College of NATURAL SCIENCE

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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, Botany and Plant Pathology, Chemistry, Entomology, Geological Sciences, Mathematics, Microbiology and Molecular Genetics, Physics and Astronomy, Physiology, 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 requirements 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. An additional interdepartmental major in general science is available *only* to students who have been accepted in elementary education. 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 Botany and Plant Pathology, Biological Science, Entomology, Microbiology, Physiology, 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
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 preparation for science education possible.

This underrepresentation is due, in part, to the lack of information available to minorities and others about career opportunities in the sciences and, in part, to inadequate high school preparation in mathematics and science. In addition, the transition from high school to college may be particularly difficult for such students.

The purpose of this program is to help interested and motivated students to develop the necessary science background by presenting science and mathematics in ways that are stimulating and exciting. 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 predental program in the College of Natural Science as their major preference. Students who are enrolled in the predental 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 predental students. Therefore, upon reaching junior standing, students who have been enrolled in the predental 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 predental program.

Requirements for the Predental Program

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: — CREDITS: 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[1]	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. 3 credits in a biological science course in addition to Biological Science 110, 111, and 111L.
2. Students who are enrolled in the predental 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 Predental 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 predental program referenced in item 1. a. above.

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

[1] Some dental colleges do not require Chemistry 252.

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

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: — CREDITS: 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.

   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, general 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, general 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.

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 deferreds 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 deferreds 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 deferreds 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

Michigan State University has implemented a new integrative studies program that was recommended by the Council to Review Undergraduate Education. Centers for integrative studies in the colleges of Arts and Letters, Natural Science, and Social Science serve as focal points of convergence and community for the Knowledge and Emphasis Areas.

The three Knowledge Areas are Arts and Humanities; Biological and Physical Sciences; and Social, Economic, and Behavioral Sciences. The four Emphasis Areas are International and Multicultural Experiences and National Diversity, Historical Consciousness, Values and Ethical Judgment, and Modes of Inquiry and Critical Analysis.

The Center for Integrative Studies in General Science in the College of Natural Science will have primary responsibility for developing and administering courses in the Knowledge Area of Physical and Biological Sciences. The Center cooperates with the Office of Integrative Studies in the development of transcollegiate courses.

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. 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:			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
		BCH	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[1]		10
Additional Requirements for Plan B					
1.	NSC	899	Research for Inservice Teachers[2]		10

[1] Research for the thesis involves developing laboratories and demonstrations as part of a new teaching unit and teaching that unit.

[2] Research for inservice teachers requires a curriculum based project and implementation report.

CELL AND MOLECULAR BIOLOGY

GRADUATE STUDY

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):		
	BCH 801	Molecular Biology and Protein Structure	4
	BCH 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):		
	MIC 833	Microbial Genetics	3
	MIC 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 371 or 422. 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:		24
	AST 207	The Science of Astronomy	3
	GEO 203	Introduction to Meteorology	3
	GLG 201	The Dynamic Earth	4
	GLG 303	Oceanography	4
	GLG 371	Plate Tectonics (W)	4
	GLG 422	Organic Geochemistry (W)	3
	MTH 132	Calculus I	3
	With the approval of the student's academic adviser, Geological Sciences 301 may be substituted for Geological Sciences 201.		
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
	GLG 202	Physical and Biological History of the Earth	4
	GLG 302	Geology of Michigan	3
	GLG 321	Mineralogy and Geochemistry	4
	GLG 411	Hydrogeology	4
	GLG 412	Glacial and Quaternary Geology	4
	GLG 421	Environmental Geochemistry	4
g.	Three of the following courses, no more than two of which may be from a given department:		9 to 12
	AST 202	Astrophysics and Astronomy II	4
	AST 401	Stars	3
	BOT 335	Plants Through Time	3
	CSS 455	Pollutants in the Soil Environment	3
	GEO 306	Environmental Geomorphology	3
	GEO 404	Synoptic Climatology	4
	GEO 407	Regional Geomorphology of the United States	3
	GEO 424	Advanced Remote Sensing	4
	GLG 331	Vertebrate Life of the Past	3
	RD 324	Water Resource Development	3

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

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 *In-*

terdepartmental Graduate Specializations in Cognitive Science in the *College of Social Science* section of this catalog. For additional information, contact the College of Natural Science.

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, Botany and Plant Pathology, Crop and Soil Sciences, Entomology, Fisheries and Wildlife, Forestry, Geological Sciences, Horticulture, Microbiology, Philosophy, Psychology, and Zoology. The student doe *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.

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 courses is available from the director of the ecology, evolutionary biology and behavior program.	
3.	Twenty-four credits in Doctoral Dissertation Research (course number 999) from one of the departments referenced in item 2. above.	
4.	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.	
5.	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

UNDERGRADUATE PROGRAM

The Bachelor of Science degree program with a major in general science—interdepartmental is a *preprofessional* program that is limited to students with an elementary teacher certification option. The program is designed for persons who plan to be certified by the State of Michigan as general science teachers in grades K-8 in public schools. Students in the program work toward certification as an elementary teacher.

To be admitted as a junior to the Bachelor of Science degree program with a major in general science—interdepartmental, a student must have been admitted to the elementary teacher certification program. Continued enrollment in the teacher certification program is a condition of continued enrollment in the Bachelor of Science degree program with a major in general science—interdepartmental. Students who were admitted to the degree program, but who are no longer enrolled in the elementary teacher certification program, will have to change their majors. The Bachelor of Science degree programs with majors in Biological Science—Interdepartmental, Earth Science—Interdepartmental, and Physical Science—Interdepartmental in the College of Natural Science will be available to students in good standing.

Upon satisfactory completion of the requirements for the Bachelor of Science degree with a major in general science—interdepartmental, the bachelor's degree is granted. However, in order for Michigan State University to recommend a person for a teaching certificate, that person must also complete the requirements for the Internship-Year Studies program described under the heading TEACHER CERTIFICATION in the *Department of Teacher Education* section of this catalog.

Students who have been admitted to the Bachelor of Science degree program with a major in general science—interdepartmental are thereby qualified to pursue the Internship-Year

Studies program upon completion of the baccalaureate degree.

Requirements for the Bachelor of Science Degree in General 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 General Science—Interdepartmental.

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

   The completion of Mathematics 124 or 201 or Statistics and Probability 201 referenced in item 3. below may also satisfy the University mathematics requirement.

   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.

   The completion of Mathematics 124 and either Mathematics 126 or Statistics and Probability 201 referenced in item 3. below may also satisfy the College mathematics requirement.
3. The following requirements for the major:

				CREDITS
a.	All of the following courses:			69
	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	143	Survey of Organic Chemistry	4
	CEM	161	Chemistry Laboratory I	1
	GLG	201	The Dynamic Earth	4
	GLG	304	Physical and Biological History of the Earth	4
	GLG	401	Plate Tectonics (W)	4
	MTH	124	Survey of Calculus with Applications I	3
	MTH	201	Mathematical Investigations I	3
	MTH	202	Mathematical Investigations II	3
	NSC	401	Science Laboratories for Secondary Schools (W)	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
	TE	150	Reflections on Learning	3
	TE	301	Learners and Learning in Context (W)	4
	TE	401	Teaching Subject Matter to Diverse Learners (W)	5
	TE	402	Crafting Teaching Practice (W)	6
b.	One of the following courses:			3
	CEP	240	Diverse Learners in Multicultural Perspective	3
	TE	250	Human Diversity, Power, and Opportunity in Social Institutions	3
c.	One of the following courses:			3 or 4
	ENT	319	Introduction to Earth System Science	3
	ZOL	306	Invertebrate Zoology	4
d.	One of the following courses:			3 or 4
	MTH	126	Survey of Calculus with Applications II	3
	STT	201	Statistical Methods	4

e. *One* of the following alternatives:

Alternative 1: Complementary Studies

A total of 20 credits in courses in the following subject matter areas: anthropology; economics; geography; history; political science; psychology; sociology; integrative studies in arts and humanities; integrative studies in social, behavioral, and economic sciences; and Transcollegiate Courses involving related disciplines. Credits in courses that are used to satisfy University requirements [referenced in item 1. above] and College requirements [referenced in item 2. above] may be used to satisfy this requirement. Credits in courses that are used to satisfy the requirements for a disciplinary major for teacher certification may *not* be used to satisfy this requirement.

