

COLLEGE OF NATURAL SCIENCE

Eric Hegg, DEAN

Science is central to society, and biological, physical and mathematical scientists are playing increasingly important leadership roles in such diverse areas as economic growth, technological advancement, human health, climate change, feeding the world, and environmental protection. New scientific discoveries and applications of science will continue to have profound effects in Michigan, the United States, and the World. Graduates with training in any of the biological, mathematical, chemical, computational, and physical sciences offered in the College of Natural Science are finding employment opportunities in technology, teaching, communications, policy, medicine and many other areas.

The mission of the College of Natural Science closely parallels the mission of the University and represents a commitment to research, education, and service. The College of Natural Science is one of the largest colleges within the University and includes academic programs in Biochemistry and Molecular Biology; Biomedical Laboratory Diagnostics; Chemistry; Computational Mathematics, Science, and Engineering; Earth and Environmental Sciences; Human Biology; Integrative Biology; Mathematics; Microbiology and Molecular Genetics; Neuroscience; Physics and Astronomy; Physiology; Plant Biology; and Statistics and Probability. It also includes 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. Students in the College of Natural Science have access to the broad range of research and laboratory facilities on campus, in addition to unique research opportunities in facilities like the MSU/DOE Plant Research Laboratory, the Facility for Rare Isotope Beams, and the W. K. Kellogg Biological Station. Graduate students may also choose to enter one of the college's interdisciplinary research programs in Genetics and Genome Sciences; Cell and Molecular Biology; Mathematics Education, Molecular Plant Science; Neuroscience; and Ecology, Evolution and Behavior.

Scientific literacy is now required of every critically thinking and participatory citizen, and of all our future leaders. Our environment is threatened by global warming and environmental contaminants. Population growth threatens human health, food sustainability, and world peace. Our future leaders must have a broad and deep understanding of the mathematical, physical, and biological sciences to make informed decisions. To that end, the College of Natural Science offers a broad range of courses for science and non-science majors.

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 College 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-secondary education, human biology, and physical science-secondary education. In addition, the College of Education, in cooperation with the College of Natural Science, offers an integrated science teaching major for students accepted in elementary education, as well as an integrated science endorsement for secondary education science majors. For further information, refer to the section on *MSU SUBJECT MATTER TEACHING MAJORS AND MINORS FOR TEACHER PREPARATION AND CERTIFICATION* in the *Department of Teacher Education* section of the catalog. The interdepartmental major consists of a minimum of 45 credits (biological science) or 50 credits (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 College as coordinate majors. Interdisciplinary majors are also available through Lyman Briggs College.

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 College are enrolled in the Neighborhood Student Success Collaborative but may declare a major preference in the College of Natural Science and be assigned an academic advisor 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 to the College of Natural Science

1. Completion of at least 28 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 within the college.
3. Medial Laboratory Science majors are admitted at the senior level each fall semester. For specific details see the program statement in the Biomedical Laboratory Diagnostics Program section.

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Graduation Requirements

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

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

- a. One course in Biological Science, Entomology, Microbiology, Physiology, Plant Biology, or Integrative Biology.
- 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. A minimum of 30 credits in courses numbered 300 and above.
- 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.

- 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.

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 161, 162 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 may also be members of the Honors College. A member of the faculty is selected to serve as advisor to Honors College students in each major field, and it is the advisor'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.

Charles Drew Science Scholars

The Charles Drew Science Scholars program was created to help students currently underrepresented in the sciences achieve the best possible preparation for pursuing their educational goals in science and mathematics. The program is designed to: a) assist students with the transition from high school to college and b) to expose them to the vast number of career opportunities in the sciences.

These goals are attained, in part, through problem-solving courses, specially designed courses in mathematics, and designated sections of biology and chemistry courses. In addition, academic coaching and tutoring is available and

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students are exposed to both successful undergraduate and graduate role models.

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

Pre-Health Preparation

All professional health colleges and programs 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 health college or program.

At Michigan State University, students can take the courses necessary to meet the admission requirements for professional health colleges and programs. Since the admission requirements of various professional health colleges and programs vary, it is not feasible to establish a single undergraduate degree program that satisfies the admission requirements of all colleges or programs leading to a given profession. However, for the fields of dentistry, allopathic and osteopathic medicine, chiropractic medicine, physical therapy, occupational therapy, physician assistant/associate, podiatry, public health, pharmacy, genetic counseling, and optometry, the pre-health advisors in the College of Natural Science can assist students in planning their coursework to meet the minimum admission requirements of most professional colleges in a field while also meeting the requirements for their chosen bachelor's degree program in four years. Admission requirements for professional health colleges and programs can change, and it is the student's responsibility to determine whether the planned courses meet the minimum admission requirements of a particular professional health college or program at the time of their application.

TEACHER CERTIFICATION OPTIONS

The following disciplinary majors leading to bachelor's degrees in the College of Natural Science are available for teacher certification: integrated science-secondary education, mathematics-secondary education. The following optional teaching endorsement in the College of Natural Science is also available for teacher certification: mathematics.

Students who elect the integrated science-secondary education disciplinary major must contact the College of Natural Science.

Students who elect a mathematics-secondary education major or the optional mathematics teaching endorsement must contact the Department of Mathematics.

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 advisor must be identified and the student's master's guidance committee must be established. The advisor 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,

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more than 30 credits may be required for a given degree program.

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

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

GRADUATE STUDY

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

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

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

Students who are enrolled in doctoral degree programs in departments and programs emphasizing environmental science and policy may elect the Dual Major in Environmental Science and Policy. For additional information, refer to the *Dual Major in Environmental Science and Policy* statement in the College of Social Science section of this catalog.

Students who are enrolled in doctoral degree programs in departments and programs emphasizing environmental and integrative toxicological sciences may elect the Dual Major in Environmental and Integrative Toxicological Sciences. For additional information, refer to the *Dual Major in Environmental and Integrative Toxicological Sciences* statement in the *College of Natural Science* section of this catalog.

Students who are enrolled in master's and doctoral degree programs in the College of Agriculture and Natural Resources, the College of Natural Science, and the College of Veterinary Medicine may elect the Graduate Specialization in Fish and Wildlife Disease Ecology and Conservation Medicine. For additional information, refer to the statement on Graduate Specialization in Fish and Wildlife Disease Ecology and Conservation Medicine in the College of Agriculture and Natural Resources section of this catalog.

BioMolecular Science Gateway - First Year

Students seeking a doctoral degree in biochemistry and molecular biology, cell and molecular biology, genetics and genome sciences, microbiology, genetics and immunology, pharmacology and toxicology, or molecular, cellular, and integrative physiology should apply through the BioMolecular Science Gateway—First Year for admission to any of these Ph.D. programs. Students should select the Ph.D. program in which they have the greatest interest. During the first two semesters of enrollment, students will have the opportunity to choose and complete at least four courses in appropriate disciplinary subjects. In the spring semester of the first year, they will have the opportunity to continue with the Ph.D. program initially selected or change to one of the other five programs that aligns most closely with their educational goals.

For additional information about the individual Ph.D. programs, refer to the statements in the Departments of Biochemistry and Molecular Biology, Microbiology, Genetics, and Immunology, and Physiology in the *College of Natural Science* section of this catalog, statements on the programs in Cell and Molecular Biology and Genetics and Genome Sciences in the *College of Natural Science* section of this catalog, and statement on the Department of Pharmacology and Toxicology in the *College of Osteopathic Medicine* section of this catalog.

Master of Arts for Teachers

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

The degree may be earned with a major in chemistry or geological sciences.

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.

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Requirements for the Master of Arts for Teachers Degree

An appropriate course of study is planned with the candidate by an advisor 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, most 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 15 credits of master's thesis research may be permitted.

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.

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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.

MATHEMATICS EDUCATION

The Master of Science and Doctor of Philosophy degrees in Mathematics Education are administered jointly by the College of Natural Science and the College of Education. The College of Natural Science is the primary administrative unit.

Master of Science

The Master of Science Degree in Mathematics Education prepares researchers and leaders to address critical issues in mathematics education by developing analytical perspectives on current issues in mathematics education.

In addition to meeting the requirements of the university, students must meet the requirements specified below.

Admission

The program admits students with a variety of backgrounds. Some students will have equally strong backgrounds in education and mathematics. Others may have more extensive prior preparation in one of these two disciplines.

Admissions decisions will be made by an Admissions Committee composed of members of the Mathematics Education Faculty Group.

