credits):
 - BOT 105 Plant Biology 3
 - BS 110 Organisms and Populations 4
 - BS 111 Cells and Molecules 3
 - ENT 205 Pests, Society and Environment 3
 - MMG 205 Allied Health Microbiology 3
 - PSL 250 Introductory Physiology 4
 - ZOL 141 Introductory Human Genetics 3
 - (2) All of the following courses (16 credits):
 - MTH 132 Calculus I 3
 - MTH 133 Calculus II 4
 - PHY 231 Introductory Physics I 3
 - PHY 232 Introductory Physics II 3
 - PHY 251 Introductory Physics Laboratory I 1
 - PHY 252 Introductory Physics Laboratory II 1
- c. The following courses in the Department of Chemistry: 35 or 36

- (1) One of the following pairs of courses (7 or 8 credits):
 - (a) CEM 141 General Chemistry 4
CEM 142 General and Inorganic Chemistry 3
 - (b) CEM 151 General and Descriptive Chemistry 4
CEM 152 Principles of Chemistry 3
 - (c) CEM 181H Honors Chemistry I 4
CEM 182H Honors Chemistry II 4
- (2) One of the following pairs of courses (4 credits):
 - (a) CEM 162 Chemistry Laboratory II 1
CEM 262 Quantitative Analysis 3
 - (b) CEM 185H Honors Chemistry Laboratory I 2
CEM 186H Honors Chemistry Laboratory II 2
- (3) All of the following courses (21 credits):
 - CEM 251 Organic Chemistry I 3
 - CEM 252 Organic Chemistry II 3
 - CEM 255 Organic Chemistry Laboratory 2
 - CEM 333 Instrumental Methods 3
 - CEM 383 Introductory Physical Chemistry I 3
 - CEM 384 Introductory Physical Chemistry II 3
 - CEM 411 Inorganic Chemistry 4
- (4) The following capstone course (3 credits):
 - CEM 410 Literature and Writing in Chemistry 3

- MTH 425 Complex Analysis 3
 - MTH 441 Ordinary Differential Equations 3
 - MTH 442 Partial Differential Equations 3
 - MTH 443 Boundary Value Problems for Engineers 3
 - MTH 451 Numerical Analysis I 3
- (4) One of the following pairs of courses (6 or 8 credits):
 - (a) PHY 183 Physics for Scientists and Engineers I 4
PHY 184 Physics for Scientists and Engineers II 4
 - (b) PHY 193H Honors Physics I—Mechanics 3
PHY 294H Honors Physics II—Electromagnetism 3
 - (5) One of the following courses (3 credits):
 - PHY 215 Thermodynamics and Modern Physics 3
 - PHY 410 Thermal and Statistical Physics 3
 - PHY 422 Classical Mechanics II 3
 - PHY 431 Optics 3
 - PHY 472 Quantum Physics II 3
 - PHY 482 Electricity and Magnetism II 3

c. The following courses in the Department of Chemistry: 30 to 33

- (1) One of the following pairs of courses (7 or 8 credits):
 - (a) CEM 151 General and Descriptive Chemistry 4
CEM 152 Principles of Chemistry 3
 - (b) CEM 181H Honors Chemistry I 4
CEM 182H Honors Chemistry II 4
- (2) One of the following pairs of courses (2 or 4 credits):
 - (a) CEM 161 Chemistry Laboratory I 1
CEM 162 Chemistry Laboratory II 1
 - (b) CEM 185H Honors Chemistry Laboratory I 2
CEM 186H Honors Chemistry Laboratory II 2
- (3) Six credits in organic chemistry courses other than Chemistry 143.
- (4) One of the following courses (3 credits):
 - CEM 333 Instrumental Methods 3
 - CEM 395 Analytical/Physical Laboratory 2
 - CEM 435 Analytical Chemistry Laboratory 2
 - CEM 495 Molecular Spectroscopy 2
- (5) Two of the following courses (6 credits):
 - CEM 391 Molecular Thermodynamics 3
 - CEM 392 Quantum Chemistry 3
 - CEM 434 Advanced Analytical Chemistry 3
- (6) Both of the following courses (6 credits):
 - CEM 411 Inorganic Chemistry 4
 - CEM 499 Chemical Physics Seminar 2
 The completion of Chemistry 499 fulfills the department's capstone course requirement.

CHEMICAL PHYSICS

Bachelor of Science

The major in Chemical Physics provides a strong foundation in chemistry, physics and mathematics for those students who have a professional interest in the areas of overlap between chemistry and physics. It is particularly suitable for students planning to pursue a graduate degree in the area of chemical physics.

A detailed description of this program may be obtained from either the Department of Physics and Astronomy or the Department of Chemistry.

Requirements for the Bachelor of Science Degree in Chemical Physics

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Science degree in Chemical Physics.

The University's Tier II writing requirement for the Chemical Physics major is met by completing Chemistry 499. That course is referenced in item 3. c. (6) below.

Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.

2. The requirements of the College of Natural Science for the Bachelor of Science degree.

The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.

For students who were admitted to Michigan State University as new freshmen and new transfer students prior to Fall 1993, the completion of the foreign language requirement referenced in item 3. below also satisfies the College foreign language requirement.

3. The following requirements for the major:

CREDITS

- a. First-year competency in a foreign language selected from a list approved by the Department of Chemistry (0 to 8 credits).
- b. The following courses outside the Department of Chemistry: 42 to 45
 - (1) One of the following courses (3 or 4 credits):
 - BOT 105 Plant Biology 3
 - BS 110 Organisms and Populations 4
 - BS 111 Cells and Molecules 3
 - ENT 205 Pests, Society and Environment 3
 - MMG 205 Allied Health Microbiology 3
 - PSL 250 Introductory Physiology 4
 - ZOL 141 Introductory Human Genetics 3
 - (2) All of the following courses (24 credits):
 - MTH 132 Calculus I 3
 - MTH 133 Calculus II 4
 - MTH 234 Multivariable Calculus 4
 - MTH 235 Differential Equations 3
 - PHY 191 Physics Laboratory for Scientists, I 1
 - PHY 192 Physics Laboratory for Scientists, II 1
 - PHY 321 Classical Mechanics I 3
 - PHY 471 Quantum Physics I 3
 - PHY 481 Electricity and Magnetism I 3
 - (3) Two of the following courses (6 credits):
 - MTH 310 Abstract Algebra I and Number Theory 3
 - MTH 314 Linear Algebra I 3
 - MTH 320 Analysis I 3
 - MTH 351 Elements of Numerical Analysis 3
 - MTH 421 Analysis II 3

COMPUTATIONAL CHEMISTRY

Bachelor of Science

The Bachelor of Science degree program with a major in computational chemistry is designed to provide a thorough foundation in the various fields of chemistry and the related sciences, as well as a proper educational balance in the liberal arts. In addition, it provides a means for chemistry majors with an interest in the application of computers and computing in chemistry to obtain expertise in computer fundamentals. The program is for students planning careers in the chemical industries or in governmental laboratories and for those planning graduate study in chemistry.

Requirements for the Bachelor of Science Degree in Computational Chemistry

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Science degree in Computational Chemistry.

The University's Tier II writing requirement for the Computational Chemistry major is met by completing Chemistry 355, 395, 435, and 481. Those courses are referenced in items 3. b. (3) and 3. b. (4) below.

Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.

2. The requirements of the College of Natural Science for the Bachelor of Science degree.

The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.

3. The following requirements for the major:

CREDITS

- a. The following courses outside the Department of Chemistry: 49 or 50
 - (1) One of the following courses (3 or 4 credits):

NATURAL SCIENCE
Department of Chemistry

BOT 105	Plant Biology	3
BS 110	Organisms and Populations	4
BS 111	Cells and Molecules	3
ENT 205	Pests, Society and Environment	3
MMG 205	Allied Health Microbiology	3
PSL 250	Introductory Physiology	4
ZOL 141	Introductory Human Genetics	3
(2)	All of the following courses (46 credits):	
CSE 231	Introduction to Programming I	4
CSE 232	Introduction to Programming II	4
CSE 260	Discrete Structures and Programming Concepts	4
CSE 320	Computer Organization and Assembly Language Programming	4
MTH 132	Calculus I	3
MTH 133	Calculus II	4
MTH 234	Multivariable Calculus	4
MTH 235	Differential Equations	3
MTH 314	Linear Algebra I	3
MTH 351	Elements of Numerical Analysis	3
PHY 183	Physics for Scientists and Engineers I	4
PHY 184	Physics for Scientists and Engineers II	4
PHY 191	Physics Laboratory for Scientists, I	1
PHY 192	Physics Laboratory for Scientists, II	1
b.	The following courses in the Department of Chemistry:	46 or 47
(1)	One of the following pairs of courses (7 or 8 credits):	
(a)	CEM 151 General and Descriptive Chemistry	4
	CEM 152 Principles of Chemistry	3
(b)	CEM 181H Honors Chemistry I	4
	CEM 182H Honors Chemistry II	4
(2)	One of the following pairs of courses (4 credits):	
(a)	CEM 162 Chemistry Laboratory II	1
	CEM 262 Quantitative Analysis	3
(b)	CEM 185H Honors Chemistry Laboratory I	2
	CEM 186H Honors Chemistry Laboratory II	2
(3)	All of the following courses (32 credits):	
CEM 351	Organic Chemistry I	3
CEM 352	Organic Chemistry II	3
CEM 355	Organic Laboratory I	2
CEM 391	Molecular Thermodynamics	3
CEM 392	Quantum Chemistry	3
CEM 395	Analytical/Physical Laboratory	2
CEM 411	Inorganic Chemistry	4
CEM 415	Advanced Synthesis Laboratory	3
CEM 434	Advanced Analytical Chemistry	3
CEM 435	Analytical Chemistry Laboratory	2
CEM 495	Molecular Spectroscopy	2
(4)	The following capstone course (3 credits):	
CEM 481	Seminar in Computational Chemistry	3

TEACHER CERTIFICATION OPTIONS

The chemistry disciplinary majors leading to the Bachelor of Arts and Bachelor of Science degrees are available for teacher certification.

A chemistry disciplinary minor is also available for teacher certification.

Students who elect a chemistry disciplinary major or the chemistry disciplinary minor must contact the Department of Chemistry.

For additional information, refer to the statement on *TEACHER CERTIFICATION* in the *Department of Teacher Education* section of this catalog.

GRADUATE STUDY

The Department of Chemistry offers the graduate degree programs that are listed below:

Master of Science

- Chemistry
- Computational Chemistry

Doctor of Philosophy

- Chemical Physics
- Chemistry
- Chemistry—Environmental Toxicology

Descriptions of the degree programs, organized by fields of study in alphabetical order, are presented below.

CHEMICAL PHYSICS

Doctor of Philosophy

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

Only those persons who are enrolled in a Doctor of Philosophy degree program in the Department of Chemistry or the Department of Physics and Astronomy at MSU may petition the Committee on Chemical Physics for admission to the doctoral program in chemical physics.

Requirements for the Doctor of Philosophy Degree in Chemical Physics

The student must:

1. Pass doctoral comprehensive examinations of the cumulative type. Details about these examinations may be obtained from the department.
2. Complete at least 6 credits in 800–900 level Chemistry courses.
3. Complete at least 6 credits in 800–900 level Physics and Astronomy courses.
4. Pass an oral examination on the proposed research.

CHEMISTRY

Master of Science

For the Master of Science program in chemistry, the areas of study are analytical, inorganic, organic, and physical.

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

The student must have a bachelor's degree and an acceptable grade–point average, and must have had in an undergraduate program one year each of general, analytical, organic, and physical chemistry, one year of physics, and one year of calculus. Deficiencies in the undergraduate program, such as deficiencies in calculus or in foreign language, must be removed before the degree will be recommended.

Requirements for the Master of Science Degree in Chemistry

A total of 30 credits are required for the program under either Plan A (with thesis) or Plan B (without thesis). Most students earn the degree under Plan A. For Plan A, students are required to complete 8 credits of master's thesis research and may be permitted to complete up to 15 credits of master's thesis research; approximately two-thirds of the remaining credits are in the major area and the balance is in other areas.

All entering graduate students must take an orientation examination in each of the four major areas of chemistry and must ultimately achieve at the doctoral qualifying level in one area (for students on Plan A, that area must be the one in which the research is to be performed), and at the minimum proficiency level established by the department in the other three areas.

The program is planned by the student and the major professor in accordance with the student's desire for earning only the master's degree or continuing on to the doctorate.

Doctor of Philosophy

Programs for the Doctor of Philosophy degree, based on a broad and thorough undergraduate program, emphasize study and original research in one of the following areas: analytical, inorganic, organic, or physical chemistry, or chemical physics. Numerous cross-disciplinary research opportunities involving, for example, biochemistry or the cyclotron laboratory, are also available.

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

Students holding bachelor's degrees, or master's degrees or the equivalent, may be admitted for study at the doctoral level on either a provisional or regular basis. Applicants are expected to have had in their undergraduate programs one year each of general, analytical, organic, and physical chemistry, one year of physics, and one year of calculus or their equivalents. Deficiencies in the undergraduate program must be removed. Admission to the doctoral program is dependent on having a 3.00 or better grade-point average and upon satisfactory performance on the qualification examinations given in the areas of analytical, inorganic, organic, and physical chemistry. The qualification examinations will be waived for students who score at the 75th percentile or higher on the Graduate Record Examination Subject Test in Chemistry.

Requirements for the Doctor of Philosophy Degree in Chemistry

Satisfactory performance on doctoral comprehensive examinations of the cumulative type is required. Details about these and the qualification examinations may be obtained from the department.

Satisfactory performance on two oral examinations, one to demonstrate research preparedness and the other as a defense of the dissertation, is required.

CHEMISTRY—ENVIRONMENTAL TOXICOLOGY

Doctor of Philosophy

For information about the Doctor of Philosophy degree program in chemistry—environmental toxicology, refer to the statement on *Multidepartmental Doctoral Programs in Environmental Toxicology* in the *Graduate Education* section of this catalog.

COMPUTATIONAL CHEMISTRY

Master of Science

The Master of Science with a major in Computational Chemistry is designed to prepare individuals to implement, manage, and support all aspects of the application of computers and computing in chemistry within academic, governmental, and industrial scientific settings. Graduates will also be equipped to serve as professional resources for visualization, modeling, and database activities.

Computers and computing have revolutionized the way chemistry is practiced in both academia and industry. Representative uses of computers and computing in both settings include: collecting, analyzing, and visualizing data in an experiment; devising mathematical models of chemical systems; simulating and interpreting the results of experiments using mathematical models; preparing reports and organizing information; communicating with colleagues via local networks and the Internet; calculating the properties of chemical systems using the laws of physics; and using sophisticated visualization techniques to interpret complex calculations. Each of these activities requires that students have a working understanding of computers and computing as well as of the underlying chemistry.

Students who want to enhance their managerial, leadership and business skills may elect an optional certification program in business management and communication offered by The Eli Broad College of Business and the College of Communication Arts and Sciences. This optional combination of technical and managerial skills will uniquely qualify these graduates to function as professionals in industrial, governmental, and academic settings.

Admission

To be admitted to this program, students must have earned a Bachelor of Science in Chemistry or its equivalent, and completed one year of physics, the equivalent of four semesters of calculus, and the equivalent of 16 credits in computer-science courses.

Promising students who do not possess an adequate background in computer science or mathematics will be required to complete approved undergraduate courses to remove these deficiencies. These courses may not count toward the master's degree.

In addition to meeting the University and College of Natural Science requirements, students must meet the requirements specified below.

Requirements for the Master of Science Degree in Computational Chemistry

This program is available only under Plan B (without thesis). The student's program of study must be approved by the academic adviser.

1. The student must complete the requirements specified below:
 - a. Entering graduate students must take a qualifying examination in analytical, inorganic, organic, and physical chemistry and must earn a qualifying grade in at least two areas. Students who do not earn at least two qualifying grades will be required to complete course work that may not count toward the degree.

Students who took the GRE Advanced Test in Chemistry, and scored at least at the 75 percentile, may request an exemption from the qualifying examination. Examination results will be used by the student's adviser to assist in developing the student's program of study.
 - b. A minimum of 30 credits.
 - c. At least eight of the following courses (minimum 22 credits):

BMB	461	Biochemistry I	3
CEM	481	Seminar in Computational Chemistry	1 to 6
CEM	811	Advanced Inorganic Chemistry	3
CEM	838	Computer-Based Scientific Instrumentation	3
CEM	881	Atomic and Molecular Structure	3
CEM	883	Computational Quantum Chemistry	3
CEM	890	Chemical Problems and Reports	3
CEM	924	Selected Topics in Analytical Chemistry	3
CEM	987	Selected Topics in Physical Chemistry I	1
CEM	988	Selected Topics in Physical Chemistry II	3
CEM	991	Quantum Chemistry and Statistical Thermodynamics I	3
 - d. Electives (a minimum of 8 credits): Courses in biochemistry, chemistry, computer science and engineering, or statistics.
 - e. Pass a certifying examination.
 - f. Complete an internship in a professional setting.

Optional Certificate

Concurrently, a student may choose to complete a Certificate in Basic Business and Communication Skills.

NATURAL SCIENCE
Department of Chemistry

The certificate program is organized as a series of weekend Workshops covering such topics as project management, business law, intellectual property, management theory, finance, writing skills, presentation skills, information retrieval, interpersonal skills and group work. The certificate program offered by the faculty of The Eli Broad College of Business and the College of Communication Arts and Sciences will include a case-study approach. It will normally be undertaken during the first year of enrollment and will involve an additional cost to the student beyond usual tuition and fees.

After the completion of the certificate program is approved by the Director of Executive Development Programs in The Eli Broad College of Business and by the Associate Dean of the College of Natural Science, the Office of the Registrar will enter on the student's academic record the name of the certificate program and the date it was completed. This certification will appear on the student's transcript upon completion of the requirements for the degree program.

DEPARTMENT of ENTOMOLOGY

Edward J. Grafius, Chairperson

The Department of Entomology is administered jointly by the College of Agriculture and Natural Resources and the College of Natural Science. The College of Agriculture and Natural Resources offers Master of Science and Doctor of Philosophy degree programs with majors in entomology and in entomology—urban studies. In addition, the College of Agriculture and Natural Resources offers a Doctor of Philosophy degree program with a major in entomology—environmental toxicology. For additional information about the department and its graduate degree programs, refer to the statement on the *Department of Entomology* in the *College of Agriculture and Natural Resources* section of this catalog.

DEPARTMENT of GEOLOGICAL SCIENCES

Michael A. Velbel, Chairperson

The Earth is a dynamic system subject to both cyclic and directional changes over time. Energy from the Sun drives the Earth's water and biogeochemical cycles which, in turn, control surface processes, including climate change and sedimentation. Energy from the Earth's interior drives the tectonic cycle and its surface manifestations, including volcanic eruptions and earthquakes. Biological evolution adds directionality to the history of the Earth, and is not reducible to simple physical forces. The geological sciences study these changes and processes as they exist now, as they will develop in the future, and as they have evolved during the 4.5 billion-year history of the Earth.

The biological, chemical, isotopic, and physical aspects of the Earth are all integrated into the geological sciences, which draw heavily on all of those other sciences, as well as mathematics and statistics. Geological studies provide knowledge concerning the availability of natural resources, including groundwater and fossil fuels; the reduction of damage from such hazards as landslides and earthquakes; and processes affecting biological evolution, such as those producing major extinctions. From these diverse studies geologists gain knowledge about the controls on the physical and biological environment. That knowledge allows peo-

ple to deal with issues ranging from groundwater pollution to climate change.

The undergraduate programs in environmental geosciences, geological sciences and geophysics lead to the Bachelor of Science degree. The department offers degree options for more specialized study in geophysics and secondary education.

UNDERGRADUATE PROGRAMS

ENVIRONMENTAL GEOSCIENCES

Requirements for the Bachelor of Science Degree in Environmental Geosciences

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Science degree in Environmental Geosciences.
 - The University's Tier II writing requirement for the Environmental Geosciences major is met by completing one of the following courses: Geological Sciences 361 or 431. Those courses are referenced in item 3. b. (1) below.
 - Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
2. The requirements of the College of Natural Science for the Bachelor of Science degree.
 - The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.

	CREDITS
3. The following requirements for the major:	69 or 70
a. The following courses outside the Department of Geological Sciences:	29 or 30
(1) All of the following courses (8 credits):	
CEM 161 Chemistry Laboratory I	1
MTH 132 Calculus I	3
MTH 133 Calculus II	4
(2) One of the following courses (3 credits):	
CE 421 Engineering Hydrology	3
CE 481 Environmental Engineering Chemistry	3
CEM 251 Organic Chemistry I	3
CSS 455 Pollutants in the Soil Environment	3
MMG 426 Biogeochemistry	3
Botany 335 and Microbiology and Molecular Genetics 426 may be used to satisfy <i>either</i> the requirements for the major or the requirements referenced under the heading <i>Graduation Requirements</i> in the College statement, but not both of those requirements.	
(3) One of the following courses (3 or 4 credits):	
MTH 234 Multivariable Calculus	4
One Statistics and Probability course	3 or 4
(4) One of the following pairs of courses (7 credits):	
(a) CEM 141 General Chemistry	4
CEM 142 General and Inorganic Chemistry	3
(b) CEM 151 General and Descriptive Chemistry	4
CEM 152 Principles of Chemistry	3
(5) One of the following groups of courses (8 credits):	
(a) PHY 231 Introductory Physics I	3
PHY 232 Introductory Physics II	3
PHY 251 Introductory Physics Laboratory I	1
PHY 252 Introductory Physics Laboratory II	1
(b) PHY 183 Physics for Scientists and Engineers I	4
PHY 184 Physics for Scientists and Engineers II	4
b. The following courses in the Department of Geological Sciences:	40
(1) All of the following courses (32 credits):	
GLG 201 The Dynamic Earth	4
GLG 304 Physical and Biological History of the Earth	4
GLG 321 Mineralogy and Geochemistry	4
GLG 351 Structural Geology	4
GLG 361 Petrology (W)	4
GLG 411 Hydrogeology	4
GLG 421 Environmental Geochemistry	4
GLG 431 Sedimentology and Stratigraphy (W)	4
The completion of Geological Sciences 431 fulfills the department's capstone course requirement.	
(2) One of the following courses (3 or 4 credits):	
GLG 303 Oceanography	4
GLG 412 Glacial and Quaternary Geology	4
GLG 422 Organic Geochemistry (W)	3

GLG 471 Applied Geophysics	4
GLG 481 Reservoirs and Aquifers	3

NOTE: Geography 306 or Geography 408 may be substituted for one of the courses listed above.

- (3) Additional credits in Geological Sciences courses at the 300–400 level as needed to meet the requirement of at least 40 credits in Geological Sciences courses.
- Botany 335 and Microbiology 426 may be used to satisfy *either* the requirements for the major *or* the requirements referenced under the heading *Graduation Requirements* in the College statement, but not both of those requirements.
- The credits that are used to satisfy this requirement may be used to satisfy *either* the requirements for the environmental geosciences major *or* the requirements for the geological sciences major, but not both of those requirements.