Alternative 2: Approved Minor

The requirements for an approved disciplinary minor that is available for teacher certification. The requirements for the approved minors are specified in the statement on *REQUIREMENTS FOR THE DISCIPLINARY MINORS LISTED ABOVE* in the *Department of Teacher Education* section of this catalog.

TEACHER CERTIFICATION OPTION

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

Students who elect the general 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 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[1]	5
	TE	860	Practice and Inquiry in Science Education	3
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

[1] 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.

GENETICS

GRADUATE STUDY

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.

GENETICS—ENVIRONMENTAL TOXICOLOGY

Doctor of Philosophy

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

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
a.	All of the following courses:			44
	BCH	461	Biochemistry I	3
	BCH	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
	MIC	409	Eukaryotic Cell Biology	3
	MIC	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[1]:			6
	MIC	301	Introductory Microbiology	3
	MIC	302	Introductory Microbiology Laboratory	1
	MIC	413	Virology	3
	MIC	431	Microbial Genetics	3
	MIC	461	Molecular Pathogenesis	3
	MIC	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

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

[1] 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.

NEUROSCIENCE

Several colleges and departments within Michigan State University[1] 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.

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
BCH	825	Cell Structure and Function	3
PHM	827	Advanced Neurobiology	4
PHM	980	Problems[2]	6
PSY	811	Advanced Behavioral Neuroscience	3
PTH	830	Concepts in Molecular Biology	2

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 *each* of *two* 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.

[1] 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
Pathology
Pharmacology and Toxicology
Physiology
Psychology
Zoology

[2] In order for Pharmacology and Toxicology 980 to be counted toward the requirements for the degree, 3 credits must focus on statistical analysis of data related to neuroscience and 3 credits must focus on neuroscience laboratory.

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, B-408 Life Sciences 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.

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:	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
	MIC 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 inGeological 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 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 (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[1]	10
Additional Requirements for Plan B		
1.	NSC 889 Research for Inservice Teachers[2]	10

[1] Research for the thesis involves developing laboratories and demonstrations as part of a new teaching unit and teaching that unit.

[2] 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.

Requirements for the Specialization in Environmental Studies:[1]

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)[2] 4
   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
      FOR 464 Natural Resource Economics and Social Science (W) 3
      JRN 408 Topics in Specialized Reporting and Writing[3] . . . 3
      PKG 370 Packaging and the Environment 3
      PLS 342 Comparative Political Economy 3
      PRM 260 World Food, Population and Poverty 3
      PRM 320 Public Policy Analysis Methods 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
   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

[1] 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.

[2] 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.

[3] Journalism 408 may be used to satisfy requirement 2.a. only when the topic deals with environmental journalism.

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.

GRADUATE

BIOTECHNOLOGY

The interdepartmental doctoral specialization in biotechnology is administered by the College of Natural Science. The specialization is available as an elective to students who are enrolled in Doctor of Philosophy degree programs with majors in Biochemistry, Botany and Plant Pathology, Chemical Engineering, Chemistry, and Microbiology.

The specialization is designed to provide an opportunity for doctoral students in the departments referenced above to understand the needs and operations of biotechnology industries and to become familiar with specific biotechnological problems that exist in an industrial setting. Graduates with a specialization in biotechnology may be employed in corporations which apply modern biological techniques to achieve commercial goals.

The interdepartmental doctoral specialization in biotechnology focuses on the broad areas of biomedical engineering and applied microbiology. Students in the specialization may study protein structure and function relationships and protein engineering, the genetic engineering of microbes for industrial processes, and the use of microbes and protein products in chemical engineering processes.

Persons who are interested in the specialization must contact the College of Natural Science. To be accepted into the specialization, a student must have been admitted to a Doctor of Philosophy degree program with one of the majors specified above.

With the approval of the department and college that administer the student's degree program, courses that are used to satisfy the requirements for the specialization may also be used to satisfy the requirements for the Doctor of Philosophy degree.

Requirements for the Interdepartmental Doctoral Specialization in Biotechnology:

The student must complete:

CREDITS

1. Both of the following courses (5 credits):
   BCH 801 Molecular Biology and Protein Structure. 4
   NSC 830 Nature and Practice of Science 1
2. One of the following courses (3 credits):
   CHE 481 Biochemical Engineering[1] 3
   CHE 882 Advanced Biochemical Engineering 3
   ENE 804 Biological Processes in Environmental Engineering 3
3. One of the following courses (3 credits):
   BCH 821 Biochemical Mechanisms and Structure 3
   BOT 856 Plant Molecular Biology 3
   MIC 425 Microbial Ecology[1] 3
   MIC 821 Microbial Physiology 3
   MIC 829 Advanced Microbial Ecology 3
4. An internship of at least two semesters in a biotechnology–related industry approved by the College of Natural Science. The internship involves research that is directed toward achieving market–oriented goals. With the approval of the student's guidance committee, that research may be the basis for the student's doctoral dissertation.

[1] Only *one* of the following courses may be counted toward the requirements for the specialization: Chemical Engineering 481 or Microbiology 425.

Upon completion of the requirements for the Doctor of Philosophy degree and the requirements for the interdepartmental doctoral specialization in biotechnology, 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, Botany and Plant Pathology, Crop and Soil Sciences, Entomology, Fisheries and Wildlife, Forestry, Geological Sciences, Horticulture, Microbiology and Molecular Genetics, Philosophy, Psychology, and Zoology. The College of Natural Science administers the specialization.

The interdepartmental graduate specialization in ecology, evolutionary biology and behavio 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.

ENVIRONMENTAL TOXICOLOGY

The College of Natural Science, the College of Agriculture and Natural Resources, and the College of Engineering 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 require-

ments 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).[1]

(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.
- (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.[2]
- (c) One of the following courses: Lyman Briggs School 330, 331, 332, 333, 334, 335, 336, 355, 490E;[2] English 483; History 425.

(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
  Botany and Plant Pathology
  Chemical Physics
  Chemistry
  Computational Mathematics
  Earth Science—Interdepartmental
  Entomology
  Environmental Biology/Botany and Plant Pathology
  Environmental Biology/Microbiology
  Environmental Biology/Zoology
  Environmental Geosciences
  Geological Sciences
  Human Biology
  Mathematics
  Medical Technology
  Microbiology
  Physical Science—Interdepartmental
  Physics
  Physiology
  Statistics
  Zoology

(2) College of Engineering:
- (a) Computer Science[3]

[1] 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.

[2] 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.

[3] 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):

BCH	461	Biochemistry I	3
BCH	462	Biochemistry II	3
MIC	301	Introductory Microbiology	3
MIC	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 and Plant Pathology 414 and 415 to satisfy requirement 1.a.(2) above must complete one of the following courses:

ZOL	306	Invertebrate Biology	4
ZOL	328	Compatrative Anatomy and Biology Of Vertebrates	4
ZOL	353	Marine Biology	4
ZOL	431	Comparative Limnology	4
ZOL	445	Evolution	3

(b) *Cellular, Molecular, and Developmental Biology*

BOT	416	Experiments in Plant Physiology and Molecular Biology	4
LBS	347	Advances in Applied Biology	3
MIC	409	Eukaryotic Cell Biology	3
MIC	413	Virology	3
MIC	421	Prokaryotic Cell Physiology	3
MIC	431	Microbial Genetics	3
MIC	451	Immunology	3
ZOL	320	Developmental Biology	4
ZOL	421	Hormones and Development	3

2. **Computer Science** 35

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	4
CSE	260	Discrete Structures in Computer Science	3
CSE	320	Computer Organization and Assembly Language Programming	4
CSE	330	Data Structures and Programming Concepts	4
CSE	360	Auto mata and Formal Language Theory	3
CSE	410	Operating Systems	4
LBS	220	Calculus III	5

(2) At least two of the following courses (6 to 8 credits):