Requirements for the Master of Science Degree in Mathematics Education

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

- | | CREDITS |
|--|---------|
| 1. All of the following courses (12 credits): | |
| MTHE 926 Proseminar in Mathematics Education I | 3 |
| MTHE 927 Proseminar in Mathematics Education II | 3 |
| TE 950 Mathematical Ways of Knowing | 3 |
| MTHE 954 Design and Methods in Mathematics Education Research | 3 |
| 2. Complete a minimum of 18 credits of course work relevant to the student's focus within mathematics education. | |
| 3. Complete a final evaluation. | |

Doctor of Philosophy

The Doctor of Philosophy degree in Mathematics Education is designed for persons who show promise of becoming leaders in local, state, national, and international mathematics education communities. The program prepares researchers and leaders to address critical issues in mathematics education by developing analytical perspectives for research, engaging in reflective teaching, and deepening mathematical knowledge.

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 program admits students with a variety of backgrounds. Some students will have equally strong backgrounds in education and mathematics. Others may have more extensive prior preparation in one of these two disciplines.

Admissions decisions will be made by an Admissions Committee composed of members of the Mathematics Education Faculty Group. A student who shows promise for success at doctoral study but who needs additional background to be eligible for admission to the Ph.D. program will be provided with specific conditions to be met before admission. Upon successful completion of these requirements, the student may reapply.

Requirements for the Doctor of Philosophy Degree in Mathematics Education

The student must complete the requirements listed below. The student's program of study must be approved by the student's guidance committee and must include:

- | | CREDITS |
|--|---------|
| 1. All of the following courses (12 credits): | |
| MTHE 926 Proseminar in Mathematics Education I | 3 |
| MTHE 927 Proseminar in Mathematics Education II | 3 |
| MTHE 954 Design and Methods in Mathematics Education Research | 3 |
| TE 950 Mathematical Ways of Knowing | 3 |
| 2. Research Methods (9 credits): | |
| a. One course in quantitative research methods | 3 |
| b. One course in qualitative research methods | 3 |
| c. One additional research methods course | 3 |
| Research methods courses must be approved by the student's guidance committee. | |
| 3. Research Practicum (1 to 3 credits): | |
| MTHE 995 Research Practicum | 1 to 3 |
| 4. Mathematics and Mathematical Knowledge for Teaching (12 credits): | |

Complete 12 credits of course work, approved by the student's guidance committee, focusing on mathematics content, both traditional mathematical sciences content and specialized knowledge needed by those engaging in research on teaching and learning mathematics.

5. Area of Concentration (12 credits):
Complete 12 credits of course work in an area of concentration as approved by the student's guidance committee.
6. Successful completion of comprehensive examinations administered by program faculty.
7. Doctoral Dissertation
Complete at least 24 credits and no more than 36 credits of MTHE 999 Doctoral Dissertation Research and successfully defend the oral dissertation.

CENTER for INTEGRATIVE STUDIES in GENERAL SCIENCE

Gabriel Ording, Director

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

Courses in Michigan State University's Integrative Studies Program are aimed at developing intellectual abilities, including critical thinking and interpretive skills. They help increase knowledge about other times, places, and cultures, key ideas and issues in human experience, and the scientific method and its usefulness in understanding the natural and social worlds. They are expected to enhance appreciation of the role of knowledge, and of values and ethics, in understanding human behavior and solving social problems. Finally, they help students recognize responsibilities and opportunities associated with democratic citizenship and with living in an increasingly interconnected, interdependent world. The Center for Integrative Studies in the Arts and Humanities in the College of Arts and Letters has primary responsibility for the Arts and Humanities area of Integrative Studies at Michigan State University.

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

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

INTERDEPARTMENTAL DEGREE PROGRAMS

The College of Natural Science offers interdepartmental degree programs in cell and molecular biology; ecology, evolution, and behavior; general science; genetics; human biology; integrated science-secondary education; and mathematics-secondary education. 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.

Students interested in elementary education who wish to major in science should reference the section on *MSU SUBJECT MATTER TEACHING MAJORS AND MINORS FOR TEACHER PREPARATION AND CERTIFICATION* in the *Department of Teacher Education* section of this catalog.

UNDERGRADUATE EDUCATION

INTEGRATED SCIENCE—SECONDARY EDUCATION

The Bachelor of Science Degree in Integrated Science-Secondary Education is designed for persons who want a broad background in biology, chemistry, earth and space science, and physics and to understand the interrelationships between these disciplines. This major is designed primarily for persons who plan to teach science (life science, chemistry, earth and space science, or physics) in secondary schools.

Requirements for the Bachelor of Science Degree in Integrated Science-Secondary Education

CREDITS

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 Integrated Science-Secondary Education.
The University's Tier II writing requirement for the Integrated Science-Secondary Education major is met by completing Integrated Science Education 401. That course is referenced in item 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.
Students may substitute Teacher Education 101 and 102 for two ISS requirements.
Students may substitute Teacher Education 341 for the first-level IAH requirement (courses numbered 201 through 210). Those courses are referenced in item 3. 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 for the major:
 - a. One of the following groups of courses (9 or 10 credits):

(1)	BS	161	Cell and Molecular Biology	3
	BS	162	Organismal and Population Biology	3
	BS	171	Cell and Molecular Biology Laboratory	2
	BS	172	Organismal and Population Biology Laboratory	2

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(2)	BS	181H Honors Cell and Molecular Biology	3
	BS	182H Honors Organismal and Population Biology	3
	BS	191H Honors Cell and Molecular Biology Laboratory	2
	BS	192H Honors Organismal and Population Biology Laboratory	2
(3)	LB 144	Biology I: Organismal Biology	4
	LB 145	Biology II: Cellular and Molecular Biology	5
b.	One of the following groups of courses (9 or 10 credits):		
(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	
(4)	LB 171	Principles of Chemistry I	4
	LB 171L	Introductory Chemistry Laboratory I	1
	LB 172	Principles of Chemistry II	3
	LB 172L	Principles of Chemistry II-Reactivity Laboratory	1
c.	One of the following groups of courses (8 or 10 credits):		
(1)	PHY 173	Studio Physics for Scientists and Engineers I	5
	PHY 174	Studio Physics for Scientists and Engineers II	5
(2)	PHY 183	Physics for Scientists and Engineers I	4
	PHY 184	Physics for Scientists and Engineers II	4
	PHY 191	Physics Laboratory for Scientists, I	1
	PHY 192	Physics Laboratory for Scientists, II	1
(3)	PHY 221	Studio Physics for Life Scientists I	4
	PHY 222	Studio Physics for Life Scientists II	4
(4)	PHY 231	Introductory Physics I	4
	PHY 232	Introductory Physics II	3
	PHY 251	Introductory Physics Laboratory I	1
	PHY 252	Introductory Physics Laboratory II	1
(5)	LB 273	Physics I	4
	LB 274	Physics II	4
d.	All of the following courses (14 credits):		
	IBIO 355	Ecology	3
	ISE 322	Foundational Earth Systems for Secondary Science Education	4
	ISE 401	Science Laboratories for Secondary Schools (W)	4
	ISE 420	Integrated Science Research	3
e.	The following Professional Education Courses in the College of Education (36 credits):		
(1)	All of the following courses from the shared professional sequence (18 credits):		
	CEP 240	Diverse Learners in Multicultural Perspective	3
	TE 101	Social Foundations of Justice and Equity in Education	3
	TE 102	Pedagogy and Politics of Justice and Equity in Education	3
	TE 150	Reflections on Learning	3
	TE 302	Literacy and Adolescent Learners in School and Community Contexts	3
	TE 341	Teaching and Learning of (Bi)Multilingual Learners	3
(2)	All of the following courses from the subject-specific professional sequence (18 credits):		
	TE 321	Clinical Experience in Science Education I	3
	TE 421	Clinical Experience in Science Education II	3
	TE 422	Seminar in Science Education I	3
	TE 423	Seminar in Science Education II	3
	TE 424	Student Teaching Internship in Science Education	6
f.	One of the following concentrations:		
	Biology		
(1)	One course from group (a) and one course from group (b) (6 to 8 credits):		
(a)	MTH 124	Survey of Calculus I	3
	MTH 132	Calculus I	3
	MTH 152H Honors Calculus I	3	
	LB 118	Calculus I	4
(b)	MTH 126	Survey of Calculus II	3
	MTH 133	Calculus II	4
	MTH 153H Honors Calculus II	3	