GEOLOGICAL SCIENCES

Requirements for the Bachelor of Science Degree in Geological Sciences

- The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Science degree in Geological Sciences.
 The University's Tier II writing requirement for the Geological Sciences major is met by completing one of the following courses: Geological Sciences 361, 431, or 491. Those courses are referenced in item 3. b. below.
 Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
- The requirements of the College of Natural Science for the Bachelor of Science degree.
 The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
- The following requirements for the major:

CREDITS

a.	The following courses outside the Department of Geological Sciences:	26 or 27
(1)	All of the following courses (8 credits):	
	CEM 161 Chemistry Laboratory I	1
	MTH 132 Calculus I	3
	MTH 133 Calculus II	4
(2)	One of the following pairs of courses (7 credits):	
(a)	CEM 141 General Chemistry	4
	CEM 142 General and Inorganic Chemistry	3
(b)	CEM 151 General and Descriptive Chemistry	4
	CEM 152 Principles of Chemistry	3
(3)	One of the following options (3 or 4 credits):	
(a)	MTH 234 Multivariable Calculus	4
(b)	One course of at least 3 credits in statistics and probability.	
(4)	One of the following groups of courses (8 credits):	
(a)	PHY 231 Introductory Physics I	3
	PHY 232 Introductory Physics II	3
	PHY 251 Introductory Physics Laboratory I	1
	PHY 252 Introductory Physics Laboratory II	1
(b)	PHY 183 Physics for Scientists and Engineers I	4
	PHY 184 Physics for Scientists and Engineers II	4
b.	The following courses in the Department of Geological Sciences:	40
	GLG 201 The Dynamic Earth	4
	GLG 304 Physical and Biological History of the Earth	4
	GLG 321 Mineralogy and Geochemistry	4
	GLG 351 Structural Geology	4
	GLG 361 Petrology (W)	4
	GLG 431 Sedimentology and Stratigraphy (W)	4
	GLG 491 Field Geology – Summer Camp (W)	6
	Ten additional credits in Geological Sciences courses at the 300–400 level. Botany 335 and Microbiology 426 may be used to satisfy <i>either</i> the requirements for the major <i>or</i> the requirements referenced under the heading <i>Graduation Requirements</i> in the College statement, but not both of those requirements. The credits that are used to satisfy this requirement may be used to satisfy <i>either</i> the requirements for the geological sciences major <i>or</i> the requirements for the environmental geosciences major, but not both of those requirements.	
	The completion of Geological Sciences 491 fulfills the department's capstone course requirement.	

Geophysics Option

A Geophysics Option is available only to those students who are enrolled in the Bachelor of Science degree program with a major

in environmental geosciences or geological sciences. Students who elect this option must complete the following courses:

CREDITS

1.	All of the following courses (15 credits):	
	MTH 234 Multivariable Calculus	4
	MTH 235 Differential Equations	3
	PHY 183 Physics for Scientists and Engineers I	4
	PHY 184 Physics for Scientists and Engineers II	4
2.	Seven credits from the following courses:	
	GLG 471 Applied Geophysics	4
	GLG 472 Principles of Modern Geophysics	3
	400–level Physics courses approved by the student's academic adviser	3 to 7

Upon completion of the requirements for both the Bachelor of Science degree with a major in environmental geosciences or geological sciences and the requirements for the Geophysics Option, the student should contact the Department of Geological Sciences and request certification for the completion of the Geophysics Option. After the certification is approved by the chairperson of the department and the Dean of the College of Natural Science, the Office of the Registrar will enter on the student's academic record the name of the option and the date that it was completed. This certification will appear on the student's transcript.

GEOPHYSICS

Bachelor of Science

The Bachelor of Science degree with a major in Geophysics is designed to provide a solid geological background together with rigorous study in quantitative methods as applied to the geological sciences. It is designed for those with an interest in graduate programs in geophysics or quantitative geology or employment in environmental geosciences or the energy sector.

Students who elect this degree program, either as a first or second degree or as a dual major, and a degree or dual major in either geological sciences or environmental geosciences, are not eligible to obtain the Geophysics Option.

A Bachelor of Science degree in Physics and Geophysics is also available and is administered by the Department of Physics and Astronomy. For additional information, refer to the Department of Physics and Astronomy section of this catalog.

Requirements for the Bachelor of Science Degree in Geophysics

- The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Science in Geophysics.
 The University's Tier II writing requirement for the Geophysics major is met by completing one of the following courses: Geological Sciences 361 or 431. Those courses are referenced in item 3. b. below.
 Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
- The requirements of the College of Natural Science for the Bachelor of Science degree.
 The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.

CREDITS

3.	The following requirements for the major (78 credits):	
a.	The following courses outside the Department of Geological Sciences:	43
(1)	All of the following courses (36 credits):	
	CEM 161 Chemistry Laboratory I	1
	CSE 231 Introduction to Programming I	4
	MTH 132 Calculus I	3
	MTH 133 Calculus II	4
	MTH 234 Multivariable Calculus	4
	MTH 235 Differential Equations	3
	PHY 183 Physics for Scientists and Engineers I	4
	PHY 184 Physics for Scientists and Engineers II	4
	PHY 215 Thermodynamics and Modern Physics	3

NATURAL SCIENCE
Department of Geological Sciences

PHY 321	Classical Mechanics I	3
PHY 481	Electricity and Magnetism I	3
(2)	One of the following pairs of courses (7 credits):	
(a)	CEM 141 General Chemistry	4
	CEM 142 General and Inorganic Chemistry	3
(b)	CEM 151 General and Descriptive Chemistry	4
	CEM 152 Principles of Chemistry	3
b.	The following courses in the Department of Geological Sciences:	35
GLG 201	The Dynamic Earth	4
GLG 304	Physical and Biological History of the Earth	4
GLG 321	Mineralogy and Geochemistry	4
GLG 351	Structural Geology	4
GLG 361	Petrology (W)	4
GLG 411	Hydrogeology	4
GLG 431	Sedimentology and Stratigraphy (W)	4
GLG 470	Principles of Modern Geophysics	3
GLG 471	Applied Geophysics	4

TEACHER CERTIFICATION OPTIONS

The earth science—interdepartmental disciplinary major leading to the Bachelor of Science degree is available for teacher certification. Students who complete the requirements for this disciplinary major and the requirements for teacher certification choose whether they wish to be recommended for certification in earth science or general science.

An earth science disciplinary minor is also available for teacher certification.

Students who elect the earth science—interdepartmental disciplinary major or the earth science disciplinary minor must contact the Department of Geological Sciences.

For additional information, refer to the statement on *TEACHER CERTIFICATION* in the *Department of Teacher Education* section of this catalog.

GRADUATE STUDY

The Department of Geological Sciences offers programs in geological sciences leading to the Master of Science, Master of Arts, and Doctor of Philosophy degrees. The department also offers programs in environmental geosciences leading to the Master of Science and Doctor of Philosophy degrees.

The goal of the graduate programs in the Department of Geological Sciences is to develop creative and productive scientists who will address problems facing the modern environment and problems related to understanding the Earth's past and future.

The department's graduate programs emphasize the study of the biological, chemical, and physical processes of the Earth and the application of knowledge about these processes to solve applied and basic problems. Environmental studies focus on fluids, minerals, and biologically mediated processes and their interactions in the environment. Studies of the Earth's past involve time periods ranging in days to billions of years. From this knowledge, predictions on Earth's future may be made.

The department is focused around three research areas: solid earth systems (tectonics, earthquake seismology, structural geology, and igneous petrology), paleobiology (evolution; paleoenvironments; paleoecology; and fossil plants, invertebrates, and vertebrates), and environmental geosciences (physical and chemical hydrogeology; geochemical cycles; glacial geology; isotropic, aqueous, environmental, inorganic, and organic geochemistry; sedimentology; mineral weathering; and petrology of low temperature systems).

The Department of Geological Sciences is affiliated with the Doctor of Philosophy degree program with a major in ecology, evolutionary biology and behavior. For information about a Doctor of Philosophy degree program that involves ecology, evolutionary biology and behavior and a major in the Department of Geological Sciences, refer to the statement on the doctoral program in ecology, evolutionary biology and behavior.

Students who are enrolled in the Master of Science degree program in the Department of Geological Sciences may elect specializations in ecology, evolutionary biology and behavior and in environmental toxicology. For additional information, refer to the statement on the Specialization in Ecology, Evolutionary Biology and Behavior and to the *Graduate Specialization in Environmental Toxicology* statement in the *College of Agriculture and Natural Resources* section of this catalog.

ENVIRONMENTAL GEOSCIENCES

Master of Science

The Master of Science degree program in environmental geosciences is available under either Plan A (with thesis) or Plan B (without thesis).

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

When applying for admission to the program, an applicant must specify either Plan A or Plan B.

Academic record, letters of recommendation, and Graduate Record Examination (GRE) General Test scores are considered in admission decisions.

For regular admission to the master's degree program in environmental geosciences under Plan A, the student must have:

1. A bachelor's degree in a physical or biological science or in engineering from a recognized educational institution.
2. Completed the courses in physics, chemistry, and mathematics that are required for the Bachelor of Science degree with a major in geological sciences at MSU, or equivalent courses.
3. At least 12 credits in geological sciences courses.
4. A grade–point average of at least 3.00.
5. Satisfactory scores on the GRE General Test.

Provisional admission may be granted to an applicant who has not completed the course work referenced in items 2. and 3. above. Deficiencies must be removed by completing collateral courses.

For regular admission to the master's degree program in environmental geosciences under Plan B, the student must have:

1. Completed a Master of Science degree in the geosciences for which a thesis was required.
2. A grade–point average of at least 3.00.
3. Satisfactory scores on the GRE General Test.

Requirements for the Master of Science Degree in Environmental Geosciences

A total of 30 credits is required for the degree under either Plan A or Plan B. The student's program of study must be approved by the student's guidance committee. The student must meet the requirements specified below:

Requirements for Both Plan A and Plan B

	CREDITS
1. Tier I requirements (10 to 12 credits):	
a. General Component. The following course (1 credit):	
GLG 423 Environmental Geosciences	1
b. Soil Component. One of the following courses (3 or 4 credits):	
CSS 455 Pollutants in the Soil Environment	3
CSS 825 Clay Mineralogy and Soils Genesis	4
CSS 855 Interfacial Environmental Chemistry	4

c. Chemical Component. One of the following courses (3 credits):			
GLG	421	Environmental Geochemistry	3
GLG	821	Aqueous Geochemistry	3
GLG	823	Isotope Geochemistry	3
d. Hydrogeology Component. One of the following courses (3 or 4 credits):			
CE	421	Engineering Hydrology	3
CE	821	Groundwater Hydraulics	3
GLG	411	Hydrogeology	4
2. Tier II requirement. One of the following courses (3 or 4 credits):			
GEO	408	Soil Geomorphology Field Study	4
GLG	412	Glacial and Quaternary Geology	3
GLG	422	Organic Geochemistry	3
GLG	471	Applied Geophysics	4
GLG	481	Reservoirs and Aquifers	4
GLG	822	Analytical Applications for Biogeochemical Research	3
GLG	863	Mineral–Water Interactions	4

With the approval of the guidance committee, a student may substitute a course listed in the Tier I requirements for one of the courses listed above.

A student who completed any course listed in the Tier I requirements or in the Tier II requirement prior to enrollment in the program must substitute another course approved by the student's guidance committee.

A given course may be used to satisfy *either* the Tier I requirements *or* the Tier II requirement, but **not** both of those requirements.

Additional Requirements for Plan A

1. Tier III requirement:
Seven to 13 credits in courses approved by the student's guidance committee.
2. Tier IV requirement:
Four to 7 credits in GLG 899 Master's Thesis Research. The research area may focus on any topic that may have applications to solving problems related to the environment. The student must include in the thesis proposal a paragraph that addresses the environmental applications of the thesis topic selected.

Additional Requirements for Plan B

1. Tier III requirement:
Thirteen to 16 credits in courses approved by the student's guidance committee.
2. Tier IV requirement:
One credit of GLG 898 Special Problems in Environmental Geosciences. The student must complete a research paper or project while enrolled in Geological Sciences 898. The topic of the paper or project must be mutually agreed upon by the student and the student's academic adviser.

Doctor of Philosophy

The core of the Doctor of Philosophy degree program in environmental geosciences is independent research. Course requirements are designed to support the student's professional goals. Commonly, research programs are pursued within the specialty of the staff. However, innovative research is encouraged in any area of environmental geosciences.

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

Students holding bachelor's or master's degrees may be admitted to the doctoral program in environmental geosciences on the basis of their performance during the previous two years of academic work.

Requirements for the Doctor of Philosophy Degree in Environmental Geosciences

The program of study is determined by mutual agreement between the student and the guidance committee. The student must complete, or have completed prior to admission, 9 credits of course work in geological sciences including a course in physical geology and at least 3 credits in 800-level course work.

The required comprehensive examination involves both an oral and a written portion and covers the area of the student's research specialty, those areas that interface with that specialty, and the significance of the proposed research program. Students who are admitted to the doctoral program with master's degrees must pass the comprehensive examination during the second

year of enrollment in the program. Students who are admitted to the doctoral program with bachelor's degrees must pass the comprehensive examination during the third year of enrollment in the program.

ENVIRONMENTAL GEOSCIENCES— ENVIRONMENTAL TOXICOLOGY

Doctor of Philosophy

For information about the Doctor of Philosophy degree program in environmental geosciences—environmental toxicology, refer to the statement on *Multidepartmental Doctoral Programs in Environmental Toxicology* in the *Graduate Education* section of this catalog.

Master of Science

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

Academic record, letters of recommendation, and Graduate Record Examination (GRE) General Test scores are considered in admission decisions. For regular admission, the student must have:

1. A bachelor's degree in a physical or biological science or in mathematics from a recognized educational institution.
2. Completed the courses in physics, chemistry, mathematics, and geological sciences that are required for the Bachelor of Science degree with a major in geological sciences at MSU, or equivalent courses.
3. A grade–point average of at least 3.00.
4. Satisfactory scores on the GRE General Test.

Depending on the proposed area of specialization, provisional admission may be granted to an applicant who has not completed the courses referenced in item 2. above. Deficiencies must be removed by completing collateral courses before a thesis proposal will be accepted.

Requirements for the Master of Science Degree in Geological Sciences

The student must complete a total of 30 credits for the degree under Plan A (with thesis). Of the 30 credits, no more than 7 credits may be in Geological Sciences 899.

Doctor of Philosophy

The core of the Doctor of Philosophy degree program in geological sciences is independent research. Course requirements are designed to support the student's professional goals. Commonly, research programs are pursued within the specialty of the staff. However, innovative research is encouraged in any area of geological sciences.

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

Students holding bachelor's or master's degrees may be admitted to the doctoral program in geological sciences on the basis of

their performance during the previous two years of academic work.

Requirements for the Doctor of Philosophy Degree in Geological Sciences

The program of study is determined by mutual agreement between the student and the guidance committee.

The required comprehensive examination involves both an oral and a written portion and covers the area of the student's research specialty, those areas that interface with that specialty, and the significance of the proposed research program. Students who are admitted to the doctoral program with master's degrees must pass the comprehensive examination during the second year of enrollment in the program. Students who are admitted to the doctoral program with bachelor's degrees must pass the comprehensive examination during the third year of enrollment in the program.

**W. K. KELLOGG
 BIOLOGICAL STATION**

Michael J. Klug, Director

The W. K. Kellogg Biological Station is administered jointly by the College of Natural Science and the College of Agriculture and Natural Resources. The Station developed from the environmental foresight and interest of W. K. Kellogg and has evolved into a world-renowned ecological research center and public education facility for biological, agricultural, and natural resource sciences.

Located 50 miles southwest of East Lansing near Battle Creek and Kalamazoo, the Biological Station's 3,352 acres encompass the Kellogg Bird Sanctuary, Kellogg Experimental Forest, Kellogg Farm, Kellogg Dairy Center, Kellogg Education Center and Research Laboratories, and Lux Arbor Reserve. Within this multiple-land use facility, a unique community of scholars addresses ways to achieve harmony between biological conservation and productive agriculture and forestry.

The teaching and research programs of the Biological Station are closely coordinated with those of the College of Natural Science and the College of Agriculture and Natural Resources. The programs focus on the study of natural and managed landscapes and cover a spectrum that includes basic ecology, evolutionary biology, wildlife management, forestry, and agriculture.

The Biological Station's resident faculty hold joint appointments with appropriate departments and teach courses both at the Station and on the main campus. Field oriented courses in the biological sciences are offered at the Station during the summer session.

Research facilities are provided for students who are candidates for Master of Science and doctor of Philosophy degrees and for postdoctoral research associates. Residence may be established upon approval of the research problem and the sponsorship of a resident faculty member.

Thesis or dissertation research is supervised by the candidate's major professor, the guidance committee, and, if not otherwise included, a member of the resident faculty at the Biological Station. Investigations by independent research workers are encouraged throughout the year.

Information concerning the instructional program and research opportunities may be obtained by either writing the Director, W.K. Kellogg Biological Station, Hickory Corners, Michigan 49060-9516.

**DEPARTMENT of
 MATHEMATICS**

Peter W. Bates, Chairperson

Mathematics, which may partially be defined as the science of number and form, is a vital tool in all branches of knowledge the University covers, from accounting to zoology. Mathematics is also studied for its own sake by those who become fascinated by the results of modern mathematics and the making of new discoveries. The department offers a wide variety of courses that begin with extensions of high school mathematics and reach to the frontiers of mathematical knowledge.

Mathematics majors can build their programs in many different ways to pursue a career path of their choice. The department offers several Honors sequences, so that highly motivated mathematics students will find challenging programs. Students in mathematics, regardless of their major preferences, are encouraged to consult with the department before registration concerning the possibility of advanced placement or enrollment in honors sections.

UNDERGRADUATE PROGRAMS

Either a Bachelor of Arts or Bachelor of Science degree may be earned with a major in Mathematics or Computational Mathematics.

Requirements for the Bachelor of Science Degree in Mathematics

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Science degree in Mathematics.

The University's Tier II writing requirement for the Mathematics major is met by completing Mathematics 496 and Mathematics 309 or 310 or 418H. Those courses are referenced in items 3.c.(1) and 3.c.(3) below.

Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.

2. The requirements of the College of Natural Science for the Bachelor of Science degree.

The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.

3. The following requirements for the major:

CREDITS

- a. The following courses outside the Department of Mathematics: 19 to 21
 - (1) One course of at least 3 credits in biological science, entomology, microbiology, physiology, plant biology, or zoology.
 - (2) One of the following groups of courses (8 or 10 credits):
 - (a) CEM 141 General Chemistry 4
 - CEM 142 General and Inorganic Chemistry 3
 - CEM 161 Chemistry Laboratory I 1
 - (b) CEM 181H Honors Chemistry I 4
 - CEM 182H Honors Chemistry II 4
 - CEM 185H Honors Chemistry Laboratory I 2
 - (3) Both of the following courses (8 credits):
 - PHY 183 Physics for Scientists and Engineers I 4
 - PHY 184 Physics for Scientists and Engineers II 4
 - b. First-year competency in a foreign language
 or
 For students who have been admitted to the teacher certification program, completion of the Professional Education Courses in the Department of Teacher Education.
 - c. A total of 38 credits in courses in the Department of Mathematics including:

- (1) All of the following courses (17 credits):
- MTH 132 Calculus I 3
 - MTH 133 Calculus II 4
 - MTH 234 Multivariable Calculus 4
 - MTH 309 Linear Algebra I 3
 - MTH 496 Capstone in Mathematics 3
- The completion of Mathematics 496 fulfills the department's capstone course requirement.
- (2) A total of 24 credits in approved Mathematics courses at the 300 level or above. At least four of the approved Mathematics courses must be at the 400 level or above. Mathematics 415, 424, and 443 may not be used to fulfill the requirements of the major. The 300-400 level courses that are referenced in items 3.c. (1), 3.c. (3), 3.c. (4), and 3.c. (5) partially satisfy this requirement. Students may not use both Mathematics 309 and 314 to satisfy the requirement in 3.c.(2). One course from a list of approved cognates may be used to satisfy this requirement; the list is available in the Department of Mathematics. Statistics and Probability 351 is required for students in the teacher certification program.
- (3) One of the following groups of courses (6 credits):
- (a) MTH 310 Abstract Algebra I and
Number Theory 3
- MTH 411 Abstract Algebra II 3
- Mathematics 414 or 417 or 418H or 481 may be substituted for Mathematics 411.
- (b) MTH 418H Honors Algebra I 3
- MTH 419H Honors Algebra II 3
- (4) One of the following pairs of courses (6 credits):
- (a) MTH 320 Analysis I 3
- MTH 421 Analysis II 3
- Mathematics 425 or 441 or 442 may be substituted for Mathematics 421.
- (b) MTH 428H Honors Analysis I 3
- MTH 429H Honors Analysis II 3
- (5) One of the following courses (3 credits):
- MTH 330 Higher Geometry 3
 - MTH 340 Ordinary Differential Equations I 3
 - MTH 432 Axiomatic Geometry 3
- Students with credit in Mathematics 235 or 255H may substitute an approved 400-level Mathematics course for Mathematics 340. Students in the teacher certification program must take either Mathematics 330 or 432.

- 415, 424, and 443 may not be used to fulfill the requirements of the major. The 300-400 level courses that are referenced in items 3.c. (1), 3.c. (3), 3.c. (4) and 3.c. (5) partially satisfy this requirement. Students may not use both Mathematics 309 and 314 to satisfy the requirement in 3.c. (2). One course from a list of approved cognates may be used to satisfy this requirement; the list is available in the Department of Mathematics. Statistics and Probability 351 is required for students in the teacher certification program.
- (3) One of the following groups of courses (6 credits):
- (a) MTH 310 Abstract Algebra I and
Number Theory 3
- MTH 411 Abstract Algebra II 3
- Mathematics 414 or 417 or 418H or 481 may be substituted for Mathematics 411.
- (b) MTH 418H Honors Algebra I 3
- MTH 419H Honors Algebra II 3
- (4) One of the following pairs of courses (6 credits):
- (a) MTH 320 Analysis I 3
- MTH 421 Analysis II 3
- Mathematics 425 or 441 or 442 may be substituted for Mathematics 421.
- (b) MTH 428H Honors Analysis I 3
- MTH 429H Honors Analysis II 3
- (5) One of the following courses (3 credits):
- MTH 330 Higher Geometry 3
 - MTH 340 Ordinary Differential Equations I 3
 - MTH 432 Axiomatic Geometry 3
- Students with credit in Mathematics 235 or 255H may substitute an approved 400-level Mathematics course for Mathematics 340. Students in the teacher certification program must take either Mathematics 330 or 432.