CSE	420	Computer Architecture	4
CSE	422	Computer Networks	4
CSE	440	Artificial Intelligence and Symbolic Programming	4
CSE	450	Translation of Programming Languages	4
CSE	452	Organization of Programming Languages	3
CSE	470	Software Engineering	4
CSE	472	Computer Graphics	3
CSE	474	Vector and Parallel Programming	3
CSE	480	Database Systems	4

3. **Earth Science** 27

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	3
AST	202	Astrophysics and Astronomy II	4

(b) *Geology of the Solid Earth*

GLG	201	The Dynamic Earth	4
GLG	321	Mineralogy and Geochemistry	4
GLG	351	Structural Geology	4
GLG	361	Petrology (W)	4
GLG	371	Plate Tectonics (W)	4
GLG	481	Reservoirs and Aquifers	4
GLG	491	Field Geology – Summer Camp (W)	6

(c) *Paleobiology*

BOT	335	Plants Through Time	3
GLG	331	Vertebrate Life of the Past	3
GLG	431	Sedimentology and Stratigraphy (W)	4
GLG	433	Vertebrate Paleontology	4
GLG	434	Evolutionary Paleobiology	4

(d) *Environmental Geosciences and Meteorology*

GEO	203	Introduction to Meteorology	3
GEO	401	Geography of Plants of North America	3
GEO	402	Agricultural Climatology	3
GEO	404	Synoptic Climatology	4
GEO	405	Applied Synoptic Climatology: Principles and Methods	4
GLG	421	Environmental Geochemistry	4
GLG	422	Organic Geochemistry (W)	3
GLG	423	Environmental Geosciences	1

(e) *Geomorphology*

CSS	470	Soil Resources	3
GEO	406	Environmental Geomorphology	3
GEO	407	Regional Geomorphology of the United States	3
GEO	408	Soil Geomorphology Field Study	4

Geography 206 and 206L, combined, may be substitued for one of the courses listed above.

4. **Environmental Sciences and Management** 41

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	5
STT	231	Statistics for Scientists	3

(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*:

BCH	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*:

MIC	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[1]	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

[1]Students who elect Sociology 452 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 student'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 laboratory 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

requirement. Courses outside Lyman Briggs School may be used to satisfy 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

Bachelor of Science

The Bachelor of Science program in Biochemistry 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

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 Biochemistry.

   The University's Tier II writing requirement for the Biochemistry major is met by completing Biochemistry 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.
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.	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
	BCH 100 Current Issues in Biochemistry	1
	BCH 101 Frontiers in Biochemistry	1
(2)	All of the following courses:	

BCH 461 Biochemistry I . . . 3
BCH 462 Biochemistry II . . . 3
BCH 471 Biochemistry Laboratory (W) . . . 3
BCH 472 Biochemistry Laboratory . . . 3
BCH 495 Undergraduate Seminar . . . 2
The completion of Biochemistry 495 fulfills the department's capstone course requirement.

BIOCHEMISTRY/BIOTECHNOLOGY

Bachelor of Science

The Bachelor of Science program in Biochemistry/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/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/Biotechnology

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 Biochemistry/Biotechnology.

   The University's Tier II writing requirement for the Biochemistry/ Biotechnology major is met by completing Biochemistry 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.
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:
   a. Competency in a foreign language equivalent to the completion f two 100–level courses at Michigan State University . . . 0 to 8
   b. All of the following courses: . . . 68
      BCH 461 Biochemistry I . . . 3
      BCH 462 Biochemistry II . . . 3
      BCH 471 Biochemistry Laboratory (W) . . . 3
      BCH 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
      MIC 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
      BCH 100 Current Issues in Biochemistry . . . 1
      BCH 101 Frontiers in Biochemistry . . . 1
   d. One of the following courses: . . . 3 or 4
      BCH 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
      MIC 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
         MIC 301 Introductory Microbiology . . . 3
         MIC 302 Introductory Microbiology Laboratory . . . 1
         MIC 421 Prokaryotic Cell Physiology . . . 3
         MIC 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 Fundame ntals 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 may be administered by any one of the three colleges referenced above. Study for the Doctor of Philosophy degree with a major in biochemistry—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.

Students who are enrolled in the Doctor of Philosophy degree program with a major in biochemistry may elect a specialization in biotechnology. For additional information, refer to the statement on the specialization.

BIOCHEMISTRY

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 Osteo-

pathic 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

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

Person's 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

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—ENVIRONMENTAL TOXICOLOGY

Doctor of Philosophy

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

DEPARTMENT of BOTANY and PLANT PATHOLOGY

Raymond Hammerschmidt, Acting Chairperson

The Department of Botany and Plant Pathology 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.

Plant pathology is concerned with fundamental relationships involving the diseased plant. This includes study of the interaction between the plant, its environment, and in most instances a microorganism or virus. Ecological, morphological, biochemical, and physiological aspects of disease development are studied in the more specialized fields of molecular biology, cellular biology, virology, bacteriology, mycology, genetics, and others. Plant pathological research also contributes to fundamental biology, as well as to practical plant disease control.

UNDERGRADUATE PROGRAMS

The Department of Botany and Plant Pathology offers two Bachelor of Science degree programs: one in botany and plant pathology and one in environmental biology/botany and plant pathology.

BOTANY AND PLANT PATHOLOGY

The Bachelor of Science degree program with a major in botany and plant pathology 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 of plant pathology.

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

Requirements for the Bachelor of Science Degree in Botany and Plant Pathology

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 Botany and Plant Pathology.

   The University's Tier II writing requirement for the Botany and Plant Pathology major is met by completing Botany and Plant Pathology 498 and 499 and one of the following courses: Botany and Plant Pathology 301, 405, 407, 416, or 441 or Zoology 355L. 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.
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. 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 . . . 4

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) BCH 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) BCH 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 with Applications I . . . 3
  MTH 126 Survey of Calculus with Applications II . . . 3
- (3) MTH 132 Calculus I . . . 3
  STT 331 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):
- ZOL 341 Fundamental Genetics . . . 4
- CSS 350 Introduction to Plant Genetics . . . 3

g. *One* of the following seven 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[1] . . . 3
- ZOL 355L Ecology Laboratory[1] . . . 1

(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*
- BOT 405 Introductory Plant Pathology . . . 4
- BOT 407 Diseases and Insects of Forest and Shade Trees . . . 4

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

[1] Both Zoology 355 and 355L combined, or Botany and Plant Pathology 441, must be completed to satisfy this requirement.

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
- MIC 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[1] . . . 3
- ZOL 355L Ecology Laboratory[1] . . . 1

(d)
- BCH 200 Introduction to Biochemistry . . . 4
- BCH 401 Basic Biochemistry . . . 4
- BCH 461 Biochemistry I . . . 3

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

[1] Both Zoology 355 and 355L combined, or Botany and Plant Pathology 218 or 418 or 441, must be completed to satisfy this requirement.

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):
- BOT 405 Introductory Plant Pathology . . . 4
- BOT 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 . . . 3
- BOT 434 Plant Structure and Function . . . 4

(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).