	LB 119	Calculus II	4
	STT 201	Statistical Methods	4
	STT 231	Statistics for Scientists	3
	STT 351	Probability and Statistics for Engineering	3
	STT 421	Statistics I	3
(2)	One of the following groups of courses (3 or 6 credits):		
(a)	CEM 144	Organic Chemistry and Applications	3
(b)	CEM 251	Organic Chemistry I	3
	CEM 252	Organic Chemistry II	3
(c)	CEM 351	Organic Chemistry I	3
	CEM 352	Organic Chemistry II	3
(3)	All of the following courses (7 credits):		
	IBIO 341	Fundamental Genetics	4
	IBIO 355L	Ecology Laboratory (W)	1
	IBIO 445	Evolution (W)	3
(4)	One of the following courses (3 or 4 credits)		
	BMB 401	Comprehensive Biochemistry	4
	FW 417	Wetland Ecology and Management	3
	IBIO 408	Histology	4
	IBIO 425	Cells and Development (W)	4
	MMG 301	Introductory Microbiology	3
	NEU 300	Neurobiology	3
	PLB 415	Plant Physiology	3
	PLB 418	Plant Systematics	3
	PLB 441	Plant Ecology	3
	PSL 250	Introductory Physiology	4
	PSL 310	Physiology for Pre-Health Professionals	4
	Chemistry		
(1)	One course from group (a) and one course from group (b) (6 to 8 credits):		
(a)	MTH 132	Calculus I	3
	MTH 152H Honors Calculus I	3	
	LB 118	Calculus I	4
(b)	MTH 133	Calculus II	4
	MTH 153H Honors Calculus II	3	
	LB 119	Calculus II	4
(2)	One of the following groups 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
(3)	All of the following courses (9 credits):		
	CEM 255	Organic Chemistry Laboratory	2
	CEM 262	Quantitative Analysis	3
	CEM 383	Introductory Physical Chemistry I	3
	CEM 444	Chemical Safety	1
(4)	One of the following courses (3 or 4 credits):		
	BMB 401	Comprehensive Biochemistry	4
	CEM 311	Inorganic Chemistry	3
	CEM 384	Introductory Physical Chemistry II	3
	Physics		
(1)	One course from group (a) and one course from group (b) (6 to 8 credits):		
(a)	MTH 132	Calculus I	3
	MTH 152H Honors Calculus I	3	
	LB 118	Calculus I	4
(b)	MTH 133	Calculus II	4
	MTH 153H Honors Calculus II	3	
	LB 119	Calculus II	4
(2)	One of the following groups of courses (3 or 6 credits):		
(a)	CEM 144	Organic Chemistry and Applications	3
(b)	CEM 251	Organic Chemistry I	3
	CEM 252	Organic Chemistry II	3
(c)	CEM 351	Organic Chemistry I	3
	CEM 352	Organic Chemistry II	3
(3)	All of the following courses (14 credits):		
	CMSE 201	Computational Modeling and Data Analysis I	4
	MTH 234	Multivariable Calculus	4
	MTH 235	Differential Equations	3
	PHY 215	Thermodynamics and Modern Physics	3
(4)	One of the following courses (3 or 4 credits):		
	PHY 321	Classical Mechanics I	3
	PHY 431	Optics I	3
	PHY 440	Electronics	4
	PHY 481	Electricity and Magnetism I	3
	Earth Science		
(1)	One course from group (a) and one course from group (b) (6 to 8 credits):		
(a)	MTH 124	Survey of Calculus I	3

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	MTH 132	Calculus I	3
	MTH 152H	Honors Calculus I	3
	LB 118	Calculus I	4
(b)	MTH 126	Survey of Calculus II	3
	MTH 133	Calculus II	4
	MTH 153H	Honors Calculus II	3
	LB 119	Calculus II	4
	STT 201	Statistical Methods	4
	STT 231	Statistics for Scientists	3
	STT 351	Probability and Statistics for Engineering	3
	STT 421	Statistics I	3
(2)	One of the following groups of courses (3 or 6 credits):		
(a)	CEM 144	Organic Chemistry and Applications	3
(b)	CEM 251	Organic Chemistry I	3
	CEM 252	Organic Chemistry II	3
(c)	CEM 351	Organic Chemistry I	3
	CEM 352	Organic Chemistry II	3
(3)	The following course (4 credits):		
	GLG 201	The Dynamic Earth	4
(4)	Two of the following courses (6 to 8 credits):		
	GLG 303	Oceanography	3
	GLG 304	Physical and Biological History of the Earth	4
	GLG 321	Mineralogy and Geochemistry	4
	GLG 361	Igneous and Metamorphic Geochemistry and Petrology	4
	GLG 401	Global Tectonics and Earth Structure (W)	4
	GLG 411	Hydrogeology	3
	GLG 412	Glacial Geology and the Record of Climate Change	4
	GLG 421	Environmental Geochemistry	4
	GLG 435	Geomicrobiology	4
	GLG 440	Planetary Geology	3

GRADUATE STUDY

CELL AND MOLECULAR BIOLOGY

Master of Science

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

Admission

Most students enter the Master of Science degree program in cell and molecular biology with the goal of eventually obtaining a Ph.D. degree. However, students with limited research experience or specific deficiencies in their undergraduate training may be admitted to this program to obtain additional experience. Applicants will be considered by the Cell and Molecular Biology admissions committee, and in general the criteria for admission are similar to those of the Ph.D. program (an undergraduate major in biological science, acceptable GPA and GRE scores, and letters of recommendation).

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

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

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

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

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

Doctor of Philosophy

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

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

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

Admission

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

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

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

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

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

The student must:

	CREDITS
1. Complete all of the following courses (15 credits):	
BMB 801 Molecular Biology and Protein Structure	4
BMB 825 Cell Structure and Function	3
CMB 800 Cell and Molecular Biology Seminar	3
CMB 892 Research Forum	4
One graduate course in scientific ethics	1
2. Complete one of the following courses (3 credits):	
MMG 833 Microbial Genetics	3
MMG 835 Eukaryotic Molecular Genetics	3

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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.

BIOMOLECULAR SCIENCE GATEWAY - FIRST YEAR

Students seeking a doctoral degree in biochemistry and molecular biology, cell and molecular biology, genetics and genome sciences, microbiology, genetics and immunology, pharmacology and toxicology, or molecular, cellular, and integrative physiology should apply through the BioMolecular Science Gateway—First Year for admission to any of these Ph.D. programs. Students should select the Ph.D. program in which they have the greatest interest. During the first two semesters of enrollment, students will have the opportunity to choose and complete at least four courses in appropriate disciplinary subjects. In the spring semester of the first year, they will have the opportunity to continue with the Ph.D. program initially selected or change to one of the other five programs that aligns most closely with their educational goals.

For additional information about the individual Ph.D. programs, refer to the statements in the Departments of Biochemistry and Molecular Biology, Microbiology, Genetics, and Immunology, and Physiology in the *College of Natural Science* section of this catalog, statements on the programs in Cell and Molecular Biology and Genetics and Genome Sciences in the *College of Natural Science* section of this catalog, and statement on the Department of Pharmacology and Toxicology in the *College of Osteopathic Medicine* section of this catalog.

TEACHER CERTIFICATION OPTIONS

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

Students who elect the earth science disciplinary minor must contact the Department of Earth and Environmental Sciences.

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

GRADUATE STUDY

ECOLOGY, EVOLUTION, AND BEHAVIOR

Dual Major

The interdepartmental dual major in ecology, evolution, and behavior is administered by the College of Natural Science. The dual major is available only to those students who plan to complete a Ph.D. degree program that involves ecology, evolution, and behavior and who have a graduate major at

Michigan State University. The student does not have the option of completing a dual major in ecology, evolution, 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, evolution, and behavior.
2. stimulate doctoral students with an interest in ecology, evolution, 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, evolution, and behavior.

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

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

Admission

In order to enroll in the dual major in ecology, evolution, and behavior a student must also have been admitted to a major at Michigan State University. A minimum undergraduate grade-point average of 3.0 and undergraduate mathematics through calculus are required for admission to the dual major. The Graduate Admissions Committee, composed of members of the ecology, evolution, and behavior faculty 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 dual major on a provisional basis.

Guidance Committee

During the first year of enrollment in the dual major, the student and a member of the ecology, evolution, 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, evolution, and behavior faculty shall be members of the committee. The student's program of study will involve ecology, evolution, and behavior and a major in the student's department. 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 dual major in ecology, evolution, and behavior are expected to attend weekly seminars and to participate in the graduate student-organized research colloquium.

COLLEGE OF NATURAL SCIENCE

Requirements for the Dual Major in Ecology, Evolution, and Behavior

CREDITS

1. One 3-credit course in ecology at the 800-900 level from a list of approved courses available from the office of the ecology, evolution, and behavior program.
2. One 3-credit course in evolution at the 800-900 level from a list of approved courses available from the office of the ecology, evolution, and behavior program.
3. Both of the following quantitative methods courses (6 credits):

IBIO 830 Statistical Methods in Ecology and Evolution I	3
IBIO 831 Statistical Methods in Ecology and Evolution II	3
4. Twenty-four credits in Doctoral Dissertation Research (course number 999) from the student's departmental major.
5. Pass a comprehensive examination that will be defined by the requirements of the student's major 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.
6. Submit a dissertation that, in the judgment of the student's guidance committee, represents the integration of ecology, evolution, and behavior and the student's departmental major.