Requirements for the Bachelor of Science Degree in Computational Mathematics

- The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Science degree in Computational Mathematics.
The University's Tier II writing requirement for the Computational Mathematics major is met by completing Mathematics 309 or 310 and 496. Those courses are referenced in item 3. c. (1) below.
Students who are in the teacher certification program are required to complete Mathematics 330 or 432 and Statistics and Probability 351.
Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements in the College* statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
- The requirements of the College of Natural Science for the Bachelor of Science degree.
The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
- The following requirements for the major:

CREDITS
27 or 29

- a. The following courses outside the Department of Mathematics:
- One course of at least 3 credits in biological science, entomology, microbiology, physiology, plant biology, or zoology.
 - One of the following groups of courses (8 or 10 credits):
 - CEM 141 General Chemistry 4
 - CEM 142 General and Inorganic Chemistry 3
 - CEM 161 Chemistry Laboratory I 1
 - CEM 181H Honors Chemistry I 4
 - CEM 182H Honors Chemistry II 4
 - CEM 185H Honors Chemistry Laboratory I 2
 - Both of the following courses (8 credits):
 - CSE 231 Introduction to Programming I 4
 - CSE 232 Introduction to Programming II 4
 - Both of the following courses (8 credits):
 - PHY 183 Physics for Scientists and Engineers I 4
 - PHY 184 Physics for Scientists and Engineers II 4
- b. First-year competency in a foreign language
or
For students, who have been admitted to the teacher certification program, first-year competency in a foreign language and completion of the Professional Education Courses in the Department of Teacher Education.
- c. The following courses in the Department of Mathematics: 35
- All of the following courses (29 credits):
 - MTH 132 Calculus I 3
 - MTH 133 Calculus II 4
 - MTH 234 Multivariable Calculus 4
 - MTH 309 Linear Algebra I 3
 - MTH 310 Abstract Algebra I and Number Theory 3
 - MTH 320 Analysis I 3
 - MTH 451 Numerical Analysis I 3

Requirements for the Bachelor of Arts Degree in Mathematics

- The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Arts degree in Mathematics.
The University's Tier II writing requirement for the Mathematics major is met by completing Mathematics 496 and Mathematics 309 or 310 or 418H. Those courses are referenced in items 3. c. (1) and 3. c. (3) below.
Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements in the College* statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
 - The requirements of the College of Natural Science for the Bachelor of Arts degree.
The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
 - The following requirements for the major:
- CREDITS
- a. The following courses outside the Department of Mathematics:11
- One course of at least 3 credits in biological science, entomology, microbiology, physiology, plant biology, or zoology.
 - The following course (4 credits):
PHY 183 Physics for Scientists and Engineers I 4
 - One of the following courses (4 credits):
CEM 141 General Chemistry 4
CEM 181H Honors Chemistry I 4
- b. Second-year competency in a foreign language
or
For students who have been admitted to the teacher certification program, first-year competency in a foreign language and completion of the Professional Education Courses in the Department of Teacher Education.
- c. A total of 38 credits in courses in the Department of Mathematics including: 38
- All of the following courses (17 credits):
 - MTH 132 Calculus I 3
 - MTH 133 Calculus II 4
 - MTH 234 Multivariable Calculus 4
 - MTH 309 Linear Algebra I 3
 - MTH 496 Capstone in Mathematics 3

The completion of Mathematics 496 fulfills the department's capstone course requirement.
 - A total of 24 credits in approved Mathematics courses at the 300-level or above. At least 4 of the approved Mathematics courses must be at the 400-level or above. Mathematics

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- MTH 481 Discrete Mathematics I 3
- MTH 496 Capstone in Mathematics 3
- The completion of Mathematics 496 satisfies the capstone course requirement of the computational mathematics major.
- (2) One of the following courses (3 credits):
 - MTH 452 Numerical Analysis II. 3
 - MTH 482 Discrete Mathematics II. 3
- (3) One of the following courses (3 credits):
 - MTH 235 Differential Equations 3
 - MTH 340 Ordinary Differential Equations I. 3

d. At least one of the following courses: 3 or 4
 Students who select Mathematics 452 or 482 may count the credits toward either requirement 3.c.(2) or 3.d. but not toward both of those requirements.

Approval of the Department of Computer Science and Engineering is required to enroll in Computer Science and Engineering 331 and 440.

- CSE 331 Algorithms and Data Structures 4
- CSE 440 Artificial Intelligence and Symbolic Programming 4
- MTH 415 Applied Linear Algebra 3
- MTH 416 Introduction to Algebraic Coding 3
- MTH 441 Ordinary Differential Equations II 3
- MTH 452 Numerical Analysis II. 3
- MTH 472 Mathematical Logic 3
- MTH 482 Discrete Mathematics II. 3
- STT 441 Probability and Statistics I: Probability 3
- STT 461 Computations in Probability and Statistics 3

Requirements for the Bachelor of Arts Degree in Computational Mathematics

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Arts degree in Computational Mathematics.

The University's Tier II writing requirement for the Computational Mathematics major is met by completing Mathematics 309 or 310 and 496. Those courses are referenced in item 3.c.(1) below.

Students who are in the teacher certification program are required to complete Mathematics 330 or 432 and Statistics and Probability 351.

Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.

- 2. The requirements of the College of Natural Science for the Bachelor of Arts degree. The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
- 3. The following requirements for the major:

CREDITS

- a. The following courses outside the Department of Mathematics:19
 - (1) One course of at least 3 credits in biological science, entomology, microbiology, physiology, plant biology, or zoology.
 - (2) The following course (4 credits):
 - PHY 183 Physics for Scientists and Engineers I 4
 - (3) One of the following courses (4 credits):
 - CEM 141 General Chemistry 4
 - CEM 181H Honors Chemistry I 4
 - (4) Both of the following courses (8 credits):
 - CSE 231 Introduction to Programming I. 4
 - CSE 232 Introduction to Programming II 4
- b. Second-year competency in a foreign language.
 or
 For students, who have been admitted to the teacher certification program, first-year competency in a foreign language and completion of the Professional Education Courses in the Department of Teacher Education.
- c. The following courses in the Department of Mathematics: 35
 - (1) All of the following courses (29 credits):
 - MTH 132 Calculus I 3
 - MTH 133 Calculus II 4
 - MTH 234 Multivariable Calculus 4
 - MTH 309 Linear Algebra I. 3
 - MTH 310 Abstract Algebra I and Number Theory. 3
 - MTH 320 Analysis I. 3
 - MTH 451 Numerical Analysis I 3
 - MTH 481 Discrete Mathematics I 3
 - MTH 496 Capstone in Mathematics 3
 The completion of Mathematics 496 satisfies the capstone course requirement of the computational mathematics major.
 - (2) One of the following courses (3 credits):
 - MTH 452 Numerical Analysis II. 3
 - MTH 482 Discrete Mathematics II. 3
 - (3) One of the following courses (3 credits):
 - MTH 235 Differential Equations 3
 - MTH 340 Ordinary Differential Equations I. 3
- d. At least one of the following courses: 3 or 4

Students who select Mathematics 452 or 482 may count the credits toward either requirement 3.c.(2) or 3.d. but not toward both of those requirements.

Approval of the Department of Computer Science and Engineering is required to enroll in Computer Science and Engineering 331 and 440.

- CSE 331 Algorithms and Data Structures 4
- CSE 440 Artificial Intelligence and Symbolic Programming 4
- MTH 415 Applied Linear Algebra 3
- MTH 416 Introduction to Algebraic Coding 3
- MTH 441 Ordinary Differential Equations II 3
- MTH 452 Numerical Analysis II. 3
- MTH 472 Mathematical Logic 3
- MTH 482 Discrete Mathematics II. 3
- STT 351 Probability and Statistics for Engineering 3
- STT 441 Probability and Statistics I: Probability 3
- STT 461 Computations in Probability and Statistics 3

TEACHER CERTIFICATION OPTIONS

The mathematics disciplinary majors leading to the Bachelor of Arts and Bachelor of Science degrees are available for teacher certification.

A mathematics disciplinary minor is also available for teacher certification.

Students who elect a mathematics disciplinary major or the mathematics disciplinary minor must contact the Department of Mathematics.

For additional information, refer to the statement on *TEACHER CERTIFICATION* in the *Department of Teacher Education* section of this catalog.

GRADUATE STUDY

The Department of Mathematics offers graduate work leading to the degrees of Master of Science in Mathematics, Applied Mathematics, and Industrial Mathematics, and Master of Arts for Teachers. The Department also offers graduate work leading to the degrees of Doctor of Philosophy in Mathematics, Applied Mathematics, and Mathematics Education.

APPLIED MATHEMATICS

Master of Science

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

To be admitted to the Master of Science degree program in applied mathematics, a person should have completed (1) the mathematics or applied mathematics courses normally required for the bachelor's degree with a major in mathematics, physics, or engineering, (2) a minimum of a year's work in mathematical analysis at the senior year level, and (3) courses in matrices and linear algebra.

Requirements for the Master of Science Degree in Applied Mathematics

The student must complete a total of 30 credits for the degree under Plan B (without thesis). The student's program of study must be approved by the student's academic adviser and must include:

- 1. At least 24 credits in mathematics courses including:
 - a. At least 6 credits from the following courses: Mathematics 818, 819, 828, 829, 848, 849, 868, 869.

- b. At least 12 credits in 800–level applied mathematics courses including 6 credits in *one* of the following *groups* of courses: Mathematics 841, 842; 848, 849; 850, 851; or 880, 881.

The completion of Mathematics 848 and 849 may be used to satisfy **either** the requirement referenced in item 1 a. **or** the requirement referenced in item 1. b., but **not** both of those requirements.

- 2. At least 18 credits in 800–900 level courses.

Doctor of Philosophy

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

Regular admission to the Doctor of Philosophy degree program in applied mathematics presupposes academic preparation equivalent to a Master of Science degree with a major in mathematics with a grade–point average of 3.00 or better. However, a student with a bachelor's degree whose undergraduate preparation is strong may be admitted directly to the program upon passing a qualifying examination.

Requirements for the Doctor of Philosophy Degree in Applied Mathematics

The student must:

- 1. Pass the qualifying examination.
- 2. Complete at least 30 credits in approved 800–900 level mathematics courses excluding courses taken in preparation for the qualifying examination and Mathematics 999; at least 18 of the 30 credits must be in applied mathematics courses.
- 3. Present at least two seminars acceptable to the faculty.
- 4. Pass the comprehensive examination.
- 5. Demonstrate a reading knowledge of one foreign language, normally from among French, German, and Russian, sufficient to read the mathematical literature written in that language.
- 6. Complete a dissertation in applied mathematics.

For detailed information regarding the qualifying and comprehensive examinations, contact the Department of Mathematics.

INDUSTRIAL MATHEMATICS

Master of Science

The degree of Master of Science in Industrial Mathematics is designed to produce generalized problem solvers of great versatility, capable of moving within an organization from task to task. The graduate will have acquired not only the standard mathematical and statistical tools, but also the basic ideas of engineering and business, and will have received training in project development and in modes of industrial communication. The program is for students planning careers in business, government or industry.

Admission

To be admitted to the Master of Science in Industrial Mathematics program, a person should have completed (1) the mathematics or applied mathematics courses normally required for the bachelor's degree with a major in mathematics, physics or engineering,

(2) courses at the senior level in mathematical analysis, linear algebra and differential equations, and (3) have some familiarity with mathematical software programs such as Mathematica, Matlab, etc.

Students entering the program are expected to have a mathematical preparation at the level of Mathematics 421, 414 and 442. Students with deficiencies may be required to take additional credits.

Requirements for the Master of Science Degree in Industrial Mathematics

In addition to meeting the requirements of the University and the College of Natural Science, the student must complete a total of 36 credits for the degree under Plan B (without thesis). The student's program of study must be approved by the student's academic adviser, including:

1. The following requirements for the major:	36
a. Both of the following courses:	
MTH 843 Survey of Industrial Mathematics	3
MTH 844 Projects in Industrial Mathematics	3
b. A minimum of four of the following courses:	
MTH 810 Error-Correcting Code	3
MTH 841 Boundary Value Problems I	3
MTH 842 Boundary Value Problems II	3
MTH 848 Ordinary Differential Equations	3
MTH 849 Partial Differential Equations	3
MTH 850 Numerical Analysis I	3
MTH 851 Numerical Analysis II	3
MTH 852 Numerical Methods for Ordinary Differential Equations	3
MTH 880 Combinatorics	3
MTH 881 Graph Theory	3
c. A minimum of two of the following courses:	
STT 461 Computations in Probability and Statistics	3
STT 471 Statistics for Quality and Productivity	3
STT 801 Design of Experiments	3
STT 844 Time Series Analysis	3
STT 852 Stochastic Methods in Operations Research	3
STT 861 Theory of Probability and Statistics I	3
STT 862 Theory of Probability and Statistics II	3
STT 887 Applications of Probability	3
d. At least four of the following courses:	
CE 810 Reliability-Based Design in Civil Engineering	3
CE 841 Traffic Flow Theory	3
CSE 802 Pattern Recognition and Analysis	4
CSE 803 Computer Vision	3
CSE 808 Modelling and Discrete Simulation	3
CSE 830 Design and Theory of Algorithms	3
CSE 835 Algorithmic Graph Theory	3
EC 805 Microeconomic Analysis	3
EC 807 Applied Microeconomic Analysis	3
EC 811 The Structure of Economic Analysis	3
EC 812A Microeconomics I	3
EC 812B Microeconomics II	3
EC 813A Macroeconomics I	3
EC 813B Macroeconomics II	3
EC 820 Econometrics I	3
EC 827 Economic Forecasting	2
ECE 466 Digital Signal Processing and Filter Design	3
ECE 809 Algorithms and Their Hardware Implementation	3
ECE 826 Linear Control Systems	3
ECE 827 Nonlinear Systems Analysis	3
ECE 829 Optimal Multivariate Control	3
ENE 801 Dynamics of Environmental Systems	3
ME 451 Control Systems	4
ME 852 Intermediate Control Systems	3
ME 855 Digital Data Acquisition and Control	3
ME 857 Modeling and Simulation of Dynamic Systems	3
ME 860 Theory of Vibrations	3
ME 863 Nonlinear Vibrations	3
MSM 401 Intermediate Mechanics of Deformable Solids	3
MSM 402 Computational Mechanics	3
MSM 444 Introduction to Composite Materials	3
MSM 809 Finite Element Method	3
MSM 810 Continuum Mechanics	3
MSM 813 Linear Elasticity	3
MSM 865 Advanced Theory of Solids	3
e. Completion of a Certificate in Basic Business and Communication Skills. The certificate program is organized as a series of week-end workshops covering such topics as project management, business law, intellectual property, management theory, finance, writing skills, presentation skills, information re- trieval, interpersonal skills and group work. The certificate pro- gram offered by the faculty of The Eli Broad College of Business and the College of Communication Arts and Sciences, will include a case-study approach. It will normally be undertaken during the	

NATURAL SCIENCE Department of Mathematics

first year of enrollment and will involve an additional cost to the student beyond usual tuition and fees.

After the completion of the certificate program is approved by the Director of Executive Development Programs in The Eli Broad College of Business and by the Associate Dean of the College of Natural Science, the Office of the Registrar will enter on the student's academic record the name of the certificate program and the date it was completed. This certification will appear on the student's transcript upon completion of the requirements for the degree program.

MATHEMATICS

Master of Arts for Teachers

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

To be admitted to the Master of Arts for Teachers degree program in mathematics, a person should have (1) at least one year of calculus and (2) at least 10 credits of acceptable junior and senior mathematics courses. Normally these 10 credits should include courses in advanced calculus and modern algebra. The candidate should also possess, or be a candidate for, teacher certification.

Requirements for the Master of Arts for Teachers Degree in Mathematics

The student must complete a total of 30 credits for the degree under Plan B (without thesis). The student's program of study must be approved by the student's academic adviser and must include:

1. At least 9 credits from the following courses: Mathematics 801, 802A, 802B, and 903.
2. At least 15 additional credits in mathematics or statistics courses including one course sequence, such as algebra or discrete mathematics, from a list of approved courses that is available in the Department of Mathematics.
3. Course work in each of the following five areas of mathematics: geometry, algebra, analysis, discrete mathematics, and probability and statistics. Courses completed while enrolled in a bachelor's degree program may be used to satisfy this requirement.

Master of Science

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

To be admitted to the Master of Science degree program in mathematics, a person should have (1) at least one year of calculus and (2) at least 10 credits of acceptable junior and senior mathematics courses. Normally these 10 credits should include courses in advanced calculus and modern algebra.

Requirements for the Master of Science Degree in Mathematics

The student must complete a total of 30 credits for the degree under Plan B (without thesis). The student's program of study must be approved by the student's academic adviser and must include:

1. At least 24 credits in mathematics courses including at least 6 credits from the following courses: Mathematics 818, 819, 828, 829, 848, 849, 868, 869.

2. At least 18 credits in 800–900 level courses.

Doctor of Philosophy

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

Regular admission to the Doctor of Philosophy degree program in mathematics presupposes academic preparation equivalent to a Master of Science degree with a major in mathematics with a grade–point average of 3.00 or better. However, a student with a bachelor's degree whose undergraduate preparation is strong may be admitted directly to the program upon passing a qualifying examination.

Requirements for the Doctor of Philosophy Degree in Mathematics

The student must:

1. Pass the qualifying examination.
2. Complete at least 30 credits in approved 800–900 level mathematics courses excluding courses taken in preparation for the qualifying examination and Mathematics 999.
3. Present at least two seminars acceptable to the faculty.
4. Pass the comprehensive examination.
5. Demonstrate a reading knowledge of one foreign language, normally from among French, German, and Russian, sufficient to read the mathematical literature written in that language.

For detailed information regarding the qualifying and comprehensive examinations, contact the Department of Mathematics.

MATHEMATICS EDUCATION

Doctor of Philosophy

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

Regular admission to the Doctor of Philosophy degree program in mathematics education presupposes academic preparation equivalent to a Master of Science degree with a major in mathematics with a grade–point average of 3.00 or higher. However, a student with a bachelor's degree whose undergraduate preparation is strong may be admitted directly to the program upon passing a qualifying examination.

Requirements for the Doctor of Philosophy Degree in Mathematics Education

The student must:

1. Pass the qualifying examination.
2. Pass the comprehensive examination.
3. Complete 36 credits of 800–900 level courses *excluding* core courses, in areas in which the qualifying examination requirements are fulfilled, and thesis credits, distributed as follows:

- a. 6 credits in mathematics education within the Department of Mathematics.
 - b. 9 credits in mathematics courses within the Department of Mathematics.
 - c. 12 credits in research methods including a research practicum, from an approved list selected in consultation with the student's guidance committee.
 - d. 9 credits in electives selected in consultation with the student's guidance committee. These courses may be additional 800 or 900 level courses from the Department of Mathematics or courses chosen from an approved list of courses in other departments.
4. Satisfy the foreign language requirement.
 5. Satisfy the seminar requirement.
 6. Complete 24 credits of Mathematics 999.
 7. Complete and defend a doctoral dissertation acceptable to the student's guidance committee.

For detailed information regarding the qualifying and comprehensive examinations, contact the Department of Mathematics.

MEDICAL TECHNOLOGY PROGRAM

Kathryn M. Doig, Director

UNDERGRADUATE PROGRAMS

Medical technology (clinical laboratory science) is a health profession with a firm foundation in the basic sciences of chemistry, biology, mathematics, and physics. Medical technology is a challenging career as well as a satisfying and growing profession for persons with an interest in the application of the basic sciences. Clinical laboratory scientists contribute to quality health care through the analysis of blood, body fluids, and tissue samples for evidence of pathology. In addition, clinical laboratory scientists contribute to the development and application of new technologies for the improved diagnosis of pathologic conditions. Courses in hematology, immunohematology, hemostasis, clinical microbiology, and clinical chemistry are designed to prepare students for their roles as laboratorians.

The traditional orientation of medical technology toward the diagnostic testing laboratories is only one of many areas available for the program graduate. Federal, state, and local health departments, commercial and research laboratories, and medical and scientific supplies sales areas are arenas in which clinical laboratory scientists apply their knowledge and skills.

Two undergraduate programs that lead to the Bachelor of Science degree are available: medical technology and clinical laboratory sciences. These programs are designed to meet the growing professional needs of a rapidly expanding and changing laboratory profession. These programs are also designed to provide students with preparation for advanced study in the clinical laboratory sciences and to assist students in meeting the preprofessional requirements for careers in a variety of medical and medically related fields.

MEDICAL TECHNOLOGY

The medical technology major is designed to prepare students for careers as laboratorians in a variety of settings. The clinical laboratory experience required for certification by external agencies is not included in this program. Students desiring certification are

responsible for securing their own clinical experiences subsequent to the completion of their degree requirements.

Admission as a Junior

Students must meet the requirements for admission to the College of Natural Science.

Requirements for the Bachelor of Science Degree in Medical Technology

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Science degree in Medical Technology.
The University's Tier II writing requirement for the Medical Technology major is met by completing Medical Technology 455. That course is referenced in item 3. b. below.
Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
2. The requirements of the College of Natural Science for the Bachelor of Science degree.
The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
3. The following requirements for the major:

	CREDITS
a. Courses outside Medical Technology:	48 or 49
(1) All of the following courses (45 credits):	
BMB 401 Basic Biochemistry	4
BS 111 Cells and Molecules	3
BS 111L Cell and Molecular Biology Laboratory	2
CEM 141 General Chemistry	4
CEM 161 Chemistry Laboratory I	1
CEM 162 Chemistry Laboratory II	1
CEM 251 Organic Chemistry I	3
CEM 252 Organic Chemistry II	3
MMG 205 Allied Health Microbiology	3
MMG 302 Introductory Microbiology Laboratory	1
MMG 463 Medical Microbiology	3
MMG 464 Diagnostic Microbiology Laboratory	1
PHY 231 Introductory Physics I	3
PHY 232 Introductory Physics II	3
PSL 250 Introductory Physiology	4
ZOL 316 General Parasitology	3
(2) One of the following courses (3 credits):	
MTH 124 Survey of Calculus with Applications I	3
MTH 132 Calculus I	3
(3) One of the following courses (3 or 4 credits):	
STT 200 Statistical Methods	3
STT 201 Statistical Methods	4
STT 231 Statistics for Scientists	3
STT 351 Probability and Statistics for Engineers	3
STT 421 Statistics I	3
b. All of the following Medical Technology courses:	23
MT 212 Fundamentals of Laboratory Analysis	3
MT 213 Application of Clinical Laboratory Principles	1
MT 414 Clinical Chemistry I: Laboratory Analysis and Practice	4
MT 416 Clinical Chemistry II: Pathophysiology and Body Fluid Analysis	4
MT 422 Hematology and Hemostasis	4
MT 432 Clinical Immunology and Immunohematology	5
MT 455 Integrating Clinical Laboratory Science Discipline (W)	2

CLINICAL LABORATORY SCIENCES

The clinical laboratory sciences major is designed to prepare students for certification in medical technology/clinical laboratory science. The program includes courses in the biomedical laboratory sciences, communications, mathematics and statistics, and clinical laboratory sciences coupled with clinical practicum experiences. It is designed to prepare graduates for certification and immediate employment in clinical laboratories upon graduation. Admission to this program is limited. Students seeking admission must complete the admission procedure outlined below.

The Bachelor of Science degree program in clinical laboratory sciences has been accredited by the National Accrediting Agency for Clinical Laboratory Sciences, 8410 West Bryn Mawr Avenue, Suite 670, Chicago, Illinois 60631.

NATURAL SCIENCE
Medical Technology Program

Admission as a Junior

Enrollment in the clinical laboratory sciences major is limited. A new class is admitted at the junior level fall semester of each year. Applications for admission must be received by March 1 of that same year.

To be considered for admission, the applicant must meet the following minimal criteria, in addition to the College of Natural Science requirements:

1. Have an overall grade–point average of 2.50 or better.
2. Have completed a minimum of 56 credits which must include the following courses:
 - a. Medical Technology 212 and 213.
 - b. Chemistry 162, 251, 252.
 - c. Mathematics 124 or 132.
 - d. Physics 231 and 232.
 - e. Statistics and Probability 200 or 201 or 231 or 351 or 421.
 - f. the University's Tier I writing requirement.
 - g. Physiology 250.
 - h. Biological Science 111, 111L.

Students who have met the minimal criteria for admission as a junior to the clinical laboratory sciences major with the exception of Medical Technology 212 and 213, Chemistry 252, and Physics 232 may be admitted to the major at the time that they are enrolled in these courses.