Pathology and Mycology (25 to 28 credits)

(1) All of the following courses (13 credits):
- BOT 402 Biology of Fungi . . . 3
- BOT 405 Introductory Plant Pathology . . . 4
- BOT 418 Plant Systematics . . . 3
- MIC 301 Introductory Microbiology . . . 3

(2) *One* course from *each* of the following groups of courses (9 to 11 credits):

(a)
- BOT 202 The Plant Kingdom . . . 3
- BOT 434 Plant Structure and Function . . . 4

(b)
- BOT 301 Introductory Plant Physiology . . . 3
- BOT 414 Plant Physiology: Metabolism . . . 3
- BOT 415 Plant Physiology: Growth Development and the Environment . . . 3

(c)
- BCH 200 Introduction to Biochemistry . . . 4
- BCH 401 Basic Biochemistry . . . 4
- BCH 461 Biochemistry I . . . 3

(3) 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	
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	405	Introductory Plant Pathology	4
BOT	418	Plant Systematics	
BOT	434	Plant Structure and Function	4
BOT	441	Plant Ecology	3
MIC	409	Eukaryotic Cell Biology	3

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):

BCH	200	Introduction to Biochemistry	4
BCH	401	Basic Biochemistry	4
BCH	461	Biochemistry I	3

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

Plant Protection (30 credits)

(1) All of the following courses (21 credits):

BOT	301	Introductory Plant Physiology	3
BOT	402	Biology of Fungi	3
BOT	405	Introductory Plant Pathology	4
ENT	404	Insects: Success in Biodiversity	4
ENT	477	Pest Management I: Pesticides in Management Systems	3
ZOL	355	Ecology	3
ZOL	355L	Ecology Laboratory	1

(2) *One* course from *each* of the following groups of courses (9 credits):

(a)	CSS	402	Principles of Weed Science	3
	ENT	470	General Nematology (W)	3
	ENT	478	Pest Management II: Biological Components of Management Systems (W)	3
	FW	328	Vertebrate Pest Control	3
(b)	CSS	101	Introduction to Crop Science	3
	FOR	202	Introduction to Forestry	3
(c)	BOT	218	Plants of Michigan	3
	BOT	418	Plant Systematics	3

Upon completion of the required courses for one of the seven concentrations referenced above, the student should contact the Department of Botany and Plant Pathology 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 AND PLANT PATHOLOGY

The Bachelor of Science degree program in environmental biology/botany and plant pathology 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 and Plant Pathology

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/Botany and Plant Pathology.

   The University's Tier II writing requirement for the Environmental Biology/Botany and Plant Pathology major is met by completing the following courses: Botany and Plant Pathology 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.
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:			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 with Applications 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
	BOT	405	Introductory Plant Pathology	4
	BOT	407	Diseases and Insects of Forest and Shade Trees	4
	ENT	404	Insects: Success in Biodiversity	4
f.	One of the following courses:			3 or 4
	FW	410	Upland Ecosystem Management	4
	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	4
	(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 Botany and Plant Pathology			6 to 8

GRADUATE STUDY

The Department of Botany and Plant Pathology 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 botany and plant pathology and a Doctor of Philosophy degree program with a major in botany and plant pathology—environmental toxicology through the College of Natural Science. 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 Botany and Plant Pathology* in the *College of Agriculture and Natural Resources* section of this catalog.

The Department of Botany and Plant Pathology 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 Botany and Plant Pathology, refer to the statement on the doctoral program in ecology, evolutionary biology and behavior.

Students who are enrolled in the Doctor of Philosophy degree program with a major in botany and 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 Botany and Plant Pathology may elect a specialization in ecology, evolutionary biology and behavior. For additional information, refer to the statement on the specialization.

BOTANY AND PLANT PATHOLOGY

Graduate students in botany and plant pathology 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, 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 Botany and Plant Pathology

The master's degree program in botany and plant pathology 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.

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 Botany and Plant Pathology

All doctoral students in botany and plant pathology must meet the requirements specified below:

1. Complete at least three graduate–level seminar courses in the biological sciences.[1]
2. Pass a preliminary examination.
3. Acquire teaching experience by assisting in two courses.

Doctoral students who specialize in plant pathology must also complete:

				CREDITS
1.	All of the following courses:			
	BOT	405	Introductory Plant Pathology	4
	BOT	801	Seminar in Plant Pathology[1]	2
	BOT	810	Current Concepts in Plant Pathology	3
2.	One of the following courses:			
	BOT	812	Epidemiology of Plant Diseases	3
	BOT	881	Molecular and Biochemical Plant Pathology	3
	BOT	885	Plant Diseases in the Field	2
3.	Two of the following courses:			
	BOT	847	Advanced Mycology	5
	BOT	880	Plant Virology	4
	BOT	884	Prokaryotic Diseases of Plants	4
	ENT	870	Plant Nematology	3

[1] For doctoral students who specialize in plant pathology, the completion of 2 credits of Botany and Plant Pathology 801 satisfies two of the required three graduate–level seminars in the biological sciences.

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

BOTANY AND PLANT PATHOLOGY—ENVIRONMENTAL TOXICOLOGY

Doctor of Philosophy

For information about the Doctor of Philosophy degree program in botany and plant pathology—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, 372, 415, and 472. 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:	27 or 28
(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
	MIC 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
c.	The following courses in the Department of Chemistry:	42 to 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 (3 or 4 credits):	
(a)	CEM 162 Chemistry Laboratory II	1
	CEM 262 Quantitative Analysis	2
(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 361 Analytical–Physical Chemistry I	3
	CEM 362 Analytical–Physical Chemistry II	3
	CEM 372 Analytical–Physical Chemistry Laboratory I	3
	CEM 411 Inorganic Chemistry	4
	CEM 461 Theoretical Chemistry	3
	CEM 472 Analytical–Physical Chemistry Laboratory II	3
(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, predentistry 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
	MIC 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:	34 to 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 (3 or 4 credits):	
(a)	CEM 162 Chemistry Laboratory II	1
	CEM 262 Quantitative Analysis	2

(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
Two of the following courses may be substituted for Chemistry 383 and 384: Chemistry 361, 362, 461.
(4) The following capstone course (3 credits):
CEM 410 Literature and Writing in Chemistry. 3

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
MIC 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 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
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 331 Optics 3
PHY 410 Th ermal and Statistical Physics 3
PHY 422 Classical Mechanics II. 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 372 Analytical–Physical Chemistry Laboratory I 3
CEM 472 Analytical–Physical Chemistry Laboratory II 3
(5) Two of the following courses (6 credits):
CEM 361 Analytical–Physical Chemistry I 3
CEM 362 Analytical–Physical Chemistry II. 3
CEM 461 Theoretical 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.

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, 372, 472, 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: . 48 or 49

(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
MIC	205	Allied Health Microbiology	3
PSL	250	Introductory Physiology	4
ZOL	141	Introductory Human Genetics	3

(2) All of the following courses (45 credits):

CSE	230	Algorithms and Computing	4
CSE	260	Discrete Structures in Computer Science	3
CSE	320	Computer Organization and Assembly Language Programming	4
CSE	330	Data Structures and Programming Concepts	4
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
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: 45 to 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 (3 or 4 credits):

(a)	CEM	162	Chemistry Laboratory II	1
	CEM	262	Quantitative Analysis	2
(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	361	Analytical-Physical Chemistry I	3
CEM	362	Analytical-Physical Chemistry II	3
CEM	372	Analytical-Physical Chemistry Laboratory I	3
CEM	411	Inorganic Chemistry	4
CEM	415	Advanced Synthesis Laboratory	3
CEM	461	Theoretical Chemistry	3
CEM	472	Analytical-Physical Chemistry Laboratory II	3

(4) The following capstone course (3 credits):

CEM	481	Computational Chemistry Seminar	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

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.

Students who are enrolled in the Doctor of Philosophy degree program with a major in chemistry may elect a specialization in biotechology. For additional information, refer to the statement on the specialization.

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.[1]

[1] 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.

DEPARTMENT of ENTOMOLOGY

Edward J. Grafius, Chairperson

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

Entomology is the field of biological science concerned with the study and management of beneficial and harmful insects and their relatives in relation to other animals, plants, and the environment. Since insects and their relatives affect so many human activities, and because they must be studied and managed in such a variety of environments, the entomologist needs a broad, basic education.

UNDERGRADUATE PROGRAM

The undergraduate program in Entomology leads to the Bachelor of Science degree. The total program emphasizes the development of a sound education, with strengths in the physical and biological sciences necessary to work effectively in modern entomology. Courses are designed to give the student an understanding of the structure, classification, identification, function, biology, ecology, and management of beneficial and harmful insects, and the communities and ecosystems where they occur.

Three concentrations are available within the undergraduate Entomology degree program: general entomology, economic plant protection, and natural ecosystem protection. The general entomology concentration is broader than the other two options. Many students who select the general entomology concentration plan to pursue graduate study in entomology. The economic plant protection concentration involves the biology of pests (insects, fungi, bacteria, viruses, nematodes, weeds, and vertebrates), with special reference to their interactions with economic plants; the principles of integrated pest management; and sustainable agriculture. The natural ecosystem protection concentration involves the biology, ecology, and management of nonagricultural, long–term aquatic and terrestrial ecosystems, and the use of technology and social systems to manage them. Students are encouraged to select the concentration best suited to their interests and career objectives.