GRADUATE STUDY

ENVIRONMENTAL AND INTEGRATIVE TOXICOLOGICAL SCIENCES

Dual Major

The dual major in environmental and integrative toxicological sciences is administered by the College of Natural Science. The dual major is available only to those students who plan to complete a Ph.D. degree program that involves environmental and integrative toxicological sciences and who have a graduate major at Michigan State University. The student does not have the option of completing a dual major in environmental and integrative toxicological sciences alone.

The purpose of the Dual Major Ph.D. in Environmental and Integrative Toxicological Sciences (EITS) is to provide students with training in a basic science discipline and training and credentials in environmental and integrative toxicological sciences. Students accepted into a science-related Doctor of Philosophy degree programs may apply subsequently for admission to the environmental and integrative toxicological sciences program. Students who complete this multidisciplinary course of study earn the Ph.D. degree in a basic science discipline with a dual major in environmental and toxicological sciences.

Each program that cooperates with the environmental and integrative toxicological sciences program is represented by training faculty affiliated with Michigan State University's Institute for Integrative Toxicology, through which the Doctoral Program in Environmental and Integrative Toxicological Sciences is administered in conjunction with the College of Natural Science. The program allows students substantial flexibility in choosing areas of study. Each student's course of study is planned with that individual's particular interests, capabilities, and professional goals in mind. The student must meet the requirements for the partnering disciplinary program and the requirements for the environmental toxicology dual major.

In partial fulfillment of the environmental toxicology major, the student must complete the biomedical toxicology track, the food toxicology and ingredient safety track, or the environmental toxicology track. Course requirements for the

biomedical toxicology track are designed for doctoral students in biomedical disciplines. The food toxicology and ingredient safety track require courses in toxicology and risk assessment and regulation of food-borne ingredients. Course requirements for the environmental toxicology track are designed for doctoral students in engineering, chemistry and other fields who may have less background in mammalian biology.

When all requirements for the degree have been met, both the chairperson of the department or program that administers the student's disciplinary major and the director of the Dual Major Ph.D. in Environmental and Integrative Toxicological Sciences program will recommend the student for the degree.

Where course requirements for a disciplinary major and for the environmental toxicology major overlap, a given course may be counted toward both requirements.

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 be accepted for graduate study into a department or program that offers the student the opportunity to meet EITS admissions requirements, such as a science-based discipline, before applying for admission to the Dual Major Ph.D. in Environmental and Integrative Toxicological Sciences. Admission requires the approval of the environmental and integrative toxicological sciences graduate committee and the program director.

The student must:

1. have earned at least a bachelor's degree;
2. have completed, with a minimum grade-point average of 3.0, sufficient credits in the biological, chemical, and physical sciences to indicate probable success in the program;
3. have a dissertation project related to toxicology;
4. at least two guidance committee members affiliated with the Institute for Integrative Toxicology.

In special cases, an applicant with deficiencies in background courses may be admitted on a provisional basis. Students admitted on a provisional basis will not be considered for an advanced degree until they have fulfilled the provisional requirements. Course work required to remedy deficiencies will not count towards the dual major degree.

Guidance Committee

At least two members of the student's guidance committee must be faculty affiliated with the Institute for Integrative Toxicology. At least one member of the committee must be from a department or disciplinary program other than the one that administers the student's disciplinary major.

COLLEGE OF NATURAL SCIENCE

Requirements for the Dual Major Ph.D. Degree in Environmental in Environmental and Integrative Toxicological Sciences

1. The topic of the doctoral dissertation research must be in the broad area of environmental and integrative toxicological sciences and be acceptable to the environmental and integrative toxicological sciences faculty.
2. The student must complete the requirements for one of the three tracks with a grade-point average of at least 3.0.
3. The student must attend and participate in at least 12 EITS approved seminars in toxicological sciences.

GRADUATE STUDY

GENETICS AND GENOME SCIENCES

Master of Science

The primary purpose of the Master of Science in Genetics and Genome Sciences is to train students for a variety of careers in areas of genetics and genomics.

Admission

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

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

Requirements for the Master of Science Degree in Genetics and Genome Sciences

The Master of Science degree in Genetics and Genome Sciences is available under Plan A (with thesis). Students must earn at least 30 credits, of which a minimum of 20 credits must consist of course work and must include the following:

- | | CREDITS |
|--|---------|
| 1. Both of the following courses (4 to 6 credits): | |
| BMB 801 Molecular Biology | 3 |
| GEN 810 Theory and Practice of Teaching Genetics | 1 to 3 |
| 2. One of the following courses (3 credits): | |
| MMG 833 Microbial Genetics | 3 |
| MMG 835 Eukaryotic Molecular Genetics | 3 |
| 3. Complete 4 to 10 credits of Genetics 899, Master's Thesis Research. | |
| 4. Submission of a written thesis. | |
| 5. Presentation of a final research seminar. | |
| 6. Pass a final oral examination. | |

Doctor of Philosophy

The interdepartmental Doctor of Philosophy degree program with a major in genetics and genome sciences 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 and genome sciences, but are required to familiarize themselves with all major areas of the discipline. Students may elect to complete the requirements for a second major, in addition to the requirements for the doctoral degree in genetics and genome 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

Admission to the Doctor of Philosophy degree program with a major in genetics and genome sciences is through the BioMolecular Science Gateway – First Year (BMS). The BMS does not establish minimum cut-off values from any indices, however, the successful applicant will typically have: a bachelor's degree (four-year or equivalent) or Master of Science degree that includes course work that demonstrates proficiency in math and science; a grade point average of 3.5 or above; significant research experience (equivalent to a minimum of one full-time summer research experience or four semesters of part-time research experience); and strong letters of reference. The GRE is not required to apply to the BMS. Students admitted through the BMS typically perform three research rotations during their first two semesters before they choose their Ph.D. laboratory, and join the Ph.D. program of their choice during the spring semester of their first year in the BMS.

Requirements for the Doctor of Philosophy Degree in Genetics and Genome Sciences

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.

CREDITS

The student must:

1. Complete one of the following courses:

MMG 833 Microbial Genetics	3
MMG 835 Eukaryotic Molecular Genetics	3
2. Complete both of the following courses:

GEN 810 Theory and Practice of Teaching Genetics	1 to 3
GEN 840 Genetics Writing Skills	1 to 6
3. Complete a minimum of 12 credits of additional graduate course work approved by the student's guidance committee in genetics, molecular biology, and/or biochemistry, including at least one 3-credit course in genomics, quantitative or computational biology.
4. Complete a minimum of four 1-credit seminar courses approved by the student's guidance committee and the Genetics and Genome Sciences director.
5. Complete a minimum of 24 credits of GEN 999 Doctoral Dissertation Research.
6. Pass a comprehensive examination that includes a written research proposal, public seminar and oral examination with the student's guidance committee.
7. Write and defend a research dissertation, which shows original treatment of an important research problem.

COLLEGE OF NATURAL SCIENCE

BIOMOLECULAR SCIENCE GATEWAY - FIRST YEAR

Students seeking a doctoral degree in biochemistry and molecular biology, cell and molecular biology, genetics and genome sciences, microbiology, genetics and immunology, pharmacology and toxicology, or molecular, cellular, and integrative physiology should apply through the BioMolecular Science Gateway—First Year for admission to any of these Ph.D. programs. Students should select the Ph.D. program in which they have the greatest interest. During the first two semesters of enrollment, students will have the opportunity to choose and complete at least four courses in appropriate disciplinary subjects. In the spring semester of the first year, they will have the opportunity to continue with the Ph.D. program initially selected or change to one of the other five programs that aligns most closely with their educational goals.

For additional information about the individual Ph.D. programs, refer to the statements in the Departments of Biochemistry and Molecular Biology, Microbiology, Genetics, and Immunology, and Physiology in the *College of Natural Science* section of this catalog, statements on the programs in Cell and Molecular Biology and Genetics and Genome Sciences in the *College of Natural Science* section of this catalog, and statement on the Department of Pharmacology and Toxicology in the *College of Osteopathic Medicine* section of this catalog.

UNDERGRADUATE PROGRAM

HUMAN BIOLOGY

The Human Biology major is designed for students pursuing careers in medicine, health sciences, and biomedical sciences. The program integrates fundamental concepts from biology, chemistry, physics, and mathematics/statistics, offering a comprehensive understanding of human biology and health. Students develop key skills in information literacy, critical thinking, and scientific inquiry, empowering them to tackle complex problems and analyze both biological and cultural phenomena.