Students who do not meet the grade–point criterion noted above may be considered for admission on a space available basis.

Applications for admission to the clinical laboratory sciences major are reviewed by a committee of the faculty. Factors considered by the Admission Committee in the applicant's review and admission action are (1) grade–point average in science and nonscience courses, (2) grade–point average for select preclinical laboratory science courses, (3) clinical laboratory science exposure, (4) interview, and (5) compositions.

Academic Standards

A specific statement of **Student Policies for Clinical Laboratory Sciences Students** may be obtained from the Medical Technology Program, 322 N. Kedzie Lab. The student is responsible for knowing and adhering to these program policies.

Requirements for the Bachelor of Science Degree in Clinical Laboratory Sciences

1. A minimum of 136 credits is required for the Bachelor of Science degree in Clinical Laboratory Sciences.
2. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog.

The University's Tier II writing requirement for the Clinical Laboratory Sciences major is met by completing Medical Technology 454. That course is referenced in item 4. b. below.

Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 4. below may be used to satisfy the alternative track.
3. The requirements of the College of Natural Science for the Bachelor of Science degree.

The credits earned in certain courses referenced in requirement 4. below may be counted toward College requirements as appropriate.
4. The following requirements for the major:

a.	Courses outside Medical Technology:	CREDITS	49 or 50
(1)	All of the following courses (46 credits):		
	BMB 401 Basic Biochemistry		4
	BS 111 Cells and Molecules		3
	BS 111L Cell and Molecular Biology Laboratory		2
	CEM 141 General Chemistry		4
	CEM 161 Chemistry Laboratory I		1
	CEM 162 Chemistry Laboratory II		1
	CEM 251 Organic Chemistry I		3

	CEM 252 Organic Chemistry II	3
	MMG 205 Allied Health Microbiology	3
	MMG 302 Introductory Microbiology Laboratory	1
	MMG 463 Medical Microbiology	3
	MMG 464 Diagnostic Microbiology Laboratory	1
	PHY 231 Introductory Physics I	3
	PHY 232 Introductory Physics II	3
	PSL 250 Introductory Physiology	4
	ZOL 316 General Parasitology	3
	ZOL 316L General Parasitology Laboratory	1
(2)	One of the following courses (3 credits):	
	MTH 124 Survey of Calculus with Applications I	3
	MTH 132 Calculus I	3
(3)	One of the following courses (3 or 4 credits):	
	STT 200 Statistical Methods	3
	STT 201 Statistical Methods	4
	STT 231 Statistics for Scientists	3
	STT 351 Probability and Statistics for Engineers	3
	STT 421 Statistics I	3
b.	All of the following Medical Technology courses:	47
	MT 212 Fundamentals of Laboratory Analysis	3
	MT 213 Application of Clinical Laboratory Principles	1
	MT 414 Clinical Chemistry I: Laboratory Analysis and Practice	4
	MT 415 Clinical Chemistry and Body Fluid Analysis Laboratory	1
	MT 416 Clinical Chemistry II: Pathophysiology and Body Fluid Analysis	4
	MT 422 Hematology and Hemostasis	4
	MT 423 Hematology and Hemostasis Laboratory	1
	MT 432 Clinical Immunology and Immunohematology	5
	MT 433 Clinical Immunology and Immunohematology Laboratory	1
	MT 442 Education and Management in the Clinical Laboratory	3
	MT 454 Problem Solving Across Clinical Laboratory Disciplines (W)	4
	MT 471 Advanced Clinical Chemistry Laboratory	3
	MT 472 Advanced Clinical Chemistry	1
	MT 473 Advanced Clinical Hematology and Body Fluids Laboratory	4
	MT 474 Advanced Clinical Hematology and Body Fluids	1
	MT 475 Advanced Clinical Immunology and Immunohematology Laboratory	2
	MT 476 Advanced Clinical Immunology and Immunohematology	1
	MT 477 Advanced Clinical Microbiology Laboratory	3
	MT 478 Advanced Clinical Microbiology	1

During the clinical practicum, usually two semesters, the student may be required to relocate and/or commute to a clinical laboratory in an affiliated clinical facility.

GRADUATE STUDY

CLINICAL LABORATORY SCIENCES

The graduate program in clinical laboratory sciences leads to the Master of Science degree. The program emphasizes the multidisciplinary nature of the laboratory sciences, encourages research that crosses traditional laboratory disciplines, and promotes innovative thinking.

Hematology, immunohematology, microbiology, clinical chemistry, urinalysis and hemostasis are represented in the master's degree program in clinical laboratory sciences. Students may conduct research projects with both resident and adjunct faculty.

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

Certification as a medical technologist/clinical laboratory scientist is preferred, but not required, for admission to the master's degree program in clinical laboratory sciences.

For additional information on admission, contact the Graduate Program Director, 322 N. Kedzie Lab, Michigan State University, East Lansing, Michigan 48824–1031.

Requirements for the Master of Science Degree in Clinical Laboratory Sciences

A total of 30 credits is required for the degree under either Plan A (with thesis) or Plan B (without thesis). The student's program of study must be approved by the student's academic adviser.

		CREDITS
Requirements for Both Plan A and Plan B:		
1. Both of the following courses:		
MT 801	Medical Technology Seminar	2
MT 810	Research Planning in the Clinical Laboratory Sciences	2
2. At least two of the following courses:		
MT 812	Advanced Clinical Chemistry	2
MT 830	Concepts in Molecular Biology	2
MT 840	Advanced Hemostasis	2
MT 860	Clinical Laboratory Diagnosis of Infectious Diseases	2
3. A minimum of 6 credits in Biochemistry courses at the 800–900 level.		
4. Not more than 9 credits in 400–level courses.		
Additional Requirements for Plan A:		
MT 899	Master's Thesis Research	7
Additional Requirements for Plan B:		
MT 890	Selected Problems in Clinical Laboratory Science	3

BIOMEDICAL LABORATORY OPERATIONS

Master of Science

The master's degree program in biomedical laboratory operations (BLMO) is designed for individuals with previous clinical laboratory experience who seek career advancement as managers, administrators, researchers, entrepreneurs and policymakers in the field. The core of this program resides in three major components: science, management and practice. The science component focuses on post-baccalaureate courses planned to develop a high level of competence within the student's chosen biomedical laboratory discipline. The management component provides a solid foundation in general business including resource management, communication skills, organizational structures, decision making, and essential aspects of working in a regulated industry; it includes courses which specifically emphasize the management of a biomedical laboratory. The practice component requires participation in an industrial/clinical internship. This experience is intended to expose individuals to real-life problems with an expectation of generating positive, realistic solutions. Internships are conducted in a closely coordinated manner among non-academic industrial or clinical partners, Michigan State University faculty members and the student.

The program of study can be planned to meet individual interests and career paths, while providing a structured sequence useful for personal and professional development. For select students, opportunities are available for acquisition of professional credentials.

In addition to meeting the requirements of the University and the College of Natural Science, students must meet the requirements specified below.

Admission

Regular admission to the Master of Science degree in Biomedical Laboratory Operations requires completion of a bachelor of science degree, with a minimum grade-point average of 3.0, in a field of study directly related to the focus of this program and a minimum of two years' experience in a clinical laboratory setting. Applicants with certification in a clinical laboratory profession may apply their clinical education or internship experience towards the two-year experience requirement. Scholastic record, experience, personal qualifications and career goals are taken into consideration to determine the applicant's acceptability.

Applicants who fail to meet the criteria for regular admission, may apply for provisional admission if they have demonstrated a high probability of success. The decision regarding conversion to

regular status will be made after completion of 9 credit hours of science-based courses. Students who are admitted provisionally will be required to complete 9 credits in prescribed science courses with a 3.0 grade-point average. These collateral courses will not count toward the degree.

Requirements for the Master of Science Degree in Biomedical Laboratory Operations

The student must complete 31 credits under Plan B (without thesis). The specific program of study, including an internship in collaboration with an industrial partner, and competence in statistics must be approved by the student's guidance committee. The final oral examination, which covers both course work and research, is administered by the student's guidance committee.

		CREDITS
1. The following courses (5 credits):		
MT 842	Managing Biomedical Laboratory Operations	2
MT 844	Topics in Biomedical Laboratory Operations	1
MT 846	Decision Processes for Biomedical Laboratory Operations	2
2. Complete a minimum of 6 credits in courses with a business or management focus.		
3. Complete a minimum of 17 credits in courses with a science focus.		
4. Complete a minimum of 3 credits of an internship with an industrial partner.		
5. Pass a final oral examination.		
6. All students in the program will be required to complete a Certificate in Basic Business and Communication Skills. The certificate program is organized as a series of week-end workshops covering such topics as project management, business law, intellectual property, management theory, finance, writing skills, presentation skills, information retrieval, interpersonal skills and group work. The certificate program offered by the faculty of The Eli Broad College of Business and the College of Communication Arts and Sciences, will include a case-study approach. It will normally be undertaken during the first year of enrollment and will involve an additional cost to the student beyond usual tuition and fees.		

After the completion of the certificate program is approved by the Director of Executive Development Programs in The Eli Broad College of Business and by the Associate Dean of the College of Natural Science, the Office of the Registrar will enter on the student's academic record the name of the certificate program and the date it was completed. This certification will appear on the student's transcript upon completion of the requirements for the degree program.

**DEPARTMENT of
MICROBIOLOGY and
MOLECULAR GENETICS**

Jerry B. Dodgson, Chairperson

The Department of Microbiology and Molecular Genetics is administered jointly by the colleges of Natural Science, Human Medicine, Osteopathic Medicine, and Veterinary Medicine.

Microbiology involves the study of microscopic organisms: bacteria, viruses, algae, fungi, and protozoa, as well as animal and plant cells in culture. Microbiology also includes research on the interaction of pathogenic and symbiotic microbes with their hosts and the host response to infection.

Every area of modern biology incorporates aspects of microbiology. Microbes are not only key players in disease, industrial processes, and the environment, but some of them are also among the most intensively studied model systems in all of biological science.

The microbiologist today may specialize in one or more of the diverse aspects of the science. At the undergraduate level, formal concentrations are offered in cell and molecular biology; general microbiology; genomics and molecular genetics; medical microbiology and immunology; and microbial biotechnology.

Employment opportunities for microbiologists exist at all levels of education. Careers are available as teachers and researchers

in universities and institutes, and as scientists in a variety of governmental, medical, and industrial laboratories.

Because the programs in microbiology offer a broad overview of biology, they are excellent choices for students who are interested in fundamental and applied biological science. Because the programs in microbiology provide the opportunity to focus on infectious agents and the immune response, they are also excellent choices for students who plan to apply for admission to graduate professional programs, such as human or veterinary medicine.

Students who are enrolled in bachelor's degree programs in the Department of Microbiology and Molecular Genetics may elect the Specialization in Food Processing and Technology. For additional information, refer to the *Specialization in Food Processing and Technology* statement in the *Department of Food Science and Human Nutrition* section in the *College of Agriculture and Natural Resources* section of this catalog.

The Department of Microbiology and Molecular Genetics also participates in the joint bachelor's degree/master's degree of the College of Natural Science. For additional information, refer to the *College of Natural Science Dual Degree Program: Bachelor of Science and Master of Science* section of this catalog.

UNDERGRADUATE PROGRAMS

ENVIRONMENTAL BIOLOGY/MICROBIOLOGY

Environmental microbiology is a large and diverse field that addresses concerns such as soil fertility, water purity and quality, and safety of the food supply. Although environmental biology is concerned with all members of the biosphere and the geochemical surroundings, microorganisms are at the heart of the biological activities in the environment. Many of the environmental problems facing society are microbiological ones, or ones for which microbiological solutions may be found.

The Bachelor of Science degree program with a major in environmental biology/microbiology is designed for students who plan to pursue careers involving microbiology and the environment or who plan to pursue graduate study in microbiology and related environmental areas.

The educational objectives of the program are to:

1. Help students to acquire knowledge of microbiology and related environmental areas.
2. Prepare students to solve problems in environmental microbiology.

On completion of the program, the graduate may apply for certification with the National Registry of Microbiologists of the American Society for Microbiology.

Requirements for the Bachelor of Science Degree in Environmental Biology/Microbiology:

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Science degree in Environmental Biology/Microbiology.

The University's Tier II writing requirement for the Environmental Biology/Microbiology major is met by completing Microbiology 408. That course is referenced in item 3.a.(3)(a) below.

Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.

2. The requirements of the College of Natural Science for the Bachelor of Science degree.

The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.

3. The following requirements for the major:

CREDITS

- a. The following courses outside the Department of Microbiology:

Microbiology:	67
(1) All of the following courses (64 credits):	
BMB 461 Biochemistry I	3
BMB 462 Biochemistry II	3
BS 110 Organisms and Populations	4
BS 111 Cells and Molecules	3
BS 111L Cell and Molecular Biology Laboratory	2
CE 280 Introduction to Environmental Engineering	3
CEM 141 General Chemistry	4
CEM 142 General and Inorganic Chemistry	3
CEM 161 Chemistry Laboratory I	1
CEM 162 Chemistry Laboratory II	1
CEM 251 Organic Chemistry I	3
CEM 252 Organic Chemistry II	3
CEM 255 Organic Chemistry Laboratory	2
CSS 455 Pollutants in the Soil Environment	3
GLG 201 The Dynamic Earth	4
GLG 421 Environmental Geochemistry	4
MTH 132 Calculus I	3
PHY 231 Introductory Physics I	3
PHY 232 Introductory Physics II	3
PHY 251 Introductory Physics Laboratory I	1
PHY 252 Introductory Physics Laboratory II	1
STT 231 Statistics for Scientists	3
ZOL 355 Ecology	3
ZOL 355L Ecology Laboratory	1
(2) One of the following courses (3 credits):	
CSE 101 Computing Concepts and Competencies	3
CSE 131 Introduction to Technical Computing	3
LBS 125 Introduction to C Language with Applications	3
LBS 126 Personal Computers and Networks	3
LBS 127 Introduction to FORTRAN Language with Applications	3
Students who pass a waiver examination for Computer Science and Engineering 101 will not be required to complete Computer Science and Engineering 101 or 131.	
(3) The following courses in the Department of Microbiology and Molecular Genetics:	19
(a) All of the following courses (16 credits):	
MMG 301 Introductory Microbiology	3
MMG 302 Introductory Microbiology Laboratory	1
MMG 408 Advanced Microbiology Laboratory (W)	3
MMG 421 Prokaryotic Cell Physiology	3
MMG 425 Microbial Ecology	3
MMG 431 Microbial Genetics	3
(b) One of the following two options (3 credits):	
(i) MMG 491 Current Topics in Microbiology	3
(ii) MMG 492 Undergraduate Research Seminar	1
One of the following courses:	
MMG 499 Undergraduate Research	2
MMG 499H Honors Research	2
The completion of either of these two options fulfills the department's capstone course requirement.	
(4) One course from each of two of the following eight areas:	6 to 8
(a) FOR 404 Forest and Agricultural Ecology	4
(b) FSC 440 Food Microbiology	3
(c) GEO 206 Physical Geography	3
GEO 221 Introduction to Geographic Information	3
(d) MMG 426 Biogeochemistry	3
(e) MMG 445 Basic Biotechnology	3
(f) MMG 827 Diversity of Prokaryotes	3
(g) RD 430 Law and Resources	3
ZOL 446 Environmental Issues and Public Policy	3
(h) ZOL 431 Comparative Limnology	4
FW 472 Limnology	3

MICROBIOLOGY

The objective of the Bachelor of Science degree program with a major in microbiology is to provide a broad foundation in science, with emphasis in microbiology. A number of specific concentrations are offered in order to assist students in planning a course of study. In addition, students are given personal counsel to further assist them. Thus, different emphases may be elected by students intending to acquire technical competence in the field, to pursue graduate education in microbiology or another biological science, or to attain competence in a basic medical science preparatory to or in conjunction with professional study in human or veterinary medicine. On completion of the program, graduates may apply for certification with the National Registry of Microbiologists of the American Society for Microbiology.

In addition to the general degree requirements of the College of Natural Science, the undergraduate program in microbiology encompasses fundamental training in chemistry, mathematics,

physics, and biology. This foundation provides the prerequisites for undertaking the basic courses in microbiology.

In order to increase the flexibility of the program, and to provide additional intellectual stimulation, students are encouraged to participate in tutored independent research for at least two, and ideally three or more, semesters. Independent research is available to both Honors College and other students, and often culminates with a report written in manuscript style by the student. This research may fulfill part of the department's capstone course requirement for the bachelor's degree with a major in microbiology.

Requirements for the Bachelor of Science Degree in Microbiology

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Science degree in Microbiology.
 The University's Tier II writing requirement for the Microbiology major is met by completing Microbiology 408. That course is referenced in item 3. b. (1) below.
 Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
2. The requirements of the College of Natural Science for the Bachelor of Science degree.
 The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
3. The following requirements for the major:

	CREDITS
a. The following courses outside the Department of Microbiology:	46 or 47
(1) All of the following courses (40 credits):	
BMB 461 Biochemistry I	3
BMB 462 Biochemistry II	3
BS 110 Organisms and Populations	4
BS 111 Cells and Molecules	3
BS 111L Cell and Molecular Biology Laboratory	2
CEM 141 General Chemistry	4
CEM 142 General and Inorganic Chemistry	3
CEM 161 Chemistry Laboratory I	1
CEM 162 Chemistry Laboratory II	1
CEM 251 Organic Chemistry I	3
CEM 252 Organic Chemistry II	3
CEM 255 Organic Chemistry Laboratory	2
PHY 231 Introductory Physics I	3
PHY 232 Introductory Physics II	3
PHY 251 Introductory Physics Laboratory I	1
PHY 252 Introductory Physics Laboratory II	1
(2) One of the following groups of courses (6 or 7 credits):	
(a) MTH 124 Survey of Calculus with Applications I	3
MTH 126 Survey of Calculus with Applications II	3
(b) MTH 132 Calculus I	3
MTH 133 Calculus II	4
(c) MTH 124 Survey of Calculus with Applications I	3
and	
STT 231 Statistics for Scientists	3
Or	
STT 421 Statistics I	3
(d) MTH 132 Calculus I	3
and	
STT 231 Statistics for Scientists	3
or	
STT 421 Statistics I	3
b. The following courses in the Department of Microbiology and Molecular Genetics:	16
(1) All of the following courses (13 credits):	
MMG 301 Introductory Microbiology	3
MMG 302 Introductory Microbiology Laboratory	1
MMG 408 Advanced Microbiology Laboratory (W)	3
MMG 409 Eukaryotic Cell Biology	3
MMG 431 Microbial Genetics	3
(2) One of the following two options (3 credits):	
(a) MMG 491 Current Topics in Microbiology	3
(b) MMG 492 Undergraduate Research Seminar	1
One of the following courses:	
MMG 499 Undergraduate Research	2
MMG 499H Honors Research	2
The completion of Microbiology 491, or Microbiology 492 and 499 or 499H, fulfills the department's capstone course requirement.	
c. One of the following concentrations:	12 to 13
Advisers may recommend individual course options to accommodate student needs and abilities.	
General Microbiology	

MMG 421 Prokaryotic Cell Physiology 3
 Three courses from a list of approved electives 9 or 10
 Copies of this list are available in the department office.

- Cell and Molecular Biology**
1. All of the following courses (10 credits):
 - MMG 413 Virology 3
 - MMG 451 Immunology 3
 - ZOL 341 Fundamental Genetics 4
 2. One of the following courses (3 credits):
 - MMG 421 Prokaryotic Cell Physiology 3
 - MMG 433 Microbial Genomics 3
 - MMG 461 Molecular Pathogenesis 3
 - ZOL 342 Advanced Genetics 3
 - ZOL 344 Human Genetics 3

- Genomics and Molecular Genetics**
1. Both of the following courses (7 credits):
 - MMG 433 Microbial Genomics 3
 - ZOL 341 Fundamental Genetics 4
 2. Two of the following courses (6 credits):
 - MMG 413 Virology 3
 - MMG 421 Prokaryotic Cell Physiology 3
 - MMG 445 Basic Biotechnology 3
 - MMG 451 Immunology 3
 - ZOL 342 Advanced Genetics 3
 - ZOL 344 Human Genetics 3

- Medical Microbiology and Immunology**
1. The following courses (9 credits):
 - MMG 413 Virology 3
 - MMG 451 Immunology 3
 - MMG 461 Molecular Pathogenesis 3
 2. One of the following courses (3 credits):
 - EPI 390 Disease in Society: An Introduction to Epidemiology and Public Health 3
 - FSC 440 Food Microbiology 3
 - MMG 421 Prokaryotic Cell Physiology 3
 - MMG 463 Medical Microbiology 3

- Microbial Biotechnology**
1. All of the following courses (9 credits):
 - MMG 421 Prokaryotic Cell Physiology 3
 - MMG 433 Microbial Genomics 3
 - MMG 445 Basic Biotechnology 3
 2. One of the following courses (3 credits):
 - CHE 491 Selected Topics in Chemical Engineering 3
 - FSC 440 Food Microbiology 3
 - MMG 413 Virology 3
 - MMG 425 Microbial Ecology 3
 - MMG 451 Immunology 3
 - Topic of Chemical Engineering 491 restricted to Multidisciplinary Bioprocessing Laboratory.

GRADUATE STUDY

The Department of Microbiology and Molecular Genetics is administered jointly by the colleges of Natural Science, Human Medicine, Osteopathic Medicine, and Veterinary Medicine. Study for the Master of Science degree in microbiology or the Doctor of Philosophy degree in microbiology and molecular genetics may be administered by any one of the four colleges referenced above. Study for the Master of Science degree in industrial microbiology is administered solely by the College of Natural Science. Study for the Doctor of Philosophy degree with a major in microbiology—environmental toxicology is administered by the College of Veterinary Medicine.

The Department of Microbiology and Molecular Genetics is affiliated with the Doctor of Philosophy degree program with a major in ecology, evolutionary biology and behavior. For information about a Doctor of Philosophy degree program that involves ecology, evolutionary biology and behavior and a major in the Department of Microbiology and Molecular Genetics, refer to the statement on the doctoral program in ecology, evolutionary biology and behavior.

Students who are enrolled in the Master of Science degree program in the Department of Microbiology and Molecular Genetics may elect a Specialization in Ecology, Evolutionary Biology and Behavior. For additional information, refer to the statement on the specialization.

Students who are enrolled in Master of Science degree programs in the Department of Microbiology and Molecular Genetics may elect a Specialization in Food Safety. For additional information, refer to the statement on the specialization in the *College of Veterinary Medicine* section of this catalog.

INDUSTRIAL MICROBIOLOGY

Master of Science

Most students who are admitted to this program plan to enter industry after they graduate.

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

In general, applicants should have had the equivalent of an academic year each of physics, inorganic chemistry, and organic chemistry; one biochemistry course; mathematics through integral calculus; and one or more courses in the biological sciences. Applicants should have proficiency in written and spoken English, a minimum grade–point average of 3.00, and grades of 3.0 or above in science and mathematics courses. Scores on the Graduate Record Examination General Test and a personal letter of professional intent and objectives are required. Although preparation in the fundamentals of microbiology is desirable, interested students with degrees in any of the physical or biological sciences or mathematics are invited to apply for admission to the program. Applicants not possessing all of the requirements may be admitted to the program provisionally and permitted to make up deficiencies on a collateral basis.