There are opportunities for undergraduate Entomology students to carry out research projects in many laboratories. Students may also gain work experience in the diverse areas of entomology through employment during the academic year and summer.

Requirements for the Bachelor of Science Degree in Entomology

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 Entomology.

   The University's Tier II writing requirement for the Entomology major is met by completing Entomology 470 or 478. 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.
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 major requirements:

CREDITS

a. *One of the following 3 concentrations:*
(1) **General Entomology** (36 credits)
(a) Biological Science: A minimum of 10 credits in courses in the biological sciences other than Entomology including Biological Science 111 and 6 credits from botany and plant pathology, ecology, genetics, microbiology, physiology, and zoology. The courses other than Biological Science 111 must be approved in writing by the student's academic adviser.
(b) Entomology: A minimum of 19 credits in Entomology courses and 7 additional credits in entomology or in fields acceptable to the department as contributing to the student's development as an entomologist. The courses must be approved in writing by the student's academic adviser.
(2) **Economic–Plant Protection** (35 credits)
(a) *All of the following courses (26 credits):*
BOT 301 Introductory Plant Physiolog 3
BOT 405 Introductory Plant Pathology 4
CEM 251 Organic Chemistry I 3
CEM 255 Organic Chemistry Laboratory 2
ENT 404 General Entomology 4
ENT 442 Concepts of Biological Information Systems 3
ENT 477 Pest Management: Pesticides and Management Systems 3
ZOL 341 Fundamental Genetics 4
(b) *One of the following courses* (3 credits):
BOT 218 Plants of Michigan 3
BOT 418 Plant Systematics 3
(c) *One of the following courses* (3 credits):
BOT 402 Biology of Fungi 3
CSS 402 Principles of Weed Science 3
FW 328 Vertebrate Pest Control 3
(d) *One of the following courses* (3 credits):
CSS 101 Introduction to Crop Science 3
FOR 202 Introduction to Forestry 3
HRT 201 Principles of Horticulture I 3
(3) **Natural–Ecosystem Protection** (40 credits)
(a) *All of the following courses* (37 credits):
BOT 301 Introductory Plant Physiology 3
BOT 423 Aquatic Plant Biology 4
CEM 251 Organic Chemistry I 3
CEM 255 Organic Chemistry Laboratory 2
CSS 210 Fundamentals of Soil and Landscape Science 3
ENT 404 General Entomology 4
ENT 442 Concepts of Biological Information Systems 3
FW 420 Stream and Aquatic Insect Ecology . . . 3
ZOL 250 Ecology 4
ZOL 306 Invertebrate Biology 4
ZOL 341 Fundamental Genetics 4
(b) *One of the following courses* (3 credits):
BOT 218 Plants of Michigan 3
BOT 418 Plant Systematics 3

b. *One of the following courses* (3 credits):
ENT 470 General Nematology (W) 3
ENT 478 Pest Management II: Biological Components of Management Systems (W) 3
Entomology 850 may be substituted for one of the courses listed above with the written approval of the student's academic adviser.

c. The following course (4 credits):
LBS 492 Senior Seminar 4

Upon completion of the required courses for one of the three concentrations referenced above, the student should contact the Department of Entomology 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 Entomology offers Master of Science and Doctor of Philosophy degree programs in entomology and in entomology—urban studies. Entomology also offers a Professional Integrated Pest Management Master of Science degree (Plan B). The department offers a Doctor of Philosophy degree program in entomology—environmental toxicology. Many of the courses offered in entomology are useful in other disciplines in the biological and agricultural sciences.

The Department of Entomology 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 Entomology, 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 Entomology 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.

ENTOMOLOGY

Faculty and facilities are available for study in many subject areas, including apiculture and pollination, aquatic systems, behavior, insect biochemistry, biological control, bionomics, ecology, insect economics, forest entomology, medical entomology, morphology, nematology, population dynamics, insect physiology, pest management on many kinds of crops, plant disease vectors, systematics, systems science, environmental and analytical toxicology, and urban and ornamental entomology. Combinations of many of these specialized subject areas are necessary for all programs of study. Regardless of specialization, the student's education must provide broad training in related sciences.

Graduate students in entomology look forward chiefly to college teaching; research work in some of the many areas where insects affect our crops and our lives; professional employment with state, federal, or private agencies or companies; or employment as pest management consultants.

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

A bachelor's degree with a 3.00 grade–point average for the last two years of study is required for admission to the master's program. Although the applicant need not have an undergraduate major in entomology for regular admission, training should have been received in the physical and biological sciences equivalent to that required of an undergraduate entomology major at Michigan State University. Graduate Record Examination General Test scores are required. Applicants with a good academic record but with deficiencies in physics, chemistry, mathematics, or the biological sciences may be accepted on a provisional basis until deficiencies have been rectified by collateral course work.

Requirements for the Master of Science Degree in Entomology

Both Plan A (with thesis) and Plan B (without thesis) are available, but students planning to earn a doctoral degree must follow Plan A. The student must complete a total of 30 credits for the degree under either Plan A or Plan B. Participation in the department's teaching program is also required.

Courses and thesis topic are planned on an individual basis by the student, the student's major professor, and the student's guidance committee. At least one prescribed course from each of the following areas must be a part of the under-

graduate or graduate program: morphology, systematics, physiology, toxicology, ecology, and applied entomology. A final oral examination covering course work, research, and philosophical issues is required.

INTEGRATED PEST MANAGEMENT

Master of Science

The objective of this program is to train professionals in Integrated Pest Management with the business management and communication skills necessary for public and private sector employment. It is designed for students with bachelor's degrees in biological or agricultural sciences or for working professionals who wish to advance or change their careers.

Admission

In addition to meeting the requirements of the University and the College of Natural Science, applicants are expected to have knowledge of computer applications and appropriate curricular background in crop protection-related fields and crop production-related fields. Applicants with good academic records who lack the expected curricular backgrounds may be admitted on a provisional basis but will be expected to take collateral course work.

Requirements for the Master of Science Degree in Integrated Pest Management

In addition to meeting the requirements of the University and the College of Natural Science, the student must complete a total of 31 credits for the degree under Plan B (without thesis).

				CREDITS
1.	The following requirements for the major:			31
a.	*Two of the following core courses* (6 credits):			
	ENT	818	Systematics, Morphology, Biology: Adults	3
	or			
	ENT	838	Systematics, Morphology, Biology: Immatures	3
	ENT	850	Insect Physiology	3
	or			
	ENT	851	Plant Nematology	3
b.	*All of the following courses* (19 credits):			
	ENT	442	Concepts of Biological Information Systems	3
	ENT	447	Pest Management I: Pesticides in Management Systems	3
	ENT	478	Pest Management II: Biological Components of Management Systems	3
	ENT	812	Graduate Seminar[1]	3
	ENT	848	Biological Control of Insects and Weeds	3
	ENT	870	Plant Nematology	3
	ENT	890	Independent Study	1
c.	*A minimum of two of the following courses* (6 credits):[2]			
	BOT	362	Management of Turfgras Pests[3]	4
	BOT	407	Diseases and Insects of Forest and Shade Trees	4
	BOT	413	Virology	3
	BOT	810	Current Concepts in Plant Pathology	3
	BOT	812	Epidemiology of Plant Diseases	3
	BOT	847	Advanced Mycology	4
	BOT	884	Prokaryotic Diseases of Plants	4
	BOT	885	Plant Diseases in the Field	2
	CSS	310	Soil Management and Environmental Impact[3]	3
	CSS	455	Pollutants in the Soil Environment	3
	CSS	805	Herbicide Action and Metabolism	2
	ENT	422	Aquatic Entomology	3
	ENT	460	Medical and Veterinary Entomology	3
	ENT	470	General Nematology (W)	3
	FOR	819	Advanced Plant Breeding	3
	FOR	837	Water Law	3
	FOR	838	Land Use Law	3
	FOR	864	Agroforestry Systems	3
	FW	811	Fisheries and Wildlife Laws and Regulations	3
	FW	814	Environmental Chemodynamics	4
	FW	852	Systems Modeling and Simulation	3
	FW	878	Dynamics of Trace Contaminants on Aquatic Systems	3
	NSC	830	Nature and Practice of Science	1

d. **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 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 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.