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. One of the following groups of courses (9 or 10 credits):	
(1) BS 161 Cell and Molecular Biology	3
BS 162 Organismal and Population Biology	3
BS 171 Cell and Molecular Biology Laboratory	2
BS 172 Organismal and Population Biology Laboratory	2

(2) BS 181H Honors Cell and Molecular Biology	3
BS 182H Honors Organismal and Population Biology	3
BS 191H Honors Cell and Molecular Biology Laboratory	2
BS 192H Honors Organismal and Population Biology Laboratory	2
(3) LB 144 Biology I: Organismal Biology	4
LB 145 Biology II: Cellular and Molecular Biology	5
b. All of the following courses (15 credits):	
CEM 251 Organic Chemistry I	3
CEM 252 Organic Chemistry II	3
CEM 255 Organic Chemistry Laboratory	2
HBIO 495 Capstone in Human Biology (W)	3
IBIO 341 Fundamental Genetics	4
c. One of the following, either (1) or (2):	
(4 or 8 credits)	
(1) PSL 310 Physiology for Pre-Health Professionals	4
(2) PSL 431 Human Physiology I	4
PSL 432 Human Physiology II	4
d. One of the following, either (1) or (2):	
(4 or 6 credits)	
(1) BMB 401 Comprehensive Biochemistry	4
(2) BMB 461 Advanced Biochemistry I	3
BMB 462 Advanced Biochemistry II	3
e. One of the following groups of courses:	
(9 to 12 credits)	
(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
(4) LB 171 Principles of Chemistry I	4
LB 172 Principles of Chemistry II	3
LB 171L Introductory Chemistry Laboratory I	1
LB 172L Principles of Chemistry II - Reactivity Laboratory	1
f. One course from each of the following groups:	
(6 to 8 credits)	
(1) MTH 124 Survey of Calculus I	3
MTH 132 Calculus I	3
MTH 152H Honors Calculus I	3
LB 118 Calculus I	4
(2) MTH 126 Survey of Calculus II	3
MTH 133 Calculus II	4
MTH 153H Honors Calculus II	4
LB 119 Calculus II	4
STT 201 Statistical Methods	4
STT 231 Statistics for Scientists	3
STT 351 Probability and Statistics for Engineering	3
STT 421 Statistics I	3
g. One of the following groups of courses:	
(8 or 10 credits)	
(1) 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
(2) PHY 191 Physics Laboratory for Scientists, I	1
PHY 192 Physics Laboratory for Scientists, II	1
PHY 193H Honors Physics I—Mechanics	4
PHY 294H Honors Physics II—Electromagnetism	4
(3) PHY 221 Studio Physics for Life Scientists I	4
PHY 222 Studio Physics for Life Scientists II	4
(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
(5) PHY 241 Physics for Cellular and Molecular Biologists I	4
PHY 242 Physics for Cellular and Molecular Biologists II	4
PHY 251 Introductory Physics Laboratory I	1
PHY 252 Introductory Physics Laboratory II	1

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(6)	LB	273	Physics I	4
	LB	274	Physics II	4
(7)	PHY	173	Studio Physics for Scientists and Engineers I	5
	PHY	174	Studio Physics for Scientists and Engineers II	5
h. One of the following courses (3 credits):				
	BLD	434	Clinical Immunology	3
	MMG	409	Eukaryotic Cell Biology	3
	MMG	413	Virology	3
	MMG	451	Immunology	3
i. At least 12 credits from the following courses:				
	ANP	204	Introduction to Medical Anthropology	3
	ANP	206	Introduction to Physical Anthropology	3
	ANP	425	Issues in Medical Anthropology	3
	ANP	441	Osteology and Forensic Anthropology	4
	ANP	443	Human Adaptability	3
	BLD	204	Mechanisms of Disease	3
	BLD	213L	Clinical Laboratory Methods	2
	BLD	324	Hematology and Hemostasis	3
	BLD	430	Molecular Diagnostics	2
	BLD	434	Clinical Immunology	3
	BLD	439	Histocompatibility and Immunogenetics	1
	BLD	446	Immunobiology of Neoplasia	1
	BLD	447	Immunomodulation and Immunotherapy	1
	EPI	390	Disease in Society: Introduction to Epidemiology and Public Health	4
	HBIO	295	Human Biology and Society	2
	HNF	310	Nutrition in Medicine for Pre-Health Professionals	3
	IBIO	408	Histology	4
	IBIO	425	Cells and Development (W)	4
	IBIO	445	Evolution (W)	3
	IBIO	450	Cancer Biology (W)	3
	MMG	301	Introductory Microbiology	3
	MMG	302	Introductory Laboratory for General and Allied Health Microbiology	1
	MMG	365	Medical Microbiology	3
	MMG	365L	Medical Microbiology Laboratory	1
	MMG	404	Human Genetics	3
	MMG	409	Eukaryotic Cell Biology	3
	MMG	413	Virology	3
	MMG	431	Microbial Genetics	3
	MMG	451	Immunology	3
	MMG	461	Molecular Pathogenesis	3
	MMG	465	Advanced Medical Microbiology	3
	MMG	465L	Advanced Medical Microbiology Laboratory	2
	NEU	300	Neurobiology	3
	NEU	310	Psychology and Biology of Human Sexuality	3
	PHM	321	Common Drugs	3
	PHM	350	Introductory Human Pharmacology	3
	PHM	430	Human Pharmacology	3
	PHM	431	Pharmacology of Drug Addiction	3
	PHM	440	Principles of Drug Action	1
	PHM	450	Introduction to Chemical Toxicology	3
	PHM	461	Tropical Medicine Pharmacology	2
	PSL	311L	Physiology Laboratory for Pre-Health Professionals	2
With the approval of the director of the human biology major, a maximum of 3 credits in research (HBIO 498), internship (HBIO 497) or independent study (HBIO 496) courses may be used to satisfy this requirement.				
Courses used to fulfill requirement 3. h. may not be used to fulfill requirement 3. i.				
j. One of the following courses (3 or 4 credits):				
	ANTR	350	Human Gross Anatomy for Pre-Health Professionals	3
	IBIO	320	Developmental Biology	4
	IBIO	328	Comparative Anatomy and Biology of Vertebrates	4

GRADUATE STUDY

MOLECULAR PLANT SCIENCES

Dual Major

The interdepartmental dual major in molecular plant sciences is administered by the College of Natural Science. The dual major is available only to those students who plan to complete

a Ph.D. degree program that involves plant molecular biology and who have a graduate major at Michigan State University. The student does not have the option of completing a dual major in plant molecular biology alone.

The educational objectives of the interdepartmental program are to prepare students to:

1. function as independent scientists able to develop new knowledge and understanding about the molecular processes driving plant energy status, metabolism, growth, development, gene regulation, evolution, plant stress tolerance, and environmental interactions;
2. devise and test informative hypotheses and apply key molecular and omics approaches to problems in these areas, and;
3. engage in planning, performing, and management of independent and collaborative research and teaching.

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

Admission

In order to enroll in the dual major in plant molecular biology a student must also have been admitted to a major at Michigan State University. A minimum undergraduate grade-point average of 3.0 and a sufficient background in biology, chemistry, physics, mathematics, and/or computer science is required for admission to the dual major. In special cases, an applicant who has deficiencies in background courses may be admitted to the dual major on a provisional basis.

The Molecular Plant Sciences Graduate Admissions Committee composed of members of the molecular plant sciences faculty and the primary department/program admissions committee reviews applications for admission and recommends acceptance of applicants for admission. The application process is composed of two parts: a standard MSU application to the primary department/program of the student's choice and a one-page description of the student's interest in the molecular plant sciences program. Applicants suitable will be forwarded to the Plant Science Recruitment director for onsite interviews. Offer letters will be co-signed by the molecular plant sciences program and the student's primary department.

Guidance Committee

During the first year of enrollment in the dual major, the student and a member of the molecular plant sciences 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 molecular plant sciences faculty shall be members of the committee along with two faculty members from the student's primary department. The student's program of study will involve molecular plant sciences and a major in the student's department. 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 dual major in molecular plant sciences are expected to do research rotations in three laboratories, attend seminars and engage in other programmatic activities.

COLLEGE OF NATURAL SCIENCE

Requirements for the Dual Major in Molecular Plant Sciences

CREDITS

1. The course requirements will be specified in a graduate handbook in consultation with the student's major professor and guidance committee.
2. Three graduate seminar courses in subjects relevant to molecular plant sciences.
3. Twenty-four credits in Doctoral Dissertation Research (course number 999) from the student's departmental major.
4. Pass a comprehensive examination that will be defined by the requirements of the student's major department and that will include a written examination in which the student demonstrates a knowledge of molecular plant sciences as determined by the guidance committee.
5. Submit and defend a dissertation that, in the judgment of the student's guidance committee, shows original treatment of an important scientific question.