Requirements for the Master of Science Degree in Industrial Microbiology

The student must complete 30 credits under Plan B (without thesis). The specific program of study, including an internship with an industrial partner, will be determined by the student's guidance committee. At least 7 credits of master's thesis research are required on topics appropriate for an industrial internship and as approved by the guidance committee or program director. The final oral examination, which covers both course work and thesis research, is administered by the student's guidance committee and a representative of the department's Graduate Committee.

All students in the program will be required to complete a **Certificate Program in Basic Business and Communication Skills**. The certificate program is organized as a series of week-end workshops covering such topics as project management, business law, intellectual property, management theory, finance, writing skills, presentation skills, information retrieval, interpersonal skills and group work. The certificate program offered by the faculty of The Eli Broad College of Business and the College of Communication Arts and Sciences, will include a case-study approach. It will normally be undertaken during the first year of enrollment and will involve an additional cost to the student beyond usual tuition and fees.

After the completion of the certificate program is approved by the Director of Executive Development Programs in The Eli Broad College of Business and by the Associate Dean of the College of Natural Science, the Office of the Registrar will enter on the student's academic record the name of the certificate program and the date it was completed. This certification will appear on the student's transcript upon completion of the requirements for the degree program.

MICROBIOLOGY

In general, qualified students will be admitted to graduate study leading directly to the Ph.D. degree in microbiology and molecular genetics. Students who are enrolled in the professional programs in the colleges of Human Medicine, Osteopathic Medicine, and Veterinary Medicine, or in professional programs in other colleges, may pursue a graduate degree in microbiology concurrently.

The objective of the graduate programs in microbiology is to provide basic education in various subdisciplines of microbiology and intensive research experience in specialty areas relative to the student's interest. In the master's program, students extend their comprehension of microbiology and cognate science through advanced course work, seminars, and research. The Doctor of Philosophy is a research-oriented degree; the emphasis is placed on original research, and the aim is to enable the student to become a self-educating and creative scholar. Facilities and opportunities are also available for post doctoral associates. Financial subsidy is available for qualified applicants.

A new graduate student in microbiology is advised by the Director of Graduate Studies until a major professor is chosen. This choice should be made by the end of the second semester of enrollment in the program. The major professor assists the student in selecting a guidance committee. The committee helps the student in planning a program of study. The program must be approved by the end of the third semester of enrollment in the program. A **Manual for Graduate Study in Microbiology** is available from the department. This manual contains a philosophy of graduate education and information about the department's master's and doctoral degree programs and related procedures.

Several members of the faculty of the Department of Microbiology and Molecular Genetics are appointed jointly in other departments or are affiliated with the NSF Science and Technology Center for Microbial Ecology or with the Michigan Biotechnology Institute. Some members of the faculty contribute to interdepartmental graduate programs of study.

Scheduled courses and research are offered at the W. K. Kellogg Biological Station located at Gull Lake, near Battle Creek.

Master of Science

Most students admitted to the M.S. program in microbiology have the Ph.D. degree as their eventual goal.

In addition to meeting the requirements of the University and of the College of Natural Science, Human Medicine, Osteopathic Medicine, or Veterinary Medicine, students must meet the requirements specified below.

Admission

In general, applicants should have had the equivalent of an academic year each of physics, inorganic chemistry, and organic chemistry; one biochemistry course; mathematics through integral calculus; and one or more courses in the biological sciences. Applicants should have proficiency in written and spoken English, a minimum grade–point average of 3.00, and grades of 3.0 or above in science and mathematics courses. Scores on the Graduate Record Examination General Test and a personal letter of professional intent and objectives are required. Although preparation in the fundamentals of microbiology is desirable, interested students with degrees in any of the physical or biological sciences or mathematics are invited to apply for admission to the program. Applicants not possessing all of the requirements may

be admitted to the program provisionally and permitted to make up deficiencies on a collateral basis.

Requirements for the Master of Science Degree in Microbiology

The student must complete 30 credits under Plan A (with thesis). At least 5 credits of master's thesis research are required. The final oral examination, which covers both course work and thesis research, is administered by the student's guidance committee and a representative of the department Graduate Committee. The examining committee recommends a grade for the thesis research and the advisability of further graduate study. All master's students are required to participate in laboratory teaching, and are expected to attend departmental seminars.

Doctor of Philosophy

In addition to meeting the requirements of the University and of the College of Natural Science, Human Medicine, Osteopathic Medicine, or Veterinary Medicine, students must meet the requirements specified below.

Admission

A student may apply for admission to the doctoral program in Microbiology and Molecular Genetics when the individual is about to earn or has earned a Bachelor of Science, Bachelor of Arts, Master of Science, or a professional medical degree. In general, applicants should have had the equivalent of an academic year each of physics, inorganic chemistry, and organic chemistry; one biochemistry course; mathematics through integral calculus; and one or more courses in the biological sciences. Applicants should have proficiency in written and spoken English, a minimum grade–point average of 3.00, and grades of 3.0 or above in science and mathematics courses. Scores on the Graduate Record Examination General Test and a personal letter of professional intent and objectives are required. Although preparation in the fundamentals of microbiology is desirable, interested students with degrees in any of the physical or biological sciences or mathematics are invited to apply for admission to the program. Applicants not possessing all of the requirements may be admitted to the program provisionally and permitted to make up deficiencies on a collateral basis.

Requirements for the Doctor of Philosophy Degree in Microbiology and Molecular Genetics

The student must:

1. Complete a minimum of five graduate courses (excluding topics and seminar courses) covering the areas of genetics, microbiology, and biochemistry. At least two of these courses must be offered by the Department of Microbiology and Molecular Genetics.
2. Complete four graduate seminar courses, each of which involves an oral presentation by the student.
3. Complete at least two, and preferably three, rotations in the laboratories of different faculty members in the Department of Microbiology and Molecular Genetics. This requirement must be completed by the end of the first calendar year of enrollment in the program.
4. Pass the preliminary examination, which involves an oral defense of the research proposal. This examination is normally given at the end of the second year of enrollment in the program.

5. Submit a dissertation and a publishable manuscript, based on original research and representing a new and significant contribution to knowledge.

All doctoral students in microbiology and molecular genetics are required to participate in laboratory teaching, and are expected to attend departmental seminars.

Academic Standards

Failure to pass the preliminary examination will result in dismissal from the program.

MICROBIOLOGY—ENVIRONMENTAL TOXICOLOGY

Doctor of Philosophy

For information about the Doctor of Philosophy degree program in microbiology—environmental toxicology, refer to the statement on *Multidepartmental Doctoral Programs in Environmental Toxicology* in the *Graduate Education* section of this catalog.

DEPARTMENT of PHYSICS and ASTRONOMY

Wolfgang W. Bauer, Chairperson

Physics is the study of the physical universe. By means of observation, experiment and theoretical constructions it attempts to find the principles which describe that universe. Light, matter, sound, electricity and magnetism, energy, force and motion, atomic and nuclear structure, nuclear reactions, condensed matter, elementary particles and particle accelerators are among the topics of physics. A study of physics provides the basic understanding of nature and involves the analytical skills essential for solving environmental problems, advancing biomedical systems, and developing cutting-edge technology of the 21st century. A physics major is appropriate for the preprofessional student.

Astronomy is the study of the universe beyond the earth. The laws of physics, as they are known from laboratory experiments, are applied to interstellar gas, stars, galaxies, and space itself in an attempt to deduce the detailed physical state of these entities. Astrophysics frequently involves a study of matter under extreme conditions that cannot be duplicated in the laboratory, and from this point of view the universe becomes a laboratory in which naturally occurring phenomena subject matter to very large ranges of physical parameters. Cosmology, a branch of astronomy, attempts to use the properties of the universe, as they are known now, to understand its history and its probable future development.

The department offers diverse courses in physics and astronomy. Undergraduate programs with different emphases may be planned through an appropriate choice of electives from the departmental courses. Other interests may be pursued by concentrating the electives in geophysics, computer science, electrical engineering, or other branches of engineering.

UNDERGRADUATE PROGRAMS

Bachelor of Science

PHYSICS

The Bachelor of Science degree with a major in physics is designed to provide a thorough foundation in the field of physics together with considerable background in mathematics and a balanced program in the liberal arts. It is designed for those with an interest in:

- Graduate Study.** Within the requirements listed below, the student's electives should emphasize theory in such areas as electricity and magnetism, quantum mechanics, additional mathematics, and computer programming.
- Experimental Physics** as a preparation for positions in government and industry. Students taking this program have an opportunity to obtain a basic background in mechanics, electricity and electronics, thermodynamics, optics, and modern physics. They will also have an opportunity to acquire strong experimental training in at least two and probably three of the following areas: electronics, modern optics, nuclear physics, and solid state (materials) physics. Computer programming courses and experience are strongly recommended.

Recommended programs of study are available in a Department of Physics and Astronomy brochure.

Requirements for the Bachelor of Science Degree in Physics

- The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Science degree in Physics.
The University's Tier II writing requirement for the Physics major is met by completing one of the clusters of courses referenced in item 3. b. (2) below.
Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
- The requirements of the College of Natural Science for the Bachelor of Science degree.
The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
- The following requirements for the major:

	CREDITS
a. The following courses outside the Department of Physics and Astronomy:	31 or 32
(1) One of the following courses (3 or 4 credits):	
BOT 105 Plant Biology	3
BS 110 Organisms and Populations	4
BS 111 Cells and Molecules	3
ENT 205 Pests, Society and Environment	3
MMG 205 Allied Health Microbiology	3
PSL 250 Introductory Physiology	4
ZOL 141 Introductory Human Genetics	3
(2) One of the following pairs of courses (7 credits):	
(a) CEM 141 General Chemistry	4
CEM 142 General and Inorganic Chemistry	3
(b) CEM 151 General and Descriptive Chemistry	4
CEM 152 Principles of Chemistry	3
(3) All of the following courses (21 credits):	
CEM 161 Chemistry Laboratory I	1
MTH 132 Calculus I	3
MTH 133 Calculus II	4
MTH 234 Multivariable Calculus	4
MTH 235 Differential Equations	3
Two Mathematics courses at the 300 level or above of at least 3 credits each (6 credits).	
b. The following courses in the Department of Physics and Astronomy:	34 to 48
(1) All of the following courses (21 credits):	
PHY 191 Physics Laboratory for Scientists, I	1
PHY 192 Physics Laboratory for Scientists, II	1

PHY 321	Classical Mechanics I	3
PHY 410	Thermal and Statistical Physics	3
PHY 440	Electronics	4
PHY 451	Advanced Laboratory	3
PHY 471	Quantum Physics I	3
PHY 481	Electricity and Magnetism I	3
(2)	One of the following clusters of courses (4 to 6 credits):	
(a)	Thesis cluster:	
PHY 390	Physics Journal Seminar	1
PHY 490	Senior Thesis	3
(b)	Lecture course cluster:	
PHY 491	Atomic, Molecular, and Condensed Matter Physics	3
PHY 492	Nuclear and Elementary Particle Physics	3
(3)	One of the following courses (3 or 4 credits):	
PHY 183	Physics for Scientists and Engineers I	4
PHY 183B	Physics for Scientists and Engineers I, CBI	4
PHY 193H	Honors Physics I—Mechanics	3
(4)	One of the following courses (3 or 4 credits):	
PHY 184	Physics for Scientists and Engineers II	4
PHY 184B	Physics for Scientists and Engineers II, CBI	4
PHY 294H	Honors Physics II—Electromagnetism	3
(5)	One of the following courses (3 credits):	
PHY 215	Thermodynamics and Modern Physics	3
PHY 215B	Thermodynamics and Modern Physics, CBI	3
	The completion of Physics 390 and 490, or Physics 491 and 492, fulfills the department's capstone course requirement.	

ASTROPHYSICS

The Bachelor of Science degree with a major in Astrophysics is designed to provide an extensive background in both physics and astrophysics; a student who graduates with this degree may apply for admission to graduate study in either astronomy or physics.

Requirements for the Bachelor of Science Degree in Astrophysics

- The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Science degree in Astrophysics.
The University's Tier II writing requirement for the Astrophysics major is met by completing Astronomy and Astrophysics 301 and 3 or 4 credits of Astronomy and Astrophysics 410. Those courses are referenced in item 3. b. (1) below.
Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
- The requirements of the College of Natural Science for the Bachelor of Science degree.
The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
- The following requirements for the major:

	CREDITS
a. The following courses outside the Department of Physics and Astronomy:	25 or 26
(1) One of the following courses (3 or 4 credits):	
BS 110 Organisms and Populations	4
BS 111 Cells and Molecules	3
ENT 205 Pests, Society and Environment	3
MMG 205 Allied Health Microbiology	3
PLB 105 Plant Biology	3
PSL 250 Introductory Physiology	4
ZOL 141 Introductory Human Genetics	3
(2) One of the following pairs of courses (7 credits):	
(a) CEM 141 General Chemistry	4
CEM 142 General and Inorganic Chemistry	3
(b) CEM 151 General and Descriptive Chemistry	4
CEM 152 Principles of Chemistry	3
(3) All of the following courses (15 credits):	
CEM 161 Chemistry Laboratory I	1
MTH 132 Calculus I	3
MTH 133 Calculus II	4
MTH 234 Multivariable Calculus	4
MTH 235 Differential Equations	3
b. The following courses in the Department of Physics and Astronomy:	39 to 42
(1) All of the following courses (30 or 31 credits):	
AST 303 Planetary System Astronomy	3
AST 304 Stars	3
AST 307 The Milky Way	3
AST 308 Galaxies and Cosmology	3

AST 312	Observational Astronomy	1
AST 410	Senior Thesis	3 or 4
PHY 191	Physics Laboratory for Scientists, I	1
PHY 192	Physics Laboratory for Scientists, II	1
PHY 321	Classical Mechanics I	3
PHY 410	Thermal and Statistical Physics	3
PHY 471	Quantum Physics I	3
PHY 481	Electricity and Magnetism I	3
The student must enroll in Astronomy and Astrophysics 410 in each of two different semesters for a total of 3 or 4 credits.		
The completion of Astronomy and Astrophysics 410 fulfills the department's capstone course requirement.		
(2)	One of the following courses (3 or 4 credits):	
	PHY 183 Physics for Scientists and Engineers I	4
	PHY 183B Physics for Scientists and Engineers I	4
	PHY 193H Honors Physics I—Mechanics	3
(3)	One of the following courses (3 or 4 credits):	
	PHY 184 Physics for Scientists and Engineers II	4
	PHY 184B Physics for Scientists and Engineers II	4
	PHY 294H Honors Physics II—Electromagnetism	3
(4)	One of the following courses (3 credits):	
	PHY 215 Thermodynamics and Modern Physics	3
	PHY 215B Thermodynamics and Modern Physics	3

PHY 492	Nuclear and Elementary Particle Physics	3
(3)	One of the following courses (3 or 4 credits):	
	PHY 183 Physics for Scientists and Engineers I	4
	PHY 183B Physics for Scientists and Engineers I, CBI	4
	PHY 193H Honors Physics I—Mechanics	3
(4)	One of the following courses (3 or 4 credits):	
	PHY 184 Physics for Scientists and Engineers II	4
	PHY 184B Physics for Scientists and Engineers II, CBI	4
	PHY 294H Honors Physics II—Electromagnetism	3
(5)	One of the following courses (3 credits):	
	PHY 215 Thermodynamics and Modern Physics	3
	PHY 215B Thermodynamics and Modern Physics, CBI	3
(6)	One of the following courses (3 or 4 credits):	
	PHY 431 Optics I	3
	PHY 440 Electronics	4
(7)	One of the following courses (3 credits):	
	PHY 471 Quantum Physics I	3
	PHY 481 Electricity and Magnetism I	3
The completion of Physics 390 and 490 or Physics 491 and 492, fulfills the department's capstone course requirement.		

Bachelor of Arts

The Bachelor of Arts degree with a major in physics is provided for those students who wish a physics major combined with a broader education in the liberal arts than the Bachelor of Science degree program permits. This degree program is also suitable for those students who plan to meet the requirements for teacher certification.

Requirements for the Bachelor of Arts Degree in Physics

- The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Arts degree in Physics.
The University's Tier II writing requirement for the Physics major is met by completing one of the clusters of courses referenced in item 3. b. (2) below.
Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
- The requirements of the College of Natural Science for the Bachelor of Arts degree.
The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
- The following requirements for the major:

		CREDITS
a.	The following courses outside the Department of Physics and Astronomy:	25 or 26
(1)	One of the following courses (3 or 4 credits):	
	BOT 105 Plant Biology	3
	BS 110 Organisms and Populations	4
	BS 111 Cells and Molecules	3
	ENT 205 Pests, Society and Environment	3
	MMG 205 Allied Health Microbiology	3
	PSL 250 Introductory Physiology	4
	ZOL 141 Introductory Human Genetics	3
(2)	One of the following courses (4 credits):	
	CEM 141 General Chemistry	4
	CEM 151 General and Descriptive Chemistry	4
(3)	All of the following courses (18 credits):	
	CEM 161 Chemistry Laboratory I	1
	MTH 132 Calculus I	3
	MTH 133 Calculus II	4
	MTH 234 Multivariable Calculus	4
	MTH 235 Differential Equations	3
	One Mathematics course at the 300 level or above of at least 3 credits.	
b.	The following courses in the Department of Physics and Astronomy:	27 to 32
(1)	All of the following courses (8 credits):	
	PHY 191 Physics Laboratory for Scientists, I	1
	PHY 192 Physics Laboratory for Scientists, II	1
	PHY 321 Classical Mechanics I	3
	PHY 410 Thermal and Statistical Physics	3
(2)	One of the following clusters of courses (4 to 6 credits):	
(a)	Thesis cluster:	
	PHY 390 Physics Journal Seminar	1
	PHY 490 Senior Thesis	3
(b)	Lecture course cluster:	
	PHY 491 Atomic, Molecular, and Condensed Matter Physics	3

PHYSICS and GEOPHYSICS

The Bachelor of Science degree with a major in physics and geophysics is designed to provide a thorough foundation in the field of physics, considerable background in the geological sciences and mathematics, and a balanced program in the liberal arts. The degree program is designed for those with an interest in graduate study in the geological sciences or employment in the environmental or energy sector.

A Bachelor of Science degree in Geophysics is also available and is administered by the Department of Geological Sciences. For additional information, refer to the Department of Geological Sciences section of this catalog.

Requirements for the Bachelor of Science Degree in Physics and Geophysics

- The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Science in Physics and Geophysics.
The University's Tier II writing requirement for the Physics and Geophysics major is met by completing Physics 431, 440, and 451. Those courses are referenced in item 3. b. (1) below.
Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
- The requirements of the College of Natural Science for the Bachelor of Science degree.
The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
- The following requirements for the major:

		CREDITS
a.	The following courses outside the Department of Physics and Astronomy:	44 or 45
(1)	One of the following courses (3 or 4 credits):	
	BOT 105 Plant Biology	3
	BS 110 Organisms and Populations	4
	BS 111 Cells and Molecules	3
	ENT 205 Pests, Society and Environment	3
	MMG 205 Allied Health Microbiology	3
	PSL 250 Introductory Physiology	4
	ZOL 141 Introductory Human Genetics	3
(2)	One of the following pairs of courses (7 credits):	
(a)	CEM 141 General Chemistry	4
	CEM 142 General and Inorganic Chemistry	3
(b)	CEM 151 General and Descriptive Chemistry	4
	CEM 152 Principles of Chemistry	3
(3)	All of the following courses (15 credits):	
	CEM 161 Chemistry Laboratory I	1
	MTH 132 Calculus I	3
	MTH 133 Calculus II	4
	MTH 234 Multivariable Calculus	4
	MTH 235 Differential Equations	3
(4)	All of the following courses in the Department of Geological Sciences (19 credits):	
	GLG 201 The Dynamic Earth	4
	GLG 304 Physical and Biological History of the Earth	4
	GLG 411 Hydrogeology	4

NATURAL SCIENCE
Department of Physics and Astronomy

GLG 470 Principles of Modern Geophysics	3
GLG 471 Applied Geophysics	4
b. The following courses in the Department of Physics and Astronomy:	33 to 35
(1) All of the following courses (27 credits):	
PHY 191 Physics Laboratory for Scientists, I	1
PHY 192 Physics Laboratory for Scientists, II	1
PHY 215 Thermodynamics and Modern Physics	3
PHY 321 Classical Mechanics I	3
PHY 410 Thermal and Statistical Physics	3
PHY 431 Optics I	3
PHY 440 Electronics	4
PHY 451 Advanced Laboratory	3
PHY 471 Quantum Physics I	3
PHY 481 Electricity and Magnetism I	3
(2) One of the following courses (3 or 4 credits):	
PHY 183 Physics for Scientists and Engineers I	4
PHY 193H Honors Physics I-Mechanics	3
(3) One of the following courses (3 or 4 credits):	
PHY 184 Physics for Scientists and Engineers II	4
PHY 294H Honors Physics II-Electromagnetism	3
The completion of Geological Sciences 470 and 471, or Physics 390 and 490, fulfills the department's capstone course requirement.	

TEACHER CERTIFICATION OPTIONS

The physics disciplinary majors leading to the Bachelor of Arts and Bachelor of Science degrees are available for teacher certification.

A physics disciplinary minor is also available for teacher certification.

Students who elect a physics disciplinary major or the physics disciplinary minor must contact the Department of Physics and Astronomy.

For additional information, refer to the statement on *TEACHER CERTIFICATION* in the *Department of Teacher Education* section of this catalog.

GRADUATE STUDY

The Department of Physics and Astronomy offers graduate programs leading to the Master of Science and Doctor of Philosophy degrees.

Current experimental research programs include work in condensed matter physics, low- and medium-energy nuclear physics, elementary particles, low-temperature physics, cyclotron design, and astronomy. Theoretical studies are in progress in astrophysics and in elementary particle, nuclear, and condensed matter physics.

Students who are enrolled in master's or doctoral degree programs in the Department of Physics and Astronomy may elect an Interdepartmental Specialization in Cognitive Science. For additional information, refer to the statement on *Interdepartmental Graduate Specializations in Cognitive Science* in the *College of Social Science* section of this catalog. For additional information, contact the Department of Physics and Astronomy.

ASTROPHYSICS AND ASTRONOMY

The aim of the Master of Science and Doctor of Philosophy degree programs in astrophysics and astronomy is to help students to develop the ability to perform independent research and to teach in this field.

Master of Science

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

For admission to the master's degree program in astrophysics and astronomy on regular status, the student must have:

1. Completed mathematics and astronomy or physics courses equivalent to those that are required for an undergraduate major in physics or astronomy.
2. A satisfactory grade-point average, normally at least 3.00, in the courses referenced in item 1. above.

Students who do not meet the requirements for admission to the program on regular status may be admitted on a provisional basis to remove deficiencies.

Requirements for the Master of Science Degree in Astrophysics and Astronomy

The student must:

1. Complete a total of 30 credits for the degree under either Plan A (with thesis) or Plan B (without thesis).
2. Pass with a grade of 3.0 (B) or better *each* course in a set of core courses in physics and astronomy that covers classical mechanics, statistical mechanics, electricity and magnetism, quantum mechanics, radiation astrophysics, stellar astrophysics, galactic and extra galactic dynamics, and astronomical instrumentation and data analysis.
3. Pass with a grade of 3.0 (B) or better the qualifying examination based on undergraduate and first-year graduate-level physics and astronomy courses. This examination is offered in the fall and spring semesters and must be taken by the middle of the second year of enrollment in the program, unless the student receives permission to take the examination later. Detailed regulations and sample examinations are available from the departmental office.