[1] Students will complete a total of three 1 credit seminars, focusing on standard topics for this program.

[2] At least two courses must be from areas other than Entomology. The student's guidance committee may approve other courses to meet this requirement.

[3] Requires special approval for application toward graduate credits.

Doctor of Philosophy

The Department of Entomology aspires to develop not only capable entomologists but also capable scholars. Scholarly potential is sought in the prospective student, and course and research programs are designed to round out the student's knowledge and bring it to the stage of development where the student can work creatively in the field.

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 master's degree including a thesis in an appropriate field of study is required. Subject matter training should be in the same general areas as required for admission to the Master of Science degree program in entomology. The student's past record must indicate maturity, reliability, and scholarly potential of a high order.

Requirements for the Doctor of Philosophy Degree in Entomology

A specified number of credits is not required, but early in the student's program the guidance committee, in consultation with the student, develops a list of proposed courses and a tentative dissertation subject. The student is expected to acquire a broad knowledge of entomology and to demonstrate competence in each of the following areas: (1) applied entomology, (2) insect systematics–morphology, (3) physiology–toxicology, and (4) ecology–behavior.

The student must pass a doctoral qualification examination which primarily consists of the defense of a dissertation proposal. Written and oral doctoral comprehensive examinations are required on philosophical issues and in the three or more areas of study specified by the guidance committee. Participation in the department's teaching program is also required.

In addition to the program developed by the guidance committee for a research specialty, the student must acquire an area of knowledge separate and distinct from those research competencies. The acquisition of this knowledge means a minimum of 10 credits or its equivalent. The area selected must be agreed upon, unanimously, by the guidance committee and the student.

ENTOMOLOGY—ENVIRONMENTAL TOXICOLOGY

Doctor of Philosophy

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

ENTOMOLOGY–URBAN STUDIES

The Department of Entomology offers interdepartmental Master of Science and Doctor of Philosophy degree programs in entomology–urban studies.

To be admitted to a major in entomology–urban studies, students must meet the requirements for admission to the Master of Science or Doctor of Philosophy degree program with a major in entomology. They must also meet the requirements for admission as specified in the statement on *Interdepartmental Graduate Programs in Urban Studies* in the *Graduate Education* section of this catalog.

Students who are admitted to a major in entomology–urban studies must meet the requirements for the major in entomology leading to the Master of Science or Doctor of Philosophy degree. They must also meet the requirements for the urban studies component of the program as specified in the statement on *Interdepartmental Graduate Programs in Urban Studies*.

For the Master of Science degree, both Plan A (with thesis) and Plan B (without thesis) are available, but students who are planning to earn a doctoral degree must select Plan A. The student must complete a total of 30 credits for the degree under either Plan A or Plan B. The research methods requirement for both the entomology and urban studies components may be met by completing Statistics and Probability 421 and 422.

For the Doctor of Philosophy degree program, the courses that are used to meet requirements 2 and 3 for the urban studies component may also be used to meet part of the requirements for the entomology component.

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

The undergraduate programs in environmental geosciences and geological sciences 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
	MIC 426 Biogeochemistry[1]	3
(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.[1,2]

[1] Botany and Plant Pathology 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.

[2] 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

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 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.
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 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.[1,2] The completion of Geological Sciences 491 fulfills the department's capstone course requirement.			

[1] 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.

[2] The credits that are used to satisfy this requirement may be used to satisfy *either* the requirements for the geological sciences major *or* the requirements for the environmental geosciences major, but not both of those requirements.

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.

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; gla-

cial 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 Master of Science and Master of Arts degree programs 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):[1,2]			
	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.[1,2] One of the following courses (3 or 4 credits):[3]			
	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

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.[4]

[1] 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.

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

[3] 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 below.

[4] 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. A student who has not completed all of the courses that are required for the

Master of Science degree in Environmental Geosciences from Michigan State University, or their equivalents, will be required to complete such courses while enrolled in the doctoral degree program.

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.

GEOLOGICAL SCIENCES

Master of Arts

The Master of Arts degree program in geological sciences is available only under 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

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 geological sciences or in a cognate science.
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 upon the applicant's 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.

Requirements for the Master of Arts Degree in Geological Sciences

A total of 36 credits is required for the degree under 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:

1. *One* of the following courses (1 credit): CREDITS

GLG	891	Special Problems in Geochemistry[1]	1
GLG	892	Special Problems in Geophysics and Geodynamics[1]	1
GLG	893	Special Problems in Hydrogeology[1]	1
GLG	894	Special Problems in Paleobiology[1]	1
GLG	895	Special Problems in Petrology[1]	1
GLG	896	Special Problems in Sedimentology and Stratigraphy[1]	1
GLG	897	Special Problems in Structural Geology and Tectonics[1]	1
GLG	898	Special Problems in Environmental Geosciences[1]	1

2. Nineteen to 23 credits in approved courses in *one* of the following three areas of geological sciences: environmental geosciences, solid earth systems, or paleobiology. A list of approved courses is available in the Department of Geological Sciences.
3. Twelve to 16 credits in the two areas of geological sciences that were not used to satisfy the requirement referenced in 2. above. The student must complete at least two courses in *each* of the two areas.

[1] The student must complete a research paper or project while enrolled in this course. The topic of the paper or project must be mutually agreed upon by the student and the student's academic adviser.

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 A. Lappan, 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 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, botany and plant pathology, entomology, microbiology, physiology, 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, a minimum of 6 credits in Professional Education Courses.	
c.	A total of 38 credits in courses in the Department of Mathematics including:	38
	(1) All of the following courses (17 credits):	
	MTH 132 Calculus I	3
	MTH 133 Calculus II	4
	MTH 234 Multivariable Calculus	4
	MTH 235 Differential Equations	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. The 300-400 level courses that are referenced in items 3. (c) (1), 3.c.(3), and 3.c.(4) partially satisfy this requirement. One course from a list of approved cognates may be used to satisfy this requirement; the list is available in the Department of Mathematics.

(3) One of the following groups of courses (6 or 9 credits):
- (a) MTH 310 Abstract Algebra I and Number Theory . . . 3
  MTH 314 Linear Algebra I . . . 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

Requirements for the Bachelor of Arts 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 Arts degree in Mathematics.

   The University's Tier II writing requirement for the Mathematics major is met by completing Mathematics 496 and Mathematics 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 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: 11
   (1) One course of at least 3 credits in biological science, botany and plant pathology, entomology, microbiology, physiology, 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

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 a minimum of 6 credits in Professional Education Courses.

c. A total of 38 credits in courses in the Department of Mathematics including: . . . 38
   (1) All of the following courses (17 credits):
   MTH 132 Calculus I . . . 3
   MTH 133 Calculus II . . . 4
   MTH 234 Multivariable Calculus . . . 4
   MTH 235 Differential Equations . . . 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 4 of the approved Mathematics courses must be at the 400–level or above. The 300-400 level courses that are referenced in items 3. c. (1), 3. C. (3), and 3. C. (4) partially satisfy this requirement. One course from a list of approved cognates may be used to satisfy this requirement; the list is available in the Department of Mathematics.
   (3) One of the following groups of courses (6 or 9 credits):
   - (a) MTH 310 Abstract Algebra I and Number Theory . . . 3
     MTH 314 Linear Algebra I . . . 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

Requirements for the Bachelor of Science 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 Science degree in Computational Mathematics.