GRADUATE CERTIFICATE IN MEDICAL NEUROSCIENCE

The Graduate Certificate in Medical Neuroscience is aimed at students who are currently working in the pharmaceutical or medical device industries and students interested in applying to graduate or professional school. It provides post-baccalaureate credentials and career development for students seeking to improve their academic profile or employment qualifications meeting the needs of both working professionals and full-time students. The certificate is available online only.

Admission

To be considered for admission to the Graduate Certificate in Medical Neuroscience, students must:

1. have a bachelor's degree in a biological science background or a bachelor's degree in another area with equivalent work experience.
2. have a minimum cumulative undergraduate grade-point average of 2.5 or a graduate grade-point average of 3.0.
3. write a reflective essay describing how the certificate will enhance their professional and personal development.

Requirements for the Graduate Certificate in Medical Neuroscience

CREDITS

Students must complete a minimum of 12 credits from the following courses:

1. Both of the following courses (6 credits):

NEU 841 Medical Neuroscience	3
NEU 846 Neurobiology of Nervous System Disorders	3
2. At least 6 credits from the following courses:

NEU 842 Neuroethics	3
NEU 843 Methods for Assessing the Nervous System	3
NEU 844 The Science and Ethics of Brain Interventions	2
NEU 847 Development of the Nervous System	3
NEU 890 Independent Study in Neuroscience	1 to 3
PHM 431 Pharmacology of Drug Addiction	3

NEUROSCIENCE AND THE LAW

The Graduate Certificate in Neuroscience and the Law is designed to provide individuals working in law or social sciences fields with the scientific knowledge necessary to effectively, accurately, and ethically use neuroscientific evidence in a professional setting. The certificate will meet the needs of both working professionals and full-time students. The certificate is available online only.

Admission

To be considered for admission to the Graduate Certificate in Neuroscience and the Law, students must:

1. have a bachelor's degree.
2. have a minimum cumulative undergraduate grade-point average of 2.25.
3. write a reflective essay describing how the certificate will enhance their professional and personal development.

Requirements for the Graduate Certificate in Neuroscience and the Law

Students must complete a minimum of 12 credits from the following courses:

CREDITS

1. Both of the following courses (3 credits):

NEU 840 Introduction to Brain and Behavioral Disorders	2
NEU 892 Special Topics in Neuroscience and the Law	1
2. Complete 9 credits from the following courses:

NEU 842 Neuroethics	3
NEU 843 Methods for Assessing the Nervous System	3
NEU 844 The Science and Ethics of Brain Interventions	3
NEU 845 Neuroscience of Drug Use and Human Disorders	3

Master of Science

The major objective of the M.S. program is to provide sufficient theoretical and practical training in neuroscience to allow students to obtain professional level positions in academic, industrial, or governmental institutions.

Admission

Admission to graduate study in neuroscience is primarily to the doctoral program. Students are generally accepted for graduate study in neuroscience only if judged by a program committee to be qualified to complete the doctoral degree. However, under certain circumstances, the program may consider applications for admission to the Master of Science in Neuroscience from students who wish to earn a master's degree in preparation for the doctoral degree. For consultation, contact the program director.

To be considered for admission to the Master of Science degree in Neuroscience an applicant should:

1. have taken a broad spectrum of basic science courses.
2. have a grade-point average of at least 3.0 in science and mathematics courses.

To be eligible for regular admission to the Master of Science degree in Neuroscience, an applicant must:

1. have completed an undergraduate degree in a biological or physical science or a related discipline.
2. have earned an overall grade-point average of 3.0.

Laboratory research experience is recommended, but not required. Applicants with deficiencies in academic preparation may be admitted provisionally, with the requirement that they complete collateral science courses during the first year of study; these collateral courses will not count toward the degree.

Admission decisions are made by the Neuroscience Program Graduate Affairs Committee.

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

COLLEGE OF NATURAL SCIENCE

Requirements for the Master of Science Degree in Neuroscience

The program is available under either Plan A (with thesis) or Plan B (without thesis). 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:

CREDITS

Requirements for Plan A and Plan B

1. Complete all of the following courses (17 credits):

NEU 801	Molecular, Cellular and Developmental Neuroscience I	3
NEU 802	Systems and Behavioral Neuroscience I	3
NEU 803	Molecular, Cellular and Developmental Neuroscience II	3
NEU 805	Systems and Behavioral Neuroscience II	3
NEU 807	Strategies in Neuroscience Research	2
NEU 815	Quantitative Skills in Neuroscience Research	3
2. The following course (3 credits):

PHM 830	Experimental Design and Data Analysis	3
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3. Complete a minimum of 6 credits in Neuroscience 800 or 899. Plan A students must complete 4 credits of Neuroscience 899.
4. Complete an additional 4 credits of elective courses related to the student's research and approved by the student's guidance committee.
5. Complete a one semester laboratory rotation with each of two neuroscience faculty in the first year of study. Students will select the two laboratories in which they will rotate at the beginning of fall semester based on discussions and mutual agreement with neuroscience faculty members.
6. All students must complete Responsible Conduct of Research Training. All students are required to complete the laboratory safety and animal use training tutorials and put together an Individual Development Plan based on their career goals.

Additional Requirements for Plan A

Successful completion and defense of a thesis based on original research on an important problem in neuroscience in a seminar-based public forum.

Additional Requirements for Plan B

Successful completion and presentation of a research-based paper.

Doctor of Philosophy

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 3.0 in science and mathematics courses.
3. Experience in laboratory research.

To be eligible for regular 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, psychological, or physical science or in a related discipline.
2. An overall grade-point average of at least 3.0.

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 collateral science courses during the first year of study; these collateral courses will not count toward the degree.

Requirements for the Doctor of Philosophy Degree in Neuroscience

The student must:

CREDITS

1. Complete all of the following courses (20 credits):

CMSE 890	Selected Topics in Computational Mathematics, Science, and Engineering	3
or		
FOR 875	R Programming for Data Sciences	3
NEU 801	Molecular, Cellular and Developmental Neuroscience I	3
NEU 802	Systems and Behavioral Neuroscience I	3
NEU 803	Molecular, Cellular and Developmental Neuroscience II	3
NEU 805	Systems and Behavioral Neuroscience II	3
NEU 807	Strategies in Neuroscience Research	2
PHM 830	Experimental Design and Data Analysis	3

Students who choose CMSE 890 must complete three separate enrollments in a specific topic approved by the student's guidance committee.
2. Complete two elective courses relevant to neuroscience (4 to 6 credits).
3. Complete in the first year of enrollment in the program a minimum of 2, and no more than 3 laboratory rotations (NEU 890) with each of two or three members of the faculty. Each rotation is established by mutual agreement of the faculty member and the student.
4. Pass the written comprehensive examination given at the end of the second year of enrollment in the program.
5. Complete and orally defend a dissertation research proposal and present a seminar describing their proposal as part of the Neuroscience Program Seminar Series.
6. Complete and defend a dissertation based on original research on an important problem in neuroscience.
7. All students must complete Responsible Conduct of Research Training. All students are required to complete the laboratory safety and animal use training tutorials and put together an Individual Development Plan based on their career goals.

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, Giltner Hall, 293 Farm Lane, Room 108, Michigan State University, East Lansing, MI 48824-1317, or by visiting the Web site at <http://www.neuroscience.msu.edu>.

INTERDEPARTMENTAL MINORS AND SPECIALIZATIONS

UNDERGRADUATE

ENVIRONMENTAL AND SUSTAINABILITY STUDIES

The Minor in Environmental and Sustainability Studies is available as an elective to all students who are enrolled in bachelor's degree programs at Michigan State University. Students completing the minor will gain knowledge and skills essential for understanding the biological and physical environment that is inhabited and influenced by humans; managing complex interactions between humans and natural systems; and understanding how policy-making impacts and shapes environmental and sustainability outcomes. The College of Natural Science is the primary administrative unit for the minor with support from the College of Agriculture and Natural Resources, College of Communication Arts and Sciences, the Eli Broad College of Business, College of Engineering, and College of Social Science.

Students who have declared the intent to complete the minor or who have declared a major preference for a bachelor's degree program in one of the above listed colleges may elect to live in residence and participate in the Residential Initiative on the Study of the Environment (RISE). Students who elect this option will be housed in Bailey Hall in the Brody Neighborhood. This integrated living-learning program allows for students from multiple colleges and disciplines to develop a sense of community and promotes a team approach to managing complex problems.