Doctor of Philosophy

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

For admission to the doctoral degree program in astrophysics and astronomy on regular status, the student must have:

1. Completed mathematics and astronomy or physics courses equivalent to those that are required for an undergraduate major in physics or astronomy.
2. A satisfactory grade-point average, normally at least 3.00, in the courses referenced in item 1. above.

Students who do not meet the requirements for admission to the program on regular status may be admitted on a provisional basis to remove deficiencies.

Requirements for the Doctor of Philosophy Degree in Astrophysics and Astronomy

The student must:

1. Pass with a grade of 3.0 (B) or better **each** course in a set of core courses in physics and astronomy that covers classical mechanics, statistical mechanics, electricity and magnetism, quantum mechanics, radiation astrophysics, stellar astrophysics, galactic and extra galactic dynamics, and astronomical instrumentation and data analysis.
2. Pass with a grade of 4.0 (A) the qualifying examination based on undergraduate and first-year graduate-level physics and astronomy courses. This examination is offered in the fall and spring semesters and must be taken by the

middle of the second year of enrollment in the program, unless the student receives permission to take the examination later. Detailed regulations and sample examinations are available from the departmental office.

3. Complete a dissertation that presents the results of an original observational or theoretical investigation.
4. Complete one semester of half-time teaching.

CHEMICAL PHYSICS

For information about the Doctor of Philosophy degree program with a major in chemical physics, refer to the statement on the *Department of Chemistry*.

PHYSICS

Master of Science

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

For admission to the master's degree program in physics on regular status, the student must have:

1. Completed physics and mathematics courses equivalent to those that are required for an undergraduate major in physics.
2. A satisfactory grade-point average, normally at least 3.00, in the courses referenced in item 1. above.

Students who do not meet the requirements for admission to the program on regular status may be admitted on a provisional basis to remove deficiencies.

Requirements for the Master of Science Degree in Physics

The student must complete a total of 30 credits for the degree under either Plan A (with thesis) or Plan B (without thesis).

A grade of at least 3.0 (B) on the qualifying examination based on first-year graduate-level physics courses in classical mechanics, quantum mechanics, electrodynamics, and statistical mechanics is required. This examination is offered in the fall and spring semesters and must be taken the first time that it is offered after the student has completed his or her first year of graduate study. Detailed regulations and sample examinations are available from the departmental office.

Doctor of Philosophy

In addition to meeting the requirements of the University and the College of Natural Science, students must meet the requirements specified below.

Admission

For admission to the doctoral degree program in physics on regular status, the student must have:

1. Completed physics and mathematics courses equivalent to those that are required for an undergraduate major in physics.
2. A grade-point average of at least 3.00 in the courses referenced in item 1. above.

Evidence of some undergraduate or post graduate research experience is desirable.

Students who do not meet the requirements for admission to the program on regular status may be admitted on a provisional basis to remove deficiencies.

Requirements for the Doctor of Philosophy Degree in Physics

A grade of 4.0 (A) on the qualifying examination based on first-year graduate-level physics courses in classical mechanics, quantum mechanics, electrodynamics, and statistical mechanics is required. This examination is offered in the fall and spring semesters and must be taken the first time that it is offered after the student has completed his or her first year of graduate study. Detailed regulations and sample examinations are available from the departmental office. A dissertation presenting the results of an original laboratory or theoretical investigation is required. One semester of half-time teaching is also required.

DEPARTMENT of PHYSIOLOGY

William S. Spielman, Chairperson

The Department of Physiology is administered jointly by the colleges of Natural Science, Human Medicine, Osteopathic Medicine, and Veterinary Medicine.

Physiology is the study of the basic physicochemical processes which occur in living organisms. Its unique concerns are integrative and regulatory phenomena of cells, tissues, and organs. Examples of these are physical and chemical communication among nerve cells in the brain; digestion and absorption of food; exchange of carbon dioxide and oxygen in the lungs and in other tissues; regulation of the blood pressure and performance of the heart; control of secretion of hormones by the brain; the effect of hormones on target tissues; and the implantation, growth, and delivery of the fetus. Physiologists study the impact of stress on these functions, including the stresses of exercise, acceleration, hemorrhage, temperature, humidity, radiation, aging, pregnancy, environmental toxins, and disease, and they study the comparative aspects of these functions in different animals.

Physiology integrates the physics and chemistry of biological systems to describe the functions of the parts of the body or of the organism as a whole. Consequently, the student of physiology must have a basic understanding of cell biology, zoology, physics, chemistry, and mathematics. Because the Doctor of Philosophy is usually the working degree for professional physiologists, the undergraduate program in physiology is designed to provide preparation for advanced study in physiology. This program is also designed to prepare students for graduate study in other areas of applied biology, and can serve as preprofessional training.

UNDERGRADUATE PROGRAM

Requirements for the Bachelor of Science Degree in Physiology

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Science degree in Physiology.

The University's Tier II writing requirement for the Physiology major is met by completing two of the following courses: Physiology 440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450. Those courses are referenced in item 3. b. (2) below.

Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described

NATURAL SCIENCE
Department of Physiology

in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.

2. The requirements of the College of Natural Science for the Bachelor of Science degree.

The completion of the Biological Science, Chemistry, Mathematics, and Physics courses referenced in requirement 3. below satisfies the requirements referenced in item 3.a.(1) through (5) under the heading *Graduation Requirements* in the College statement. The credits earned in other courses referenced in requirement 3. below may be counted toward other College requirements as appropriate.

3. The following requirements for the major:

	CREDITS
a. The following courses outside the Department of Physiology: . . .	64 to 66
(1) All of the following courses (43 credits):	
BMB 461 Biochemistry I	3
BMB 462 Biochemistry II	3
BS 110 Organisms and Populations	4
BS 111 Cells and Molecules	3
BS 111L Cell and Molecular Biology Laboratory	2
CEM 141 General Chemistry	4
CEM 142 General and Inorganic Chemistry	3
CEM 161 Chemistry Laboratory I	1
CEM 162 Chemistry Laboratory II	1
CEM 251 Organic Chemistry I	3
CEM 252 Organic Chemistry II	3
CEM 255 Organic Chemistry Laboratory	2
CEM 383 Introductory Physical Chemistry I	3
PHY 231 Introductory Physics I	3
PHY 232 Introductory Physics II	3
PHY 251 Introductory Physics Laboratory I	1
PHY 252 Introductory Physics Laboratory II	1
(2) One of the following courses (3 or 4 credits):	
ANT 316 General Human Anatomy	3
KIN 216 Applied Human Anatomy	3
ZOL 320 Developmental Biology	4
ZOL 328 Comparative Anatomy and Biology of Vertebrates	4
(3) One of the following pairs of courses (6 or 7 credits):	
(a) MTH 132 Calculus I	3
MTH 133 Calculus II	4
(b) MTH 124 Survey of Calculus with Applications I	3
MTH 126 Survey of Calculus with Applications II	3
(4) Twelve credits in nonscience courses beyond the credits that are counted toward University requirements.	
b. The following courses in the Department of Physiology:	15
(1) All of the following courses (11 credits):	
PSL 410 Computational Problem Solving in Physiology	3
PSL 431 Human Physiology I	3
PSL 432 Human Physiology II	3
PSL 475 Capstone Laboratory in Physiology	2
The completion of Physiology 475 satisfies the department's capstone course requirement.	
(2) Two of the following courses (4 credits):	
PSL 440 Topics in Cell Physiology	2
PSL 441 Topics in Endocrinology	2
PSL 442 Topics in Cardiovascular Physiology	2
PSL 443 Topics in Respiratory Physiology	2
PSL 445 Topics in Environmental Physiology	2
PSL 446 Topics in Visual Physiology	2
PSL 447 Topics of Brain Function	2
PSL 448 Topics in Gastrointestinal Physiology	2
PSL 449 Developmental Neurophysiology	2
PSL 450 Laboratory in Human Physiology	2

GRADUATE STUDY

The Department of Physiology is administered jointly by the colleges of Natural Science, Human Medicine, Osteopathic Medicine, and Veterinary Medicine. Study for the Master of Science or Doctor of Philosophy degree with a major in physiology may be administered by any one of the four colleges referenced above. Study for the Doctor of Philosophy degree with a major in physiology—environmental toxicology is administered by the College of Veterinary Medicine.

Students who are enrolled in master's or doctoral degree programs in the Department of Physiology may elect an Interdepartmental Specialization in Cognitive Science. For additional information, refer to the statement on *Interdepartmental Graduate Specializations in Cognitive Science* in the *College of Social Science* section of this catalog. For additional information, contact the Department of Physiology.

PHYSIOLOGY

The department offers work leading to the Doctor of Philosophy degree and in some cases to the Master of Science degree. The principal objectives of graduate education in physiology are to obtain broad, basic knowledge in the subject matter of this and related fields, and to obtain training in physiological research methods. Major emphasis is placed upon the completion by the student of original research which should provide a significant contribution to knowledge. The facilities and staff are particularly suited to offer training in the following areas of physiology: cellular and molecular physiology, endocrinology, the cardiovascular system, gastrointestinal physiology and metabolism, neurophysiology, respiration, radiobiology, lactation, renal function, reproduction, comparative physiology, and biophysics.

A manual available at the department graduate office contains information on admission policies, financial support, and requirements for the Master of Science and Doctor of Philosophy degree programs in physiology. Departmental graduate stipends are awarded on the basis of merit, subject to the availability of funds.

Master of Science

In addition to meeting the requirements of the University and of the College of Natural Science, Human Medicine, Osteopathic Medicine, or Veterinary Medicine, students must meet the requirements specified below.

Admission

An undergraduate major in physiology is not a prerequisite to graduate study. However, a broad background in the basic sciences, including biology, chemistry, physics, and mathematics (through calculus), is essential. The minimum requirements include one year of physiology, biology, or zoology; one year each of mathematics and physics; and chemistry through organic and quantitative analysis. A deficiency in these requirements may be removed by successfully completing appropriate courses as collateral work early in the graduate program. Admission is based upon evaluation of the student's past record, results of the Graduate Record Examination, and recommendations.

Requirements for the Master of Science Degree in Physiology

The student must complete 30 credits under Plan A (with thesis). The program of study is planned by the student in consultation with a major adviser and an advisory committee that includes no fewer than two additional faculty members. Usually work in one or more supporting areas is required in addition to that taken in the major field. Completion of an original research problem and the writing of an acceptable thesis based upon at least 8 credits of research are required.

Doctor of Philosophy

In addition to meeting the requirements of the University and of the College of Natural Science, Human Medicine, Osteopathic Medicine, or Veterinary Medicine, students must meet the requirements specified below.

Admission

Entry into the Doctor of Philosophy degree program requires that the student has a major adviser and has earned 30 graduate credits, or holds a Master of Science or professional degree, or has passed the departmental Comprehensive Examination.

Requirements for the Doctor of Philosophy Degree in Physiology

Students entering a doctoral program with advanced standing must meet with the guidance committee within the first two semesters of doctoral study. The committee is composed of at least four faculty members, in addition to the major adviser, and must include one representative from another department. The course work, research program, and overall requirements needed to qualify for candidacy for the degree are planned in consultation with the guidance committee. However, the student's Guidance Committee Report is approved by the committee only after the student has demonstrated the potential to do research. Such potential may be demonstrated by any of the following:

- previous attainment of a master's degree with a thesis
- previous publication of research results
- other documented evidence of research capability.

The student must pass the Comprehensive Examination within the first two years of graduate study. The Comprehensive Examination which tests the student's breadth of knowledge in physiology, is administered by the Graduate and Professional Course and Curriculum Committee. The student prepares a thesis research proposal and presents the proposal to the faculty at a seminar. The proposal must be acceptable to the guidance committee. While the program is in progress, the student meets periodically with the guidance committee for evaluation.

A dissertation based on original research outlined in the proposal must be submitted to, approved by, and defended in an oral examination before the guidance committee. The dissertation is expected to show evidence of originality in its conception and execution and must be written in a clear and logical manner. Typically, three or more years of study beyond the bachelor's degree are needed to meet these requirements.

DEPARTMENT of PLANT BIOLOGY

Frank W. Ewers, Acting Chairperson

The Department of Plant Biology is administered jointly by the College of Natural Science and the College of Agriculture and Natural Resources.

The field of plant biology, also referred to as botany, concerns itself with the study of the structure, function, evolution, distribution, and classification of plants. The physiological, molecular, and biochemical mechanisms; systematics; development; inheritance; ecology; and geological history of plants are areas of plant biology pertinent to solving problems fundamental to all living organisms. Botanical research also contributes basic knowledge toward the discovery and improvement of plants for human use.

UNDERGRADUATE PROGRAMS

The Department of Plant Biology offers two Bachelor of Science degree programs: one in botany and one in environmental biology/botany.

BOTANY

The Bachelor of Science degree program with a major in botany is designed for students who plan to pursue careers in plant biotechnology firms, nurseries, botanical gardens, museums, herbaria, agricultural extension, or research laboratories, or who

plan to pursue graduate study in the field of plant biology or related disciplines.

The following concentrations are available to students who are enrolled in the botany program: (a) General Botany; (b) Ecology, Systematics, and Evolution; (c) Physiology and Molecular Biology; (d) Anatomy and Cell Biology; (e) Plant Protection; and (f) Botanical Gardens and Conservatories.

Requirements for the Bachelor of Science Degree in Botany

- The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Science degree in Botany.

The University's Tier II writing requirement for the Botany major is met by completing Botany 498 and 499 and one of the following courses: Botany 301, 416, or 441 or Zoology 355L or Plant Pathology 405 or 407. Those courses are referenced in items 3. e. and 3. g. below.

Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.

- The requirements of the College of Natural Science for the Bachelor of Science degree.
The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
- The following requirements for the major:

		CREDITS
a.	One of the following groups of courses (8 or 9 credits):	
(1)	BOT 105 Plant Biology	3
	BOT 106 Plant Biology Laboratory	1
	BS 110 Organisms and Populations	4
(2)	BOT 105 Plant Biology	3
	BOT 106 Plant Biology Laboratory	1
	BS 111 Cells and Molecules	3
	BS 111L Cell and Molecular Biology Laboratory	2
(3)	BS 110 Organisms and Populations	4
	BS 111 Cells and Molecules	3
	BS 111L Cell and Molecular Biology Laboratory	2
(4)	LBS 144 Biology I: Organismal Biology	4
	LBS 145 Biology II: Cellular and Molecular Biology	5
b.	One of the following pairs of courses (7 credits):	
(1)	CEM 141 General Chemistry	4
	CEM 142 General and Inorganic Chemistry	3
(2)	CEM 151 General and Descriptive Chemistry	4
	CEM 152 Principles of Chemistry	3
c.	One of the following pairs of courses (6 to 8 credits):	
(1)	BMB 200 Introduction to Biochemistry	4
	CEM 143 Survey of Organic Chemistry	4
(2)	CEM 251 Organic Chemistry I	3
	CEM 252 Organic Chemistry II	3
(3)	BMB 200 Introduction to Biochemistry	4
	CEM 251 Organic Chemistry I	3
d.	One of the following pairs of courses (6 to 8 credits):	
(1)	MTH 132 Calculus I	3
	MTH 133 Calculus II	4
(2)	MTH 124 Survey of Calculus I	3
	MTH 126 Survey of Calculus II	3
(3)	MTH 132 Calculus I	3
	STT 231 Statistics for Scientists	3
e.	All of the following courses (14 credits):	
	BOT 498 Undergraduate Research	3
	BOT 499 Senior Seminar	2
	CEM 161 Chemistry Laboratory I	1
	PHY 231 Introductory Physics I	3
	PHY 232 Introductory Physics II	3
	PHY 251 Introductory Physics Laboratory I	1
	PHY 252 Introductory Physics Laboratory II	1
f.	One of the following courses (3 or 4 credits):	
	CSS 350 Introduction to Plant Genetics	3
	ZOL 341 Fundamental Genetics	4
g.	One of the following five concentrations:	
	General Botany (22 to 26 credits)	
(1)	One course from each of the following groups (16 to 18 credits):	
(a)	Structure	
	BOT 202 The Plant Kingdom	3
	BOT 402 Biology of Fungi	3
	BOT 434 Plant Structure and Function	4
(b)	Ecology	
	BOT 441 Plant Ecology	3
	ZOL 355 Ecology	3
	ZOL 355L Ecology Laboratory	1

NATURAL SCIENCE
Department of Plant Biology

Both Zoology 355 and 355L combined, or Botany 441, must be completed to satisfy this requirement.

(c) Systematics
 BOT 218 Plants of Michigan 3
 BOT 418 Plant Systematics 3

(d) Physiology
 BOT 301 Introductory Plant Physiology 3
 BOT 412 Environmental Plant Physiology 3
 BOT 414 Plant Physiology: Metabolism 3
 BOT 415 Plant Physiology: Growth, Development and the Environment. 3

(e) Pathology
 PLP 405 Introductory Plant Pathology 4
 PLP 407 Diseases and Insects of Forest and Shade Trees. 4

(2) Two additional 300–400 level science courses (6 to 8 credits).

Anatomy and Cell Biology (25 to 29 credits)

(1) All of the following courses (10 credits):
 BOT 202 The Plant Kingdom 3
 BOT 434 Plant Structure and Function. 4
 MMG 409 Eukaryotic Cell Biology 3

(2) One course from **each** of the following groups of courses (12 to 15 credits):
 (a) BOT 301 Introductory Plant Physiology 3
 BOT 416 Experiments in Plant Physiology and Molecular Biology 4
 (b) BOT 414 Plant Physiology: Metabolism 3
 BOT 415 Plant Physiology: Growth, Development and the Environment. 3
 (c) BOT 218 Plants of Michigan 3
 BOT 418 Plant Systematics 3
 BOT 441 Plant Ecology 3
 ZOL 355 Ecology 3
 ZOL 355L Ecology Laboratory 1
 Both Zoology 355 and 355L combined, or Botany 218 or 418 or 441, must be completed to satisfy this requirement.
 (d) BMB 200 Introduction to Biochemistry 4
 BMB 401 Basic Biochemistry 4
 BMB 461 Biochemistry I 3

(3) One additional 300–400 level science course (3 or 4 credits).

Botanical Gardens and Conservatories (28 or 29 credits):

(1) All of the following courses (15 credits):
 AL 485 Museum Studies 3
 BOT 418 Plant Systematics 3
 BOT 495 Botanical Garden Internship 3
 CSS 210 Fundamentals of Soil and Landscape Science 3
 HRT 221 Greenhouse Structures and Management 3

(2) One of the following courses (3 credits):
 BOT 301 Introductory Plant Physiology 3
 BOT 412 Environmental Plant Physiology 3
 BOT 415 Plant Physiology: Growth, Development and the Environment. 3

(3) One of the following courses (4 credits):
 PLP 405 Introductory Plant Pathology 4
 PLP 407 Diseases and Insects of Forest and Shade Trees. 4

(4) Two of the following courses (6 or 7 credits):
 BOT 336 Useful Plants 3
 ENT 404 Insects: Success in Biodiversity 4
 ENT 477 Pest Management I: Pesticides in Management Systems. 3
 HRT 211 Landscape Plants I 3
 HRT 212 Landscape Plants II. 3
 FOR 460 Arboriculture 3
 FOR 461 Urban Forestry 3

Ecology, Systematics and Evolution (22 to 28 credits)

(1) All of the following courses (10 credits):
 BOT 441 Plant Ecology 3
 ZOL 355 Ecology 3
 ZOL 355L Ecology Laboratory 1
 ZOL 445 Evolution 3

(2) One course from **each** of the following groups of courses (6 or 7 credits):
 (a) BOT 202 The Plant Kingdom 3
 BOT 335 Plants Through Time 3
 BOT 402 Biology of Fungi 4
 BOT 434 Plant Structure and Function. 3
 (b) BOT 301 Introductory Plant Physiology 3
 BOT 412 Environmental Plant Physiology 3
 BOT 414 Plant Physiology: Metabolism 3
 BOT 415 Plant Physiology: Growth, Development and the Environment. 3

(3) One of the following options (3 or 7 credits):
 (a) BOT 418 Plant Systematics 3
 (b) BOT 218 Plants of Michigan 3
 BOT 423 Wetland Plants and Algae 4

(4) One additional 300–400 level science course (3 or 4 credits).

Physiology and Molecular Biology (21 to 26 credits):

(1) Three of the following courses (9 or 10 credits):
 BOT 301 Introductory Plant Physiology 3
 BOT 414 Plant Physiology: Metabolism 3

BOT 415 Plant Physiology: Growth, Development and the Environment. 3

BOT 416 Experiments in Plant Physiology and Molecular Biology 4

(2) Two of the following courses (6 to 8 credits):
 BOT 202 The Plant Kingdom 3
 BOT 402 Biology of Fungi 3
 BOT 418 Plant Systematics 4
 BOT 434 Plant Structure and Function. 4
 BOT 441 Plant Ecology 3
 MMG 409 Eukaryotic Cell Biology 3
 PLP 405 Introductory Plant Pathology 4
 Both Zoology 355 and 355L combined may be substituted for one of the courses listed above in partial fulfillment of this requirement.

(3) One of the following courses (3 or 4 credits):
 BMB 200 Introduction to Biochemistry 4
 BMB 401 Basic Biochemistry 4
 BMB 461 Biochemistry I 3

(4) One additional 300–400 level science course (3 or 4 credits).

Upon completion of the required courses for one of the five concentrations referenced above, the student should contact the Department of Plant Biology and request certification for the completion of the concentration. After the certification is approved by the Dean of the College of Natural Science, the Office of the Registrar will enter on the student's academic record the name of the concentration and the date that it was completed. This certification will appear on the student's transcript.

ENVIRONMENTAL BIOLOGY/BOTANY

The Bachelor of Science degree program in environmental biology/botany is designed for students who plan to pursue careers involving plants and the environment or who plan to pursue graduate study in the biological sciences. Graduates may be employed in nature organizations, environmental impact firms, or government.

Requirements for the Bachelor of Science Degree in Environmental Biology/ Botany

- The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Science degree in Environmental Biology/Botany. The University's Tier II writing requirement for the Environmental Biology/Botany major is met by completing the following courses: Botany 423, 498, and 499 and Zoology 355L. Those courses are referenced in item 3. a. below. Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
- The requirements of the College of Natural Science for the Bachelor of Science degree. The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
- The following requirements for the major:

	CREDITS
a. All of the following courses:	47
BOT 423 Wetland Plants and Algae	4
BOT 498 Undergraduate Research	3
BOT 499 Senior Seminar	2
CEM 141 General Chemistry	4
CEM 142 General and Inorganic Chemistry	3
CEM 161 Chemistry Laboratory I	1
CEM 251 Organic Chemistry I	3
CEM 252 Organic Chemistry II	3
CSS 210 Fundamentals of Soil and Landscape Science	3
GEO 221 Introduction to Geographic Information.	3
MTH 124 Survey of Calculus I	3
PHY 231 Introductory Physics I	3
PHY 232 Introductory Physics II.	3
PHY 251 Introductory Physics Laboratory I	1
PHY 252 Introductory Physics Laboratory II.	1
STT 231 Statistics for Scientists	3
ZOL 355 Ecology	3
ZOL 355L Ecology Laboratory	1
b. One of the following courses:	3
BOT 218 Plants of Michigan	3
BOT 418 Plant Systematics	3
c. One of the following courses:	3
BOT 301 Introductory Plant Physiology	3
BOT 412 Environmental Plant Physiology	3

	BOT 415	Plant Physiology: Growth, Development and the Environment	3	
d.	One of the following courses:		3 or 4	
	CSS 350	Introduction to Plant Genetics	3	
	ZOL 341	Fundamental Genetics	4	
e.	One of the following courses:		4	
	ENT 404	Insects: Success in Biodiversity	4	
	PLP 405	Introductory Plant Pathology	4	
	PLP 407	Diseases and Insects of Forest and Shade Trees	4	
f.	One of the following courses:		3	
	FW 410	Upland Ecosystem Management	3	
	FW 412	Wetland Ecosystem Management	3	
	FW 444	Conservation Biology	3	
g.	One of the following groups of courses:		8 or 9	
	(1)	BS 110 Organisms and Populations	4	
		BS 111 Cells and Molecules	3	
		BS 111L Cell and Molecular Biology Laboratory	2	
	(2)	LBS 144 Biology I: Organismal Biology	4	
		LBS 145 Biology II: Cellular and Molecular Biology	5	
	(3)	BOT 105 Plant Biology	3	
		BOT 106 Plant Biology Laboratory	1	
		BS 110 Organisms and Populations	4	
h.	Two 300–400 level courses relating to environmental biology approved by the Department of Plant Biology.		6 to 8	

mathematics, and physics, and appropriate training in the biological sciences.