   The University's Tier II writing requirement for the Computational Mathematics major is met by completing Mathematics 310 and 496. Those courses are referenced in item 3. c. (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 Mathematics: 27 or 29
   (1) One course of at least 3 credits in biological science, botany and plant pathology, entomology, microbiology, physiology, 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):
   CSE 231 Introduction to Programming I . . . 4
   CSE 232 Introduction to Programming II . . . 4
   (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

c. The following courses in the Department of Mathematics: . . . 35
   (1) All of the following courses (32 credits):
   MTH 132 Calculus I . . . 3
   MTH 133 Calculus II . . . 4
   MTH 234 Multivariable Calculus . . . 4
   MTH 235 Differential Equations . . . 3
   MTH 310 Abstract Algebra I and Number Theory . . . 3
   MTH 314 Linear Algebra I . . . 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[1] . . . 3
   MTH 482 Discrete Mathematics II[1] . . . 3

d. At least one of the following courses: . . . 3 or 4
   CSE 331 Algorithms and Data Structures[2] . . . 4
   CSE 440 Artificial Intelligence and Symbolic Programming[2] . . . 4
   MTH 415 Applied Linear Algebra . . . 3
   MTH 416 Introduction to Algebraic Coding . . . 3
   MTH 441 Ordinary Differential Equations . . . 3
   MTH 452 Numerical Analysis II[1] . . . 3
   MTH 471 Computational Complexity . . . 3
   MTH 472 Mathematical Logic . . . 3
   MTH 482 Discrete Mathematics II[1] . . . 3
   STT 441 Probability and Statistics I: Probability . . . 3
   STT 461 Computations in Probability and Statistics . . . 3

[1] This course may be counted toward either the requirement 3.c.(2) or 3.d., but *not* toward both of those requirements.

[2] Approval of the Department of Computer Science and Engineering is required to enroll in this course.

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 310 and 496. Those courses are referenced in item 3.c.(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 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, botany and plant pathology, entomology, microbiology, physiology, 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 langugage.		
c.	The following courses in the Department of Mathematics: . . .		35
	(1)	All of the following courses (32 credits):	
		MTH 132 Calculus I. 3	
		MTH 133 Calculus II 4	
		MTH 234 Multivariable Calculus 4	
		MTH 235 Differential Equations. 3	
		MTH 310 Abstract Algebra I and Number Theory. . . . 3	
		MTH 314 Linear Algebra I. 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[1] 3	
		MTH 482 Discrete Mathematics II[1] 3	
d.	At least one of the following courses:		3 or 4
		CSE 331 Algorithms and Data Structures[2]. 4	
		CSE 440 Artificial Intelligence and Symbolic Programming[2] 4	
		MTH 415 Applied Linear Algebra. 3	
		MTH 416 Introduction to Algebraic Coding 3	
		MTH 441 Ordinary Differential Equations 3	
		MTH 452 Numerical Analysis II[1] 3	
		MTH 471 Computational Complexity 3	
		MTH 472 Mathematical Logic. 3	
		MTH 482 Discrete Mathematics II[1] 3	
		STT 441 Probability and Statistics I: Probability 3	
		STT 461 Computations in Probability and Statistics. 3	

[1] This course may be counted toward *either* requirement 3.c.(2) or 3.d., but *not* toward both of those requirements.

[2] Approval of the Department of Computer Science and Engineering is required to enroll in this course.

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 Master of Science and Doctor of Philosophy degree programs in applied mathematics; Master of Arts for Teachers, Master of Science, and Doctor of Philosophy degree programs in mathematics; and a Doctor of Philosophy degree program in 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,[1] 849,[1] 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;[1] 850, 851; or 880, 881.
2. At least 18 credits in 800–900 level courses.

[1] 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.

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.

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.

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 and442. 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 Combinatories 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 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.

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. Complete at least 36 credits in approved 800–900 level courses *excluding* courses taken in preparation for the qualifying examination and Mathematics 999 and *including*:
   a. 12 credits in mathematics education courses.
   b. 12 credits in mathematics courses excluding the courses that are used to satisfy the requirement referenced in item 2. a.
   c. Counseling, Educational Psychology and Special Education 930.
   d. Counseling, Educational Psychology and Special Education 933 or Teacher Education 931.
3. Present at least two seminars acceptable to the faculty.
4. Pass the comprehensive examination.
5. Demonstrate a reading knowledge of one foreign language, from among French, German, and Russian sufficient to read the mathematical and educational literature written in that language.
6. Complete a dissertation in mathematics education.

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

MEDICAL TECHNOLOGY PROGRAM

Douglas Estry, 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 Major

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):		
		BCH 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
		MIC 205	Allied Health Microbiology	3
		MIC 302	Introductory Microbiology Laboratory	1
		MIC 463	Medical Microbiology	3
		MIC 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 Major

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.

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.[1]
   b. Chemistry 162, 251, 252[1].
   c. Mathematics 124 or 132.
   d. Physics 231 and 232.[1]
   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 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.

[1] 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.

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:

				CREDITS
a.	Courses outside Medical Technology:			49 or 50
	(1) All of the following courses (46 credits):			
	BCH	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
	MIC	205	Allied Health Microbiology	3
	MIC	302	Introductory Microbiology Laboratory	1
	MIC	463	Medical Microbiology	3
	MIC	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

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

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. Emphases are offered at all le in physiology; biochemistry; immunology; genetics; ecology; bacteriology; virology; parasitology; mycology; and developmental, cell, and molecular biology. A special emphasis is placed on the role of microbiologists in environmental biology.

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 persons 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 medical schools.

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* statement in the *College of Agriculture and Natural Resources* 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:			67
(1)	All of the following courses (64 credits):			
	BCH	461	Biochemistry I	3
	BCH	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):[1]			
	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
(3)	The following courses in the Department of Microbiology and Molecular Genetics:			19
(a)	All the following courses (16 credits):			
	MIC	301	Introductory Microbiology	3
	MIC	302	Introductory Microbiology Laboratory	1
	MIC	408	Advanced Microbiology Laboratory (W)	3
	MIC	421	Prokaryotic Cell Physiology	3
	MIC	425	Microbial Ecology	3
	MIC	431	Microbial Genetics	3
(b)	One of the following two options (3 credits):			
(i)	MIC	491	Current Topics in Microbiology	3
(ii)	MIC	492	Undergraduate Research Seminar	1
	One of the following courses:			
	MIC	499	Undergraduate Research	2
	MIC	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)	MIC	426	Biogeochemistry	3
(e)	MIC	445	Basic Biotechnology	3
(f)	MIC	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

[1] 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.

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):

BCH	461	Biochemistry I	3
BCH	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):

MIC	301	Introductory Microbiology 3
MIC	302	Introductory Microbiology Laboratory 1
MIC	408	Advanced Microbiology Laboratory (W) 3
MIC	409	Eukaryotic Cell Biology 3
MIC	431	Microbial Genetics 3

(2) One of the following two options (3 credits):

(a)	MIC	491	Current Topics in Microbiology	3
(b)	MIC	492	Undergraduate Research Seminar	1
	One of the following courses:			
	MIC	499	Undergraduate Research	2
	MIC	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*[1]: . . . . . 12 to 13

General Microbiology

MIC 421 Prokaryotic Cell Physiology 3
Three courses from a list of approved electives[2] . . . . . 9 or 10

Cell and Molecular Biology

1. *All of the following courses* (10 credits):

MIC	413	Virology	3
MIC	451	Immunology	3
ZOL	341	Fundamental Genetics	4

2. *One of the following courses* (3 credits):

MIC	421	Prokaryotic Cell Physiology	3
MIC	433	Microbial Genomics	3
MIC	461	Molecular Pathenogenesis	3
ZOL	342	Advanced Genetics	3
ZOL	344	Human Genetics	3

Genomics and Molecular Genetics

1. *Both of the following courses* (7 credits):

MIC	433	Microbial Genomics	3
ZOL	341	Fundamental Genetics	4

2. *Two of the following courses* (6 credits):

MIC	413	Virology	3
MIC	421	Prokaryotic Cell Physiology	3
MIC	445	Basic Biotechnology	3
MIC	451	Immunology	3
ZOL	342	Advanced Genetics	3
ZOL	344	Human Genetics	3

Medical Microbiology and Immunology

1. *The following courses* (9 credits):

MIC	413	Virology	3
MIC	451	Immunology	3
MIC	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
MIC	421	Prokaryotic Cell Physiology	3
MIC	463	Medical Microbiology	3

Microbial Biotechnology

1. *All of the following courses* (9 credits):

MIC	421	Prokaryotic Cell Physiology	3
MIC	433	Microbial Genomics	3
MIC	445	Basic Biotechnology	3

2. *One of the following courses* (3 credits):

CHE	491	Selected Topics in Chemical Engineering[3]	3
FSC	440	Food Microbiology	3
MIC	413	Virology	3
MIC	425	Microbial Ecology	3
MIC	451	Immunology	3

[1] Advisers may recommend individual course options to accommodate student needs and abilities.