With prior written approval from the RISE Coordinator who administers a course in the minor, another course may be substituted for a course from the list of approved courses. Before a student requests a substitution, the student should consult with their academic advisor to ensure that the substitution will not adversely affect the requirements for their degree program.

Requirements for the Minor in Environmental and Sustainability Studies

The student must complete a minimum of 15 credits from the following:

1. Biological and Physical Dimensions

Two of the following courses

(6 or 7 credits):

CSS 210	Fundamentals of Soil Science	3
CSS 442	Agricultural Ecology	3
CSS 455	Environmental Pollutants in the Soil and Water	3
FOR 340	Forest Ecology	3
FW 364	Ecological Problem Solving	3
FW 444	Conservation Biology	3
GEO 203	Introduction to Meteorology	3
GEO 206	Physical Geography	3
GLG 201	The Dynamic Earth	4
IBIO 355	Ecology	3
ISB 201	Insects, Globalization, and Sustainability	3
ISB 202	Applications of Environmental and Organismal Biology	3

2. Coupled Human and Natural Systems

Two of the following courses

(5 to 8 credits):

AFRE360	Environmental Economics	3
AFRE465	Corporate Environmental Management (W)	3
ANS 418	Animal Agriculture and the Environment	3
ANS 427	Environmental Toxicology and Society	3
COM 399	Special Topics in Communication	3
CSUS200	Introduction to Sustainability	3
CSUS300	Theoretical Foundations of Sustainability	3
CSUS310	History of Environmental Thought and Sustainability	3
CSUS320	Environmental Planning and Management	3
ENT 205	Pests, Society and Environment	3
ENE 280	Principles of Environmental Engineering and Science	3
FW 439	Conservation Ethics	3
GEO 235	Geography of Environment and Health	3
HST 391	Environmental History of North America	3
ISS 310	People and Environment (I)	4
JRN 472	Environment, Science and Health Reporting	3
JRN 473	Environment, Science and Health Journalism Special Topics	3
NSC 292	Applications in Environmental Studies	2
PHL 342	Environmental Ethics	3
PKG 470	Packaging Sustainability	3
SOC 452	Advanced Seminar in Environmental Sociology	3
UP 353	Land Use Planning	4

3. Environmental Policy and Law

One of the following courses

(3 credits):

CSUS 265	Exploring Environmental and Sustainability Issues and Policy Using Film	3
CSUS 465	Environmental and Natural Resource Law	3
FOR 466	Natural Resource Policy	3
FW 445	Biodiversity Conservation Policy and Practice	3
GBL 480	Environmental Law and Sustainability for Business: From Local to Global	3
GEO 211	Environmental Policy and Practice	3
IBIO 446	Environmental Issues and Public Policy	3

ECOLOGY, EVOLUTION, AND BEHAVIOR

The interdepartmental graduate Specialization in Ecology, Evolution, and Behavior is available for students who are enrolled in master's degree programs at Michigan State University whose course of study involves ecology, evolution, and behavior. The College of Natural Science administers the specialization.

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

1. provide an opportunity for master's students to obtain a comprehensive and contemporary academic experience in the field of ecology, evolution, 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, evolution, and behavior.

A student who is enrolled in a master's degree program who wishes to complete the requirements for the interdepartmental Graduate Specialization in Ecology, Evolution, 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, Evolution, 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, Evolution, and Behavior faculty.

The specialization consists of the completion of the ecology, evolution, 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

1. One 3-credit course in ecology at the 800-900 level from a list of approved courses available from the office of the ecology, evolution, and behavior program.
2. One 3-credit course in evolution at the 800-900 level from a list of approved courses available from the office of the ecology, evolution, and behavior program.
3. Both of the following quantitative methods courses (6 credits):

IBIO 830 Statistical Methods in Ecology and Evolution I	3
IBIO 831 Statistical Methods in Ecology and Evolution II	3

GRADUATE SPECIALIZATION IN ENVIRONMENTAL TOXICOLOGY

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

DEPARTMENT OF BIOCHEMISTRY and MOLECULAR BIOLOGY

Olorunseun O. Ogunwobi, 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 focused on studying the molecular basis of life. 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 diseases that result from 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 career opportunities that make use of the knowledge gained during study at the undergraduate or graduate level. These include research in industrial, academic, or government laboratories; teaching at the high school or higher levels; and science policy making, marketing, or administrative responsibilities in enterprises where training in biochemistry and molecular biology is an asset.

UNDERGRADUATE PROGRAMS

BIOCHEMISTRY and MOLECULAR BIOLOGY

Bachelor of Science

The Bachelor of Science program in Biochemistry and Molecular Biology for students in the College of Natural Science combines the elements of a liberal education with thorough preparation in biochemistry and molecular biology 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 and molecular biology 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 and molecular biology 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 and molecular biology. Interested undergraduates are encouraged to participate, along with graduate students and postdoctoral fellows, in the on-going research of one of the faculty members.

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

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

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 and Molecular Biology.

The University's Tier II writing requirement for the Biochemistry and Molecular Biology major is met by completing Biochemistry and Molecular Biology 495 or 499. Those courses are referenced in item 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

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the *College* statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.

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

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

- The following requirements for the major:

	CREDITS
a. The following courses outside the Department of Biochemistry and Molecular Biology (59 to 66 credits):	
(1) All of the following courses (8 credits):	
CEM 355 Organic Laboratory I	2
CEM 356 Organic Laboratory II	2
CMSE201 Computational Modeling and Data Analysis I	4
(2) One of the following groups of courses (8 or 9 credits):	
(a) BS 161 Cell and Molecular Biology	3
BS 162 Organismal and Population Biology	3
BS 171 Cell and Molecular Biology Laboratory	2
(b) BS 181H Honors Cell and Molecular Biology	3
BS 182H Honors Organismal and Population Biology	3
BS 191H Honors Cell and Molecular Biology Laboratory	2
(c) LB 144 Biology I: Organismal Biology	4
LB 145 Biology II: Cellular and Molecular Biology	5
(3) One course from each of the following groups of courses (7 or 8 credits):	
(a) CEM 141 General Chemistry	4
CEM 151 General and Descriptive Chemistry	4
CEM 181H Honors Chemistry I	4
LB 171 Principles of Chemistry I	4
(b) CEM 142 General and Inorganic Chemistry	4
CEM 152 Principles of Chemistry	4
CEM 182H Honors Chemistry II	4
LB 172 Principles of Chemistry II	3
(4) One of the following groups of courses (2 credits):	
(a) CEM 161 Chemistry Laboratory I	1
CEM 162 Chemistry Laboratory II	1
(b) LB 171L Introductory Chemistry Laboratory I	1
LB 172L Principles of Chemistry II - Reactivity Laboratory	1
(c) CEM 185H Honors Chemistry Laboratory I	2
(5) One course from each of the following groups of courses (7 or 8 credits):	
(a) CEM 251 Organic Chemistry I	4
CEM 351 Organic Chemistry I	4
LB 271 Organic Chemistry	3
(b) CEM 252 Organic Chemistry II	4
CEM 352 Organic Chemistry II	4
(6) One course from each of the following groups of courses (6 to 8 credits):	
(a) MTH 132 Calculus I	3
MTH 152H Honors Calculus I	3
LB 118 Calculus I	4
(b) MTH 133 Calculus II	4
MTH 153H Honors Calculus II	3
LB 119 Calculus II	4
(7) One of the following courses (3 credits):	
CEM 383 Introductory Physical Chemistry I	3
CEM 484 Molecular Thermodynamics	3
(8) One of the following groups of courses (8 or 10 credits):	
(a) PHY 183 Physics for Scientists and Engineers I	4
PHY 184 Physics for Scientists and Engineers II	4
(b) PHY 221 Studio Physics for Life Scientists I	4
PHY 222 Studio Physics for Life Scientists II	4
(c) PHY 231 Introductory Physics I	3
PHY 232 Introductory Physics II	3
PHY 233B Calculus Concepts in Physics I	2
PHY 234B Calculus Concepts in Physics II	2
(d) PHY 193H Honors Physics I – Mechanics	4
PHY 294H Honors Physics II – Electromagnetism	4
(e) LB 273 Physics I	4
LB 274 Physics II	4
(9) Ten additional credits in approved courses at the 300–400 level.	
b. The following courses in the Department of Biochemistry and Molecular Biology (18 credits):	
All of the following courses:	
BMB 101 Frontiers in Biochemistry	1
BMB 370 Introductory Biochemistry Laboratory	3

BMB 461 Advanced Biochemistry I	3
BMB 462 Advanced Biochemistry II	3
BMB 470 Advanced Molecular Biology Laboratory	4
BMB 471 Advanced Biochemistry Laboratory	4
c. One of the following capstone courses (2 to 8 credits):	
BMB 495 Undergraduate Seminar (W)	2
BMB 499 Senior Thesis (W)	2 to 8
LB 492 Senior Seminar (W)	4

BIOCHEMISTRY and MOLECULAR BIOLOGY/BIOTECHNOLOGY

Bachelor of Science

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

The core curriculum in the Biochemistry and Molecular Biology/Biotechnology program is identical to that of the Biochemistry and Molecular Biology program. Additional course work introduces the student to the chemical engineering and microbiological aspects of biotechnology and allows for specialization through a broad range of approved biotechnology courses in the junior and senior years.