Provisional admission may be granted to those students who do not meet the requirements for regular admission.

Requirements for the Master of Science Degree in Plant Biology

The master's degree program in plant biology is available under either Plan A (with thesis) or Plan B (without thesis). The student's program of study is arranged by a guidance committee which includes the major professor.

For either Plan A or Plan B, the student must:

1. Complete at least 30 credits including at least two graduate-level seminar courses in the biological sciences.
2. Acquire teaching experience by assisting in at least one course.

A reading knowledge of a foreign language may be required.

GRADUATE STUDY

The Department of Plant Biology is administered jointly by the College of Natural Science and the College of Agriculture and Natural Resources. The department offers Master of Science and Doctor of Philosophy degree programs with majors in plant biology. Those programs are referenced below. The department also offers Master of Science and Doctor of Philosophy degree programs with majors in plant breeding and genetics—botany and plant pathology through the College of Agriculture and Natural Resources. For information about those programs, refer to the statement on the *Department of Plant Biology in the College of Agriculture and Natural Resources* section of this catalog.

The Department of Plant Biology is affiliated with the Doctor of Philosophy degree program with a major in ecology, evolutionary biology and behavior. For information about a Doctor of Philosophy degree program that involves ecology, evolutionary biology and behavior and a major in the Department of Plant Biology, refer to the statement on the doctoral program in ecology, evolutionary biology and behavior.

Students who are enrolled in Master of Science degree programs in the Department of Plant Biology may elect a Specialization in Ecology, Evolutionary Biology and Behavior. For additional information, refer to the statement on the specialization.

PLANT BIOLOGY

Graduate students in plant biology may emphasize one or more of a number of special areas, including anatomy, bryology, cell biology, ecology, genetics, molecular biology, morphology, mycology, paleobotany, physiology, taxonomy, and various subdisciplines of plant pathology. Students are urged to take courses which provide a broad background in biological and physical sciences in addition to training in specialized areas.

Master of Science

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

Regular admission may be granted to those students who have a bachelor's degree or its equivalent, a 3.00 grade-point average exclusive of physical education, one year each of chemistry,

Doctor of Philosophy

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

Regular admission may be granted to those students who have a master's degree or its equivalent, a 3.00 grade-point average, and appropriate training in the biological sciences. Outstanding students without a master's degree may be accepted.

Provisional admission may be granted to those students who do not meet the requirements for regular admission.

Requirements for the Doctor of Philosophy Degree in Plant Biology

All doctoral students in plant biology must meet the requirements specified below:

1. Complete at least three graduate-level seminar courses in the biological sciences.
2. Pass a preliminary examination.
3. Acquire teaching experience by assisting in two courses.
4. Pass a final oral examination in defense of the dissertation.

Additional requirements, such as reading knowledge of one or two foreign languages, may be specified.

DEPARTMENT of PLANT PATHOLOGY

Raymond Hammerschmidt, Acting Chairperson

The Department of Plant Pathology is administered jointly by the College of Agriculture and Natural Resources and the College of Natural Science. The department offers Master of Science and Doctor of Philosophy degree programs with majors in plant pathology through the College of Agriculture and Natural Resources. For information about those programs, refer to the statement on the Department of Plant Pathology in the *College of Agriculture and Natural Resources* section of this catalog.

Students who are enrolled in Doctor of Philosophy degree programs in the Department of Plant Pathology may elect a Specialization in Biotechnology. For additional information, refer to the statement on the specialization.

Students who are enrolled in Master of Science degree programs in the Department of Plant Pathology may elect a Specialization in Food Safety. For additional information, refer to the statement on the specialization in the *College of Veterinary Medicine* section of this catalog.

DEPARTMENT of STATISTICS and PROBABILITY

Habib Salehi, Chairperson

Statistics is the study of methods of drawing inferences from sets of data. These methods are based on probability theory and depend for their application upon the existence of a **statistical regularity** in natural events. In the present century, tremendous strides have been made in the physical, biological, and social sciences as well as in engineering and business by the use of statistical methods and models to describe and aid in the explanation of basic phenomena. In the last few decades, a strong interest has developed in the intensive study of statistical inference aside from its uses, in the same way that physical sciences have developed aside from engineering.

UNDERGRADUATE PROGRAMS

The first two years of an undergraduate program in statistics stress development of a solid background in two areas: basic mathematics and computers. In addition, it is recommended that students planning to major in statistics complete either Statistics and Probability 201 or 231 in their freshman or sophomore years. The rest of the student's program involves a mixture of work selected from statistics, mathematics, computer programming, and possibly one or more fields of application. Statistics majors who plan to do graduate work should include advanced calculus in their undergraduate programs and should acquire proficiency in at least one of the following languages: French, German, or Russian.

Requirements for the Bachelor of Science or Bachelor of Arts Degree in Statistics

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits are required for the Bachelor of Science or Bachelor of Arts degree in Statistics.
 The University's Tier II writing requirement for the Statistics major is met by completing Mathematics 310 and Statistics and Probability 481. Those courses are referenced, respectively, in items 3. a. (1) and 3. b. (1) below.
 Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
2. The requirements of the College of Natural Science for the Bachelor of Science degree or Bachelor of Arts degree.
 The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
3. The following requirements for the major:

	CREDITS
a. The following courses outside the Department of Statistics and Probability:	16
(1) All of the following courses (10 credits):	

MTH 234 Multivariable Calculus	4
MTH 310 Abstract Algebra I and Number Theory.	3
MTH 314 Linear Algebra I.	3
(2) One of the following courses (3 credits):	
CSE 101 Computing Concepts and Competencies	3
CSE 131 Introduction to Technical Computing.	3
Students who pass a waiver examination for Computer Science and Engineering 101 will not be required to complete Computer Science and Engineering 101 or 131.	
(3) Three additional credits in Computer Science and Engineering courses.	
b. The following courses in the Department of Statistics and Probability:	19
(1) The following capstone course (1 credit):	
STT 481 Issues in Statistical Practice	1
(2) One of the following groups of courses (18 credits):	
(a) MTH 320 Analysis I.	3
MTH 421 Analysis II	3
STT 861 Theory of Probability and Statistics I.	3
STT 862 Theory of Probability and Statistics II.	3
Six additional credits from the Statistics and Probability courses that appear on the list below.	
(b) Three additional credits in Mathematics 235 or in 300–400 level Mathematics courses.	
STT 441 Probability and Statistics I: Probability	3
STT 442 Probability and Statistics II: Statistics	3
Nine additional credits from the Statistics and Probability courses that appear on the list below.	
c. Demonstrate knowledge of at least one software package in statistics <i>either</i> by completing relevant courses <i>or</i> by completing a departmentally approved project through enrollment in Statistics and Probability 490.	
Additional Statistics and Probability courses that may be counted toward the requirements for the Statistics major:	
STT 461 Computations in Probability and Statistics	3
STT 471 Statistics for Quality and Productivity	3
STT 825 Sample Surveys	3
STT 826 Nonparametric Statistics	3
STT 841 Linear Statistical Models	3
STT 843 Multivariate Analysis	3
STT 844 Time Series Analysis	3
STT 852 Stochastic Methods in Operations Research	3
STT 886 Stochastic Processes and Applications	3

GRADUATE STUDY

The Department of Statistics and Probability offers three majors that lead to master's degrees: applied statistics, operations research–statistics, and statistics. The department also offers a major in statistics that leads to the Doctor of Philosophy degree.

Each of the master's and doctoral degree programs is described below. For more detailed information on degree requirements, write to the department.

APPLIED STATISTICS

Master of Science

The goals of the master's degree program in applied statistics are to provide students with a broad understanding of the proper application of statistical methodology and with experience in using computers effectively for statistical analysis. The student may emphasize either theoretical or applied material. Special emphasis is placed on the concerns that an applied statistician must address in dealing with practical problems.

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

To be admitted to the master's degree program in applied statistics, the applicant should have completed at least 6 credits of junior or senior level mathematics with a minimum grade–point

average of 3.00 over the last 6 credits. No previous course work in statistics or probability is required.

Requirements for the Master of Science Degree in Applied Statistics

The program is available only under Plan B (without thesis). An academic adviser coordinates the student's program of study, which must be approved by the chairperson of the department.

The student must:

1. Complete at least 36 credits in courses in the Department of Statistics and Probability, in the Department of Mathematics, or in a field of application of probability and statistics, including computer science.
2. Complete Statistics and Probability 441, 442 or Statistics and Probability 861, 862.
3. Complete Statistics and Probability 461.
4. Complete at least 15 additional credits in Statistics and Probability including at least 12 credits from the following courses: Statistics and Probability 471, 801, 825, 826, 841, 842, 843, 844, and 886.
5. Complete Mathematics 415.
6. Complete at least 3 additional credits in mathematics courses at the 400 or 800 level if the student met requirement 2. above by completing Statistics and Probability 441 and 442.
7. Demonstrate knowledge of at least one programming language and at least one software package in statistics by completing relevant courses (for example, Statistics and Probability 461 and 890).

OPERATIONS RESEARCH—STATISTICS

Master of Science

The master's degree program in operations research—statistics focuses on mathematical programming, applied stochastic processes, systems control and simulation, and mathematical and statistical techniques of optimization. The student may emphasize either theoretical or applied material.

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

To be admitted to the master's degree program in operations research—statistics, the applicant should have completed at least 12 credits of junior or senior level mathematics with a minimum grade–point average of at least 3.00 over the last 12 credits. Preferably courses in advanced calculus and matrices would be included in the 12 credits. No previous course work in statistics or probability is required.

Requirements for the Master of Science Degree in Operations Research—Statistics

The program is available only under Plan B (without thesis). An academic adviser coordinates the student's program of study, which must be approved by the chairperson of the department.

The student must complete the requirements for one of the two options referenced below. The total number of credits required for the degree depends upon the option that the student selects.

Option 1.

The student must complete a minimum of 30 credits including:

1. Management 834.
2. At least 3 credits in mathematics courses at the 400 or 800–level.
3. Statistics and Probability 471, 852, 861, 862, and 886.
4. At least 6 credits from the following courses: Statistics and Probability 461, 801, 825, 826, 841, 842, 843, 844; Management 837.

Option 2.

The student must complete a minimum of 36 credits including:

1. Management 834.
2. Mathematics 415.
3. At least 3 additional credits in mathematics courses at the 400 or 800 level.
4. Statistics and Probability 441, 442, 471, 852, and 886.
5. At least 9 credits from the following courses: Statistics and Probability 461, 801, 825, 826, 841, 842, 843, 844; Management 837.

STATISTICS

Master of Science or Master of Arts

The goal of the master's degree programs in statistics is to provide students with a sound foundation in probability, mathematical statistics, and statistical methodology. The student may emphasize either theoretical or applied material.

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

To be admitted to either of the master's degree programs in statistics, the applicant should have completed at least 12 credits of junior or senior level mathematics with a minimum grade–point average of at least 3.00 over the last 12 credits. Preferably courses in advanced calculus and matrices would be included in the 12 credits. No previous course work in statistics or probability is required.

Requirements for the Master of Science or Master of Arts Degree in Statistics

The program is available under either Plan A (with thesis) or Plan B (without thesis). An academic adviser coordinates the student's program of study, which must be approved by the chairperson of the department.

The student must complete:

1. At least 30 credits in courses in the Department of Statistics and Probability, in the Department of Mathematics, or in a field of application of probability and statistics, including computer science.
2. One of the following three options:
 - a. Mathematics 415 and 421.
 - b. Mathematics 415 and 428H.
 - c. Mathematics 428H and 429H.This requirement must be met as soon as possible after admission to the program, if the student did not complete the courses in one of the options previously.
3. One of the following programs of study:
 - a. Statistics and Probability 871, 872, or 881, 882 and at least 6 additional credits in Statistics and Probability at the 800 or 900 level.
 - b. Statistics and Probability 861, 862 and at least 12 additional credits in Statistics and Probability at the 800 or

900 level. Of these 12 credits, at least 9 credits must be from the following courses: Statistics and Probability 801, 825, 826, 841, 842, 843, 844, 886.

Doctor of Philosophy

The Doctor of Philosophy degree program with a major in statistics is designed for students who plan to pursue careers in university teaching and research or in industrial and government consulting and research. The major emphasis in the doctoral program is on the attainment of a sound background in theoretical probability and statistics. A doctoral student may choose to emphasize either probability theory or mathematical statistics.

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

Completion of course work equivalent to that required for any one of the master's degree programs in this department and evidence of ability to work at the doctoral level are required for admission. Applicants who have not had courses equivalent to Statistics and Probability 861 and 862 or advanced calculus or linear algebra will be required to complete these courses.

Requirements for the Doctor of Philosophy Degree in Statistics

The program of study is developed by the guidance committee in consultation with the student. The program of study will usually emphasize theory, although courses in applications should be included. Although the doctorate is awarded primarily on the ability of the student to carry on significant original research in statistics or probability, as demonstrated in the dissertation, the student must also meet the requirements specified below:

1. Complete Mathematics 828 and 928.
2. Complete Statistics and Probability 871, 872, 881, and 882.
3. Complete at least two of the following advanced statistics courses: Statistics and Probability 951, 952, 953, 954.
4. Complete at least two of the following advanced probability courses: Statistics and Probability 961, 962, 963, 964.
5. Complete at least seven additional courses from a list of courses approved by the department.
6. Pass a written preliminary examination covering Statistics and Probability 871, 872, 881, and 882.
7. Pass a written preliminary examination covering Mathematics 828.

DEPARTMENT of ZOOLOGY

Richard Snider, Acting Chairperson

Zoology is the branch of natural science that deals with animal biology. It is concerned with every level of biological organization from the gene to the ecosystem, and with the structure, physiology, behavior, genetics, development, distribution, and evolution of animals in all taxonomic groups. In a broad sense, zoology also deals with the interrelationships between humans and other animals. The courses in the department span the diversity of animal life and the entire range of modern biological disciplines con-

cerned with animals. There is ample scope for students to obtain a broad education in biology while also specializing in the particular aspects of biology that interest them most.

Programs in zoology can help students to prepare for a wide variety of careers including biomedical research, biotechnology, medicine, dentistry, veterinary science, marine biology, conservation, environmental science, behavioral biology, and teaching.

UNDERGRADUATE PROGRAMS

Majors are expected to acquire broad background in the sciences fundamental to the understanding of modern zoology. The chemistry, mathematics, and physics requirements are those of the College. Chemistry and mathematics are normally taken in the freshman year, and physics in the junior year. The Biological Science sequence (110, 111, 111L) should be started in the freshman year since these courses are prerequisite to further study. Course electives in zoology are to be chosen so that they furnish an understanding of the several branches of zoology: animal behavior, cell biology, developmental biology, ecology, evolution, genetics, morphology, neurobiology, organismal biology, and physiology.

ENVIRONMENTAL BIOLOGY/ZOOLOGY

Bachelor of Science

The objective of the Bachelor of Science degree program with a major in environmental biology/zoology is to help students to understand the concepts of environmental biology and to apply those concepts to improve both the natural environment and the environment perturbed by human activities. The focus of the program is on animal biology. The zoology courses in the program emphasize ecology, systematics, and environmental science.

Students who are enrolled in this program may complete an optional capstone course: Zoology 494 or 496.

Requirements for the Bachelor of Science Degree in Environmental Biology/Zoology:

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Science degree in Environmental Biology/Zoology. The University's Tier II writing requirement for the Environmental Biology/Zoology major is met by completing Zoology 445 and 483. Those courses are referenced in item 3. a. below. Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
2. The requirements of the College of Natural Science for the Bachelor of Science degree. The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
3. The following requirements for the major:

	CREDITS
a. All of the following courses:	55
BOT 441 Plant Ecology	3
BS 110 Organisms and Populations	4
BS 111 Cells and Molecules	3
BS 111L Cell and Molecular Biology Laboratory	2
CEM 141 General Chemistry	4
CEM 161 Chemistry Laboratory I	1
CEM 251 Organic Chemistry I	3
CEM 252 Organic Chemistry II	3
CEM 255 Organic Chemistry Laboratory	2
CSS 210 Fundamentals of Soil and Landscape Science	3
PHY 231 Introductory Physics I	3
PHY 232 Introductory Physics II	3
PHY 251 Introductory Physics Laboratory I	1
PHY 252 Introductory Physics Laboratory II	1
ZOL 306 Invertebrate Biology	4
ZOL 341 Fundamental Genetics	4
ZOL 355 Ecology	3

ZOL 355L Ecology Laboratory	1
ZOL 445 Evolution	3
ZOL 483 Environmental Physiology	4
Entomology 404 or Zoology 412 may be substituted for Zoology 306.	
b. One of the following groups of courses (6 or 7 credits):	
(a) MTH 124 Survey of Calculus with Applications I	3
MTH 126 Survey of Calculus with Applications II	3
(b) MTH 132 Calculus I	3
MTH 133 Calculus II	4
(c) MTH 124 Survey of Calculus with Applications I	3
And	
STT 201 Statistical Methods	4
Or	
STT 231 Statistics for Scientists	3
Or	
STT 421 Statistics I	3
(d) MTH 132 Calculus I	3
And	
STT 201 Statistical Methods	4
Or	
STT 231 Statistics for Scientists	3
Or	
STT 421 Statistics I	3
c. One of the following courses:	4
ZOL 360 Biology of Birds	4
ZOL 365 Biology of Mammals	4
d. One course from <i>each</i> of the following three groups of courses:	10 or 11
(1) BOT 218 Plants of Michigan	3
BOT 418 Plant Systematics	3
(2) BOT 423 Wetland Plants and Algae	4
FW 420 Stream Ecology	3
ZOL 353 Marine Biology	4
(3) FW 472 Limnology	3
GLG 421 Environmental Geochemistry	4
ZOL 431 Comparative Limnology	4
e. A minimum of 33 credits in Zoology courses including the Zoology courses that satisfy the Tier II writing requirement referenced in item 1. above. Zoology courses that are not listed above must be approved in writing by the student's academic adviser. Courses offered by other departments may be substituted for Zoology courses with the written approval of the student's academic adviser.	

CEM 141 General Chemistry	4
CEM 143 Survey of Organic Chemistry	4
CEM 161 Chemistry Laboratory I	1
PHY 231 Introductory Physics I	3
ZOL 313 Animal Behavior	3
ZOL 320 Developmental Biology	4
ZOL 341 Fundamental Genetics	4
ZOL 355 Ecology	3
ZOL 355L Ecology Laboratory	1
ZOL 408 Histology	4
ZOL 457 Foundations of Evolutionary Biology	3
c. One of the following courses:	4
ZOL 306 Invertebrate Biology	4
ZOL 328 Comparative Anatomy and Biology of Vertebrates	4
d. One of the following pairs of courses:	6 or 7
(1) MTH 124 Survey of Calculus with Applications I	3
MTH 126 Survey of Calculus with Applications II	3
(2) MTH 124 Survey of Calculus with Applications I	3
STT 201 Statistical Methods	4
(3) MTH 124 Survey of Calculus with Applications I	3
STT 421 Statistics I	3
(4) MTH 132 Calculus I	3
MTH 133 Calculus II	4
Mathematics 124 or 132 and Statistics and Probability 421 may be used to satisfy both the requirement referenced in item 3. a. (2) and the requirement referenced in item 3. d.	
e. Twelve credits in 300–400 level courses offered by the Colleges of Arts and Letters, Business, Communication Arts and Sciences, and Social Science.	

ZOOLOGY

Bachelor of Arts

The Bachelor of Arts degree with a major in zoology is for students who wish to combine study in zoology with a significant amount of course work outside the sciences. It is also intended for those students who wish to prepare for careers in the applications of science to such fields as public policy, law, business, and communications.

Requirements for the Bachelor of Arts Degree in Zoology

- The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Arts degree in Zoology.
The University's Tier II writing requirement for the Zoology major is met by completing Zoology 355L and 457. Those courses are referenced in item 3. b. below.
Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Science that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
- The requirements of the College of Natural Science for the Bachelor of Arts degree.
The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
- The following requirements for the major:

	CREDITS
a. One of the following options:	
(1) Second year competency in a foreign language.	
(2) First year competency in a foreign language, Computer Science and Engineering 101 or 131, Mathematics 124 or 132, and Statistics and Probability 421. Students who pass a waiver examination for Computer Science and Engineering 101 will not be required to complete Computer Science and Engineering 101 or 131. Mathematics 124 or 132 and Statistics and Probability 421 may be used to satisfy both the requirement referenced in item 3. a. (2) and the requirement referenced in item 3. d.	
b. All of the following courses:	43
BS 110 Organisms and Populations	4
BS 111 Cells and Molecules	3
BS 111L Cell and Molecular Biology Laboratory	2

Bachelor of Science

The Bachelor of Science degree program with a major in zoology is for students who seek professional employment in animal biology, or who seek admission to graduate programs in animal biology or to health-related professional schools. Students may pursue a degree program in general zoology that encompasses the several branches of modern zoology while permitting focused study in any one of these fields. Alternatively, with the prior approval of an academic adviser, students may elect to pursue one of the following specialized concentrations in zoology: cell and developmental biology; ecology, evolution and organismal biology; genetics; neurobiology and animal behavior; zoo and aquarium science, or marine biology.