[2] Copies of this list are available in the department office.

[3] Topic 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 or Doctor of Philosophy degree with a major in microbiology may be administered by any one of the four colleges referenced above. Study for the Doctor of Philosophy degree with a major in microbiology—en-

vironmental 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 Doctor of Philosophy degree program with a major in microbiology may elect a specialization in biotechnology. For additional information, refer to the statement on the specialization.

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.

MICROBIOLOGY

In general, qualified students will be admitted to graduate study leading directly to the Ph.D. degree in microbiology. 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 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

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 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

Raymond L. Brock, 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, solid state, 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 many of the social and environmental problems of contemporary society. 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 on earth, are applied to interstellar gas, stars, galaxies, and space itself in an attempt to deduce the detailed physical state of these entities. This application frequently involves a study of matter under environmental extremes 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 ambient 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 diversified courses in physics and astronomy. Undergraduate programs with different emphases may be planned through an appropriate choice of electives from the diverse departmental courses. In addition, different emphases may be gained by concentrating the electives in geophysics, civil engineering, computer science, electrical engineering and systems science, energy science, materials science, mechanical engineering and chemical engineering.

UNDERGRADUATE PROGRAMS

Bachelor of Science with a Major in 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:

a. *Graduate Study*.[1] 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.

b. *Experimental Physics* as a preparation for positions in government and industry.[1] 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.

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

Requirements for the Bachelor of Science Degree in 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 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.
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 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

MIC 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.

Bachelor of Science with a Major in 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

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 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.
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 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
MIC 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 . . . 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: . . . 40 to 43

(1) All of the following courses (31 or 32 credits):
AST 201 Astrophysics and Astronomy I . . . 3
AST 202 Astrophysics and Astronomy II . . . 4
AST 301 Junior Research Seminar . . . 1
AST 401 Stars . . . 3
AST 402 Galaxies . . . 3
AST 410 Senior Thesis[1] . . . 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 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, CBI . . . 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, CBI . . . 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, CBI . . . 3

[1] The student must enroll in Astronomy and Astrophysics 410 in each of two different semesters for a total of 3 or 4 credits.

Bachelor of Arts with a Major in Physics

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

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 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.
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 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
MIC 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
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.

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 Doc-

tor 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 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):			
		BCH 461	Biochemistry I	3
		BCH 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:

a. previous attainment of a master's degree with a thesis
b. previous publication of research results
c. 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.

PHYSIOLOGY—ENVIRONMENTAL TOXICOLOGY

Doctor of Philosophy

For information about the Doctor of Philosophy degree program in physiology—environmental toxicology, refer to the statement on *Multidepartmental Doctoral Programs in Environmental Toxicology* in the *Graduate Education* 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):[1]
CSE 101 Computing Concepts and Compentencies . . 3
CSE 131 Introduction to Technical Computing. 3
(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 *either* by completing relevant courses *or* 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

[1] 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.

GRADUATE STUDY

The Department of Statistics and Probability offers four majors that lead to master's degrees: applied statistics, computational 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).

COMPUTATIONAL STATISTICS

Master of Science

The goal of the master's degree program in computational statistics is to provide students with a sound foundation in mathematical, computational, and statistical theory and methodology and their applications. 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 computational 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 for the last 12 credits. No previous course work in statistics or probability is required.

Requirements for the Master of Science Degree in Computational Statistics

The program is available only under Plan B (without thesis). An academic adviser coordinates the students 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. Statistics and Probability 461, 861, 862.
3. At least 6 additional credits in 800–level Statistics and Probability courses.
4. Mathematics 415 or 421 or 424; 451 or 851.
5. At least 6 credits in 800–level Computer Science and Engineering courses.
6. Additional credits in Statistics and Probability, Mathematics, or Computer Science and Engineering courses.

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 or 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

Thomas M. Burton, 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 concerned 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[1]	4

ZOL 341 Fundamental Genetics 4
ZOL 355 Ecology 3
ZOL 355L Ecology Laboratory 1
ZOL 445 Evolution 3
ZOL 483 Environmental Physiology 4

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 *each* 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.

[1] Entomology 404 or Zoology 412 may be substituted for Zoology 306.

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

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 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.
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. *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,[1] Mathematics 124 or 132, and Statistics and Probability 421[2].

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
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[2]. . . . 3
MTH 126 Survey of Calculus with Applications II. . . . 3
(2) MTH 124 Survey of Calculus with Applications I 3
STT 201 Statisticsal Methods 4
(3) MTH 124 Survey of Calculus with Applications I[2]. . . . 3
STT 421 Statistics I[2]. 3
(4) MTH 132 Calculus I[2] 3
MTH 133 Calculus II 4

e. Twelve credits in 300–400 level courses offered by the Colleges of Arts and Letters, Business, Communication Arts and Sciences, and Social Science.

[1] 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.

[2] 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.

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

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 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, 445, 457, 482, 483, 499. Those courses are referenced in item 3.d. 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: 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):

(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[1] 3
ZOL 355L Ecology Laboratory[1] 1
ZOL 445 Evolution 3

(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.

[1] If the student selects group (e), Zoology 355 and 355L combined, or Zoology 445, must be completed to satisfy this requirement.

Cell and Developmental Biology

(1) *One* of the following courses: 4
ZOL 320 Developmental Biology 4
ZOL 425 Cells and Development 4

(2) *All* of the following courses: 28
ZOL 328 Comparative Anatomy and Biology of Vertebrates. . . . 4
ZOL 341 Fundamentals of Genetics. . . . 4
ZOL 342 Advanced Genetics. . . . 3
ZOL 402 Neurobiology 3
ZOL 408 Histology 4
ZOL 417 Advanced Developmental 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[1] 3
ZOL 316L General Parasitology Laboratory[1] 1
ZOL 483 Environmental Physiology 4

(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.

[1] Zoology 316 and 316L combined must be completed to satisfy this requirement.

Genetics

(1) *All* of the following courses: 21
BCH 461 Biochemistry I 3
BCH 462 Biochemistry II 3
BCH 472 Biochemistry Laboratory. . . . 3
MIC 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[1] 3
ZOL 355L Ecology Laboratory[1]. . . . 1
ZOL 421 Hormones and Development 3
ZOL 445 Evolution 3
ZOL 457 Foundations of Evolutionary Biology 3
ZOL 483 Environmental Physiology 4

(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.

[1] Zoology 355 and 355L combined must be completed to satisfy this requirement.

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 Ecosystem Processes 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 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 de-

partments 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)	BCH	401	Basic Biochemistry	4
	CEM	383	Introductory Physical Chemistry I	3
	FW	424	Population Analysis and Measurement	4
	GEO	324	Remote Sensing of the Environment	4
	GLG	422	Organic Geochemistry (W)	3
	MIC	425	Microbial Ecology	3
	MIC	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
MIC	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 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.

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, Director

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 210, 211 and 212. 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, Botany and Plant Pathology, Crop and Soil Sciences, and Microbiology and Molecular Genetics. 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 partici-

pation 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

Karen L. Klomparens, Director

The Center for Advanced Microscopy is a facility with five electron microscopes and support equipment, located in the Integrative Plant Systems Center. A dedicated scanning transmission electron microscope with an energy loss spectrometer is located in the Physics–Astronomy Building. The Center serves the University community in teaching, research, and service in transmission and scanning electron microscopy, specimen preparation, and x–ray analysis. Graduate students may complete research projects involving electron microscopy without beam hour charges. Library and consulting services in electron microscopy are available at the Center.