Requirements for the Bachelor of Science Degree in Zoology

- The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Science degree in Zoology.
The University's Tier II writing requirement for the Zoology major is met by completing two of the following courses: Zoology 328, 342, 343, 355L, 415, 425, 428, 445, 450, 457, 482, 483, 499. Those courses are referenced in item 3. c. (2) below.
Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
- The requirements of the College of Natural Science for the Bachelor of Science degree.
The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
- The following requirements for the major:

	CREDITS
a. All of the following courses:	30
BS 110 Organisms and Populations	4
BS 111 Cells and Molecules	3
BS 111L Cell and Molecular Biology Laboratory	2
CEM 141 General Chemistry	4
CEM 161 Chemistry Laboratory I	1
CEM 251 Organic Chemistry I	3
CEM 252 Organic Chemistry II	3
CEM 255 Organic Chemistry Laboratory	2
PHY 231 Introductory Physics I	3
PHY 232 Introductory Physics II	3
PHY 251 Introductory Physics Laboratory I	1
PHY 252 Introductory Physics Laboratory II	1
b. One of the following groups of courses (6 or 7 credits):	

NATURAL SCIENCE
Department of Zoology

(a)	MTH 124	Survey of Calculus with Applications I	3
	MTH 126	Survey of Calculus with Applications II	3
(b)	MTH 132	Calculus I	3
	MTH 133	Calculus II	4
(c)	MTH 124	Survey of Calculus with Applications I	3
	And		
	STT 201	Statistical Methods	4
	Or		
	STT 231	Statistics for Scientists	3
	Or		
	STT 421	Statistics I	3
(d)	MTH 132	Calculus I	3
	And		
	STT 201	Statistical Methods	4
	Or		
	STT 231	Statistics for Scientists	3
	Or		
	STT 421	Statistics I	3
c.	One of the following seven concentrations:		
	General Zoology		
(1)	One course or pair of courses from each of four of the following five groups of courses: 14 to 16		
(a)	ZOL 306	Invertebrate Biology	4
	ZOL 328	Comparative Anatomy and Biology of Vertebrates	4
(b)	ZOL 313	Animal Behavior	3
	ZOL 483	Environmental Physiology	4
(c)	ZOL 320	Developmental Biology	4
	ZOL 408	Histology	4
	ZOL 425	Cells and Development	4
(d)	ZOL 341	Fundamental Genetics	4
(e)	ZOL 355	Ecology	3
	ZOL 355L	Ecology Laboratory	1
	ZOL 445	Evolution	3
	If the student selects group (e), Zoology 355 and 355L combined, or Zoology 445, must be completed to satisfy this requirement.		
(2)	A minimum of 33 credits in Zoology courses including the Zoology courses that satisfy the Tier II writing requirement referenced in item 1. above. Zoology courses that are not listed above must be approved in writing by the student's academic adviser. Courses offered by other departments may be substituted for Zoology courses with the written approval of the student's academic adviser.		
	Cell and Developmental Biology		
(1)	One of the following courses: 4		
	ZOL 320	Developmental Biology	4
	ZOL 425	Cells and Development	4
(2)	Thirty credits from the following courses: 30		
	MMG 301	Introductory Microbiology	3
	MMG 302	Introductory Microbiology Laboratory	1
	MMG 409	Eukaryotic Cell Biology	3
	ZOL 328	Comparative Anatomy and Biology of Vertebrates	4
	ZOL 341	Fundamentals of Genetics	4
	ZOL 342	Advanced Genetics	3
	ZOL 343	Genetics Laboratory	2
	ZOL 402	Neurobiology	3
	ZOL 408	Histology	4
	ZOL 428	Frontiers in Developmental and Tissue Biology	3
	ZOL 450	Cancer Biology	3
	ZOL 482	Cytochemistry	4
	Either Biochemistry 401, or Biochemistry 461 and 462 combined, may be substituted for one of the courses listed above.		
(3)	A minimum of 33 credits in Zoology courses including the Zoology courses that satisfy the Tier II writing requirement referenced in item 1. above. Zoology courses that are not listed above must be approved in writing by the student's academic adviser. Courses offered by other departments may be substituted for Zoology courses with the written approval of the student's academic adviser.		
	Ecology, Evolution, and Organismal Biology		
(1)	All of the following courses: 11		
	ZOL 341	Fundamental Genetics	4
	ZOL 355	Ecology	3
	ZOL 355L	Ecology Laboratory	1
	ZOL 445	Evolution	3
(2)	One of the following courses: 4		
	ZOL 306	Invertebrate Biology	4
	ZOL 328	Comparative Anatomy and Biology of Vertebrates	4
(3)	One of the following courses or pairs of courses: 3 or 4		
	ZOL 313	Animal Behavior	3
	ZOL 316	General Parasitology	3
	ZOL 316L	General Parasitology Laboratory	1
	ZOL 483	Environmental Physiology	4
	Zoology 316 and 316L combined must be completed to satisfy this requirement.		
(4)	Fourteen additional credits in courses in ecology, evolution, and organismal biology approved in writing by the student's academic adviser.		

(5)	A minimum of 33 credits in Zoology courses including the Zoology courses that satisfy the Tier II writing requirement referenced in item 1. above. Zoology courses that are not listed above must be approved in writing by the student's academic adviser. Courses offered by other departments may be substituted for Zoology courses with the written approval of the student's academic adviser.		
	Genetics		
(1)	All of the following courses: 21		
	BMB 461	Biochemistry I	3
	BMB 462	Biochemistry II	3
	BMB 472	Biochemistry Laboratory	3
	MMG 431	Microbial Genetics	3
	ZOL 341	Fundamental Genetics	4
	ZOL 342	Advanced Genetics	3
	ZOL 343	Genetics Laboratory	2
(2)	One of the following courses: 4		
	ZOL 494	Independent Study	4
	ZOL 499	Undergraduate Thesis	4
(3)	A minimum of 33 credits in Zoology courses including the Zoology courses that satisfy the Tier II writing requirement referenced in item 1. above. Zoology courses that are not listed above must be approved in writing by the student's academic adviser. Courses offered by other departments may be substituted for Zoology courses with the written approval of the student's academic adviser.		
	Neurobiology and Animal Behavior		
(1)	All of the following courses: 10		
	ZOL 313	Animal Behavior	3
	ZOL 341	Fundamental Genetics	4
	ZOL 402	Neurobiology	3
(2)	One of the following courses: 4		
	ZOL 306	Invertebrate Biology	4
	ZOL 328	Comparative Anatomy and Biology of Vertebrates	4
(3)	Both of the following courses: 7		
	ZOL 320	Developmental Biology	4
	ZOL 415	Ecological Aspects of Animal Behavior	3
(4)	One of the following courses or pairs of courses: 3 or 4		
	ZOL 342	Advanced Genetics	3
	ZOL 355	Ecology	3
	ZOL 355L	Ecology Laboratory	1
	ZOL 445	Evolution	3
	ZOL 457	Foundations of Evolutionary Biology	3
	ZOL 483	Environmental Physiology	4
	Zoology 355 and 355L combined must be completed to satisfy this requirement.		
(5)	A minimum of 33 credits in Zoology courses including the Zoology courses that satisfy the Tier II writing requirement referenced in item 1. above. Zoology courses that are not listed above must be approved in writing by the student's academic adviser. Courses offered by other departments may be substituted for Zoology courses with the written approval of the student's academic adviser.		
	Zoo and Aquarium Science		
(1)	All of the following courses: 30		
	ZOL 313	Animal Behavior	3
	ZOL 320	Developmental Biology	4
	ZOL 328	Comparative Anatomy and Biology of Vertebrates	4
	ZOL 341	Fundamental Genetics	4
	ZOL 355	Ecology	3
	ZOL 355L	Ecology Laboratory	1
	ZOL 369	Introduction to Zoo and Aquarium Science	3
	ZOL 445	Evolution	3
	ZOL 489	Seminar in Zoo and Aquarium Science	2
	ZOL 498	Internship in Zoo and Aquarium Science	3
(2)	One of the following courses: 4		
	FW 471	Ichthyology	4
	ZOL 360	Biology of Birds	4
	ZOL 365	Biology of Mammals	4
	ZOL 384	Biology of Amphibians and Reptiles	4
(3)	One of the following courses: 3 or 4		
	ANS 313	Principles of Animal Feeding and Nutrition	4
	ANS 314	Genetic Improvement of Domestic Animals	4
	ANS 315	Anatomy and Physiology of Farm Animals	4
	FW 444	Conservation Biology	3
	FW 472	Limnology	3
	ZOL 353	Marine Biology	4
(4)	Two of the following courses: 7 or 8		
	FW 364	Ecological Problem Solving	3
	FW 424	Population Analysis and Management	4
	GLG 303	Oceanography	4
	ZOL 483	Environmental Physiology	4
(5)	One additional course of at least 3 credits selected from a list of approved courses that is available from the Department of Zoology.		
(6)	A minimum of 44 credits in Zoology courses including the Zoology courses that satisfy the Tier II writing requirement ref-		

erenced in item 1. above. Zoology courses that are not listed above must be approved in writing by the student's academic adviser. Courses offered by other departments may be substituted for Zoology courses with the written approval of the student's academic adviser.

Marine Biology

- (1) All of the following courses: 17
 - GLG 303 Oceanography 4
 - ZOL 341 Fundamental Genetics 4
 - ZOL 353 Marine Biology 4
 - ZOL 355 Ecology 3
 - ZOL 355L Ecology Laboratory 1
 - ZOL 491 Seminar in Marine Biology 1
- (2) One course from each of the following three groups of courses: 10 to 12
 - (a) ZOL 445 Evolution 3
 - ZOL 483 Environmental Physiology 4
 - (b) FW 471 Ichthyology 4
 - ZOL 306 Invertebrate Biology 4
 - (c) BMB 401 Basic Biochemistry 4
 - CEM 383 Introductory Physical Chemistry I 3
 - FW 424 Population Analysis and Management 4
 - GEO 324 Remote Sensing of the Environment 4
 - GLG 422 Aquatic and Marine Organic Geochemistry (W) 3
 - MMG 425 Microbial Ecology 3
 - MMG 426 Biogeochemistry 3
- (3) One of the following courses: 3 to 5
 - BOT 423 Wetland Plants and Algae 4
 - ENT 469 Biomonitoring of Streams and Rivers 3
 - FW 491 Special Topics in Fisheries and Wildlife 5
 - MMG 426 Biogeochemistry 3
 - ZOL 431 Comparative Limnology 4
 - ZOL 440 Field Ecology and Evolution 4
 - ZOL 453 Field Studies in Marine and Estuarine Biology 3
- (4) A minimum of at least 2 credits must be completed in an aquatic biology field experience. Courses not listed above may be substituted with the written approval of the student's academic adviser.
- (5) A minimum of 33 credits in Zoology courses including the Zoology courses that satisfy the Tier II writing requirement referenced in item 1. above. Zoology courses that are not listed above must be approved in writing by the student's academic adviser.

Recognition

Upon completion of the required courses for one of the seven concentrations referenced above, the student should contact the Department of Zoology and request certification for the completion of the concentration. After the certification is approved by the Dean of the College of Natural Science, the Office of the Registrar will enter on the student's academic record the name of the concentration and the date that it was completed. This certification will appear on the student's transcript.

GRADUATE STUDY

The Department of Zoology offers Master of Science and Doctor of Philosophy degree programs in zoology. The department also offers a Master of Science in Zoo and Aquarium Management and a Doctor of Philosophy degree program in zoology-environmental toxicology.

The Department of Zoology is affiliated with the Doctor of Philosophy degree program with a major in ecology, evolutionary biology and behavior. For information about a Doctor of Philosophy degree program that involves ecology, evolutionary biology and behavior and a major in the Department of Zoology, refer to the statement on the doctoral program in ecology, evolutionary biology and behavior.

Students who are enrolled in master's or doctoral degree programs in the Department of Zoology may elect an Interdepartmental Specialization in Cognitive Science. For additional information, refer to the statement on *Interdepartmental Graduate Specializations in Cognitive Science* in the *College of Social Science* section of this catalog. For additional information, contact the Department of Zoology.

Students who are enrolled in the Master of Science degree program in the Department of Zoology may elect specializations in ecology, evolutionary biology and behavior and in environmental toxicology. For additional information, refer to the statement on the Specialization in Ecology, Evolutionary Biology and Behavior and to the *Graduate Specialization in Environmental Toxicology* statement in the *College of Agriculture and Natural Resources* section of this catalog.

ZOO AND AQUARIUM MANAGEMENT

Master of Science

The objective of Master of Science in Zoo and Aquarium Management is to train professionals in the foundations of zoo and aquarium management and to develop business management and communication skills. The program should appeal to working professionals with Bachelor of Arts or Bachelor of Science degrees who wish to advance or change their careers.

In addition to meeting the requirements of the University and the College of Natural Science, students must meet the requirements specified below.

Requirements for the Master of Science Degree in Zoo and Aquarium Management

The student must complete 30 credits under Plan B (without thesis). The specific program of study, including an internship in collaboration with an industrial partner, must be approved by the student's guidance committee. The final oral examination, which covers both course work and research, is administered by the student's guidance committee.

	CREDITS
1. The following Core courses (6 credits):	
ZOL 892 Biodiversity	2
One of the following courses:	
ZOL 896 Population and Community Ecology	4
ZOL 897 Ecosystem Ecology	4
2. All of the following courses (16 credits):	
ENT 442 Concepts of Biological Information Systems	3
FW 444 Conservation Biology	3
GEO 459 Tourism in Regional Development	3
PRR 841 Park and Recreation Administration and Policy	3
ZOL 890 Special Problems	4
3. A minimum of 8 credits from the following courses:	
FW 424 Population Analysis and Management	4
FW 811 Fisheries and Wildlife Laws and Regulation	3
FW 828 Conservation and Genetics	3
PRR 443 Park and Recreation Planning and Design Concepts	4
PRR 451 Park Interpretive Services and Visitor Information Systems	3
PRR 460 Resource and Environmental Economics	3
PRR 485 Legal Aspects of Parks, Recreation, and Sport	3
PRR 829 The Economics of Environmental Resources	3
PRR 848 The Law and Leisure Services	3
PRR 870 Park, Recreation and Natural Resources Marketing	3
ZOL 851 Quantitative Methods in Ecology and Evolution	3

- 4. Complete an internship with an industrial partner.
- 5. Pass a final oral examination.
- 6. All students in the program will be required to complete a **Certificate Program in Basic Business and Communication Skills**. The certificate program is organized as a series of week-end workshops covering such topics as project management, business law, intellectual property, management theory, finance, writing skills, presentation skills, information retrieval, interpersonal skills and group work. The certificate program offered by the faculty of The Eli Broad College of Business and the College of Communication Arts and Sciences, will include a case-study approach. It will normally be undertaken during the first year of enrollment and will involve an additional cost to the student beyond usual tuition and fees.

After the completion of the certificate program is approved by the Director of Executive Development Programs in The Eli Broad College of Business and by the Associate Dean of the College of Natural Science, the Office of the Registrar will enter on the student's academic record the name of the certificate program and the date it was completed. This certification will appear on the student's transcript upon completion of the requirements for the degree program.

ZOOLOGY

The graduate degree programs in zoology are designed for students who seek a career in teaching and research in the biological sciences. The objectives of the programs are to provide the student with a broad knowledge of the field through courses and seminars and to prepare the student for independent and original research in one of the various specialized subdisciplines of zoology. Faculty and staff provide expertise in a wide range of interests from molecular biology to ecosystem study. Areas of active research include genetics, cellular and developmental biology, animal diversity, systematics, paleontology, comparative morphology, physiology, behavior, and ecology and evolutionary biology. The studies of many types of animals include protozoology, invertebrate zoology, and vertebrate zoology, especially herpetology, ornithology, and mammalogy.

Students may obtain specialized graduate training through interdepartmental graduate programs. Zoology faculty are affiliated with interdepartmental graduate programs and research in genetics, cell and molecular biology, neuroscience, and ecology and evolutionary biology. Additional information about the doctoral programs in genetics and neuroscience, and about the Specialization in Ecology and Evolutionary Biology, may be found in other sections of this catalog. Students specializing in ecological research may take courses and carry out research at the W. K. Kellogg Biological Station located near Kalamazoo.

A brochure describing faculty research interests as well as information on admission, financial aid, and the requirements for the Master of Science and Doctor of Philosophy degrees is available from the department graduate office. Interested students are also encouraged to contact the Chairperson of the Graduate Affairs Committee for further information.

In addition to meeting the requirements of the University and of the College of Natural Science, students must meet the requirements specified below.

Admission

Regular admission to the graduate programs in zoology is granted to students having a bachelor's degree, with training in the biological sciences at least equal to that required for this degree at Michigan State University; a grade-point average of 3.00 or better; and one year each of chemistry, physics, and mathematics. Satisfactory scores on the Graduate Record Examination General Test and approval of the department also are required. Students who do not meet the requirements for regular admission may, under certain circumstances, be admitted on a provisional basis while deficiencies are being corrected.

Requirements for the Master of Science Degree

The student must complete a total of 30 credits for the degree under either Plan A (with thesis) or Plan B (without thesis).

ZOOLOGY—ENVIRONMENTAL TOXICOLOGY

Doctor of Philosophy

For information about the Doctor of Philosophy degree program in zoology—environmental toxicology, refer to the statement on *Multidepartmental Doctoral Programs in Environmental Toxicology* in the *Graduate Education* section of this catalog.

ABRAMS PLANETARIUM

Don Batch, Manager

Abrams Planetarium, with its panoramic space science theater, is an acknowledged leader in the popularization of astronomy. The facility was financed by alumni and friends of the University through contributions to the MSU Development Fund. Gifts included \$250,000 from Dr. and Mrs. Talbert Abrams. The building features a 252-seat Sky Theater housing the planetarium projector, a black light art gallery, an exhibit hall, and a gift shop.

This exciting astronomical and multimedia facility is intended not only for public sky shows, but also features programs which are tailored to the needs of visiting elementary and secondary school children. There are presentations for university instruction, and observing sessions.

Star shows, seasonal shows, sky lectures, and observing sessions are offered to the public on weekends and on special occasions. Visitors to the exhibit hall are welcome at the times of public presentations and from 8:30 a.m. to noon and 1 p.m. to 4:30 p.m. on weekdays.

Telephone 355-4672 for recorded public show information, 332-STAR for recorded sky information, and 355-4676 to reach the Planetarium office.

BIOLOGICAL SCIENCE PROGRAM

The Biological Science Program office is responsible for the development and operation of a balanced core curriculum in general biology appropriate for majors and others interested in a comprehensive introduction to the field. Currently the core consists of the three term sequence Biological Science 110, 111 and 111L. Advanced work and research projects for undergraduates are also coordinated by this office under Biological Science 499.

The Biological Science Program office also coordinates undergraduate and master's interdepartmental degree programs in biological science, and physical science on behalf of the College of Natural Science.

MSU/DOE PLANT RESEARCH LABORATORY

Kenneth G. Keegstra, Director

A center for modern plant biology, the MSU/DOE Plant Research Laboratory was established in 1964. The Laboratory is administered jointly by the College of Natural Science and the College of Agriculture and Natural Resources under a grant form with the U. S. Department of Energy.

The Laboratory conducts a broadly based research program which includes studies at the molecular, subcellular, cellular, tissue, organ, and organismal levels and draws on plant physiology, biochemistry, cell and molecular biology, genetics, and other disciplines. Among problems under investigation are photosynthesis; transduction of environmental information by the plant; effects of stress conditions upon growth and productivity; developmental biology of nitrogen fixing cyanobacteria; action of plant

hormones; plant cell wall biosynthesis; mechanisms of tissue-specificity and protein targeting; molecular genetics of plant systems; genetic analysis of physiological traits; molecular mechanisms for plant gene expression; molecular biology of symbiotic nitrogen fixation; and molecular basis of disease resistance in plants. Emphasis is placed on the role of plants in energy conversion, consumption, and conservation.

The Laboratory provides facilities and support for students intending to proceed toward the Doctor of Philosophy degree, and for postdoctoral research associates. The doctoral degree programs are administered through academic units with which the Laboratory faculty have joint appointments, particularly the departments of Biochemistry and Molecular Biology, Crop and Soil Sciences, Microbiology and Molecular Genetics, and Plant Biology. The interdepartmental doctoral program in genetics that is administered by the College of Natural Science is also available. The student's admission and program of study are subject to the regulations and approval of the appropriate department and of either the College of Natural Science or the College of Agriculture and Natural Resources.

The aim of graduate work in the Laboratory is to give students training in independent research and to provide them with sufficient strength, both in biology and in the basic sciences, to enable them to keep in the forefront of their continuously changing and developing field. Doctoral programs consist of course work in advanced subjects and research leading to a dissertation.

To be accepted for graduate work in the Laboratory the student is generally expected to have at least the Bachelor of Science degree and to have had courses in organic chemistry, mathematics through calculus, physics, and general botany or biology. Courses in plant physiology, physical chemistry, and biochemistry are desirable. In the case of highly qualified students, part of the course requirements may be completed after admission to graduate work, but admission will in such cases be on a provisional basis until these requirements have been completed satisfactorily.

Graduate students are given freedom of choice in selecting, within the Laboratory, the areas of their research and their major advisers. These selections must be compatible with the Laboratory's objectives. Students are expected to spend the first two semesters following admission familiarizing themselves with the research programs of the Laboratory's staff and related research in other departments, including participation in several research projects, and to make their selection on this basis.

Because of the intensity of the program the student is expected to work on a year-round basis.

CENTER FOR ADVANCED MICROSCOPY

Stanley L. Flegler, Director

Microscopy, the science of microscope use, traces its origins to the work of Hooke and Leeuwenhoek in the late 1600's. There are now many types of microscopes and dozens of different imaging and analytical methods. Images may be created using visible and

invisible light, electrons, magnetic forces, mechanical probes, current flow, and atomic level attractive and repulsive forces. Much of the technology in our modern world would not have been possible without the images and analytical data from microscopes.

Microscopy is a vital resource in creating and applying knowledge to help address the critical problems of the 21st century.

The Center for Advanced Microscopy (CAM), a University Core Facility, is the Central microscopy laboratory for the MSU campus. Teaching, research, and service work are provided in Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Confocal Laser Scanning Microscopy (CLSM), Scanning tunneling Microscopy (STM), Atomic Force Microscopy (AFM), and Energy Dispersive X-ray Spectroscopy (EDS). CAM has a large user base from 49 departments in nine colleges. Outreach is provided on a local and national level. Our comprehensive teaching program includes NSC-802 Lecture (FS), NSC-810 TEM Lab (FS,SS), NSC-820 SEM Lab (FS,SS), NSC-825 Independent Study (FS,SS,US) and NSC-837 LSM Lab (FS, SS).

In scanning electron microscopy we offer the following imaging/analytical capabilities: secondary electron imaging; back-scattered electron imaging; energy dispersive x-ray spectroscopy including qualitative and quantitative analysis, linescans, and X-ray dot maps; high resolution field emission scanning electron microscopy, and cryo scanning electron microscopy. Imaging may be done in both analog and digital modes.

In transmission electron microscopy we offer the following imaging/analytical capabilities: conventional bright/dark field imaging; high-resolution electron microscopy (HREM) imaging; selected area diffraction(SAD), micro/nano-diffraction, convergent beam electron diffraction(CBED); scanning transmission electron microscopy (STEM) with Z-contrast atomic resolution imaging; Lorenz electron microscopy; electron energy filtered imaging(EFI); high spatial/energy resolution electron energy loss spectroscopy(EELS); simultaneous EELS and dark field STEM imaging for line scans and spectrum imaging; energy dispersive X-ray spectroscopy(EDS) with line scans and spectrum imaging; Internet remote electron microscopy.

In confocal laser scanning microscopy, we offer the following imaging/analytical capabilities: serial optical sectioning and time series imaging in fluorescence or reflection confocal modes; transmitted imaging, including bright field, darkfield, phase contrast, DIC and polarization; and three-dimensional image rendering on many kinds of images. Laser lines available include 458, 488, 514, 543 and 633 nm. Imaging may be done in analog or digital modes.

In scanning probe microscopy we offer the following imaging/analytical capabilities: atomic force microscopy contact mode, conventional and wet cell; and scanning tunneling microscopy.

Microscopy is closely linked with modern computer technology. Numerous image processing programs and techniques enable investigations and image analysis that were not previously possible. CAM has a modern image processing center that utilizes numerous powerful computers including Unix, PC, and MAC platforms. The image processing center is equipped with a variety of digital printers utilizing laser jet, ink jet, dye sublimation, and silver halide technologies.