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

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

The University's Tier II writing requirement for the Biochemistry and Molecular Biology/Biotechnology major is met by completing Biochemistry and Molecular Biology 495 or 499. Those courses are referenced in item 3. below.

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

- The requirements of the College of Natural Science for the Bachelor of 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. The following courses outside the Department of Biochemistry and Molecular Biology (64 to 73 credits):	
(1) All of the following courses (8 credits):	
CEM 355 Organic Laboratory I	2
CEM 356 Organic Laboratory II	2
CMSE 201 Computational Modeling and Data Analysis I	4
(2) One of the following groups of courses (8 or 9 credits):	
(a) BS 161 Cell and Molecular Biology	3
BS 162 Organismal and Population Biology	3
BS 171 Cell and Molecular Biology Laboratory	2
(b) BS 181H Honors Cell and Molecular Biology	3
BS 182H Honors Organismal and Population Biology	3
BS 191H Honors Cell and Molecular Biology Laboratory	2
(c) LB 144 Biology I: Organismal Biology	4
LB 145 Biology II: Cellular and Molecular Biology	5
(3) One course from each of the following groups of courses (7 or 8 credits):	
(a) CEM 141 General Chemistry	4
CEM 151 General and Descriptive Chemistry	4
CEM 181H Honors Chemistry I	4
LB 171 Principles of Chemistry I	4

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(b)CEM 142 General and Inorganic Chemistry	4
CEM 152 Principles of Chemistry	4
CEM 182H Honors Chemistry II	4
LB 172 Principles of Chemistry II	3
(4)One of the following groups of courses (2 credits):	
(a)CEM 161 Chemistry Laboratory I	1
CEM 162 Chemistry Laboratory II	1
(b)LB 171L Introductory Chemistry Laboratory I	1
LB 172L Principles of Chemistry II-Reactivity Laboratory	1
(c)CEM 185H Honors Chemistry Laboratory I	2
(5)One course from each of the following groups of courses (7 or 8 credits):	
(a)CEM 251 Organic Chemistry I	4
CEM 351 Organic Chemistry I	4
LB 271 Organic Chemistry	3
(b)CEM 252 Organic Chemistry II	4
CEM 352 Organic Chemistry II	4
(6)One course from each of the following groups of courses (6 to 8 credits):	
(a)MTH 132 Calculus I	3
MTH 152H Honors Calculus I	3
LB 118 Calculus I	4
(b)MTH 133 Calculus II	4
MTH 153H Honors Calculus II	3
LB 119 Calculus II	4
(7)One of the following courses (3 credits):	
CEM 383 Introductory Physical Chemistry I	3
CEM 484 Molecular Thermodynamics	3
(8)One of the following groups of courses (8 or 10 credits):	
(a)PHY 183 Physics for Scientists and Engineers I	4
PHY 184 Physics for Scientists and Engineers II	4
(b)PHY 221 Studio Physics for Life Scientists I	4
PHY 222 Studio Physics for Life Scientists II	4
(c)PHY 231 Introductory Physics I	3
PHY 232 Introductory Physics II	3
PHY 233B Calculus Concepts in Physics I	2
PHY 234B Calculus Concepts in Physics II	2
(d)PHY 193H Honors Physics I - Mechanics	4
PHY 294H Honors Physics II - Electromagnetism	4
(e)LB 273 Physics I	4
LB 274 Physics II	4
(9)One of the following courses (3 or 4 credits):	
BMB 470 Advanced Molecular Biology Laboratory	3
CROP451 Biotechnology Applications for Plant Breeding and Genetics	3
MGI 408 Advanced Microbiology Laboratory (W)	3
(10) One of the following courses (3 or 4 credits):	
CROP350 Introduction to Plant Genetics	3
IBIO 341 Fundamental Genetics	4
(11) Nine additional credits in approved advanced biotechnology courses at the 300-400 level.	
b. All of the following courses in the Department of Biochemistry and Molecular Biology (14 credits):	
BMB 101 Frontiers in Biochemistry	1
BMB 370 Introductory Biochemistry Laboratory	3
BMB 461 Advanced Biochemistry I	3
BMB 462 Advanced Biochemistry II	3
BMB 471 Advanced Biochemistry Laboratory	4
c. One of the following capstone courses (2 to 8 credits):	
BMB 495 Undergraduate Seminar (W)	2
BMB 499 Senior Thesis (W)	2 to 8
LB 492 Senior Seminar (W)	4

GRADUATE STUDY

The Department of Biochemistry and Molecular Biology is administered jointly by the colleges of Natural Science, Human Medicine, and Osteopathic Medicine. Study for the Master of Science or Doctor of Philosophy degree with a major in biochemistry and molecular biology may be administered by any one of the three colleges referenced above. In addition, students may pursue dual majors with the Departments of Chemistry, Computer Science and Engineering, or Physics

and Astronomy. Most students enter the graduate program through the Biomolecular Sciences umbrella program.

Areas of active research in the department are extensive and diverse. Such areas include protein structure, molecular biophysics, computational biology, plant biochemistry, gene expression, Metallo enzymology, eukaryotic and prokaryotic molecular biology, metabolic regulation, and membrane biochemistry. Opportunities are also available for joint programs or research in genetics, cell biology, neuroscience, toxicology, biotechnology, microbial ecology, and plant sciences.

BIOCHEMISTRY and MOLECULAR BIOLOGY

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

Master of Science

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

Admission

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

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

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

CREDITS

- Complete all of the following courses (11 credits):

BMB 801 Molecular Biology	3
BMB 805 Protein Structure, Design, and Mechanism	3
BMB 829 Methods of Macromolecular Analysis and Synthesis	2
BMB 978 Seminar in Biochemistry	3

 Biochemistry and Molecular Biology 978 is completed in three separate 1 credit enrollments.
- Complete two additional 800-level courses as approved by the student's guidance committee.

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3. Complete a minimum of 4 credits with no more than 15 credits of BMB 899 Master's Thesis Research.
4. Successfully pass an oral examination covering both a defense of the thesis and course work.

Doctor of Philosophy

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

Admission

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

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

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

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

CREDITS

1. Complete all of the following courses (14 credits):

BMB 801	Molecular Biology	3
BMB 805	Protein Structure, Design, and Mechanism	3
BMB 829	Methods of Macromolecular Analysis and Synthesis	2
BMB 960	Selected Topics in Biochemistry I	1
BMB 961	Selected Topics in Biochemistry II	1
BMB 978	Seminar in Biochemistry	4

Biochemistry and Molecular Biology 978 is completed in four separate 1 credit enrollments. Equivalent course work involving student presentations may be substituted for BMB 960 and BMB 961 with approval by the Graduate Program Director.
2. Complete two additional 800-level courses as approved by the student's guidance committee.
3. Complete at least one semester as a Teaching Assistant in the second year together with enrollment in BMB 961 Selected Topics in Biochemistry II, Section 002 Instructional Methods in Biochemistry and Molecular Biology.
4. Successfully complete the comprehensive examination taken no later than one month after the start of year three.
5. Complete 24 credits of BMB 999 Doctoral Dissertation Research.
6. Successfully defend the publicly presented dissertation.

BIOMOLECULAR SCIENCE GATEWAY - FIRST YEAR

Students seeking a doctoral degree in biochemistry and molecular biology, cell and molecular biology, genetics and genome sciences, microbiology, genetics and immunology, pharmacology and toxicology, or molecular, cellular, and integrative physiology should apply through the BioMolecular Science Gateway—First Year for admission to any of these Ph.D. programs. Students should select the Ph.D. program in which they have the greatest interest. During the first two semesters of enrollment, students will have the opportunity to

choose and complete at least four courses in appropriate disciplinary subjects. In the spring semester of the first year, they will have the opportunity to continue with the Ph.D. program initially selected or change to one of the other five programs that aligns most closely with their educational goals.

For additional information about the individual Ph.D. programs, refer to the statements in the Departments of Biochemistry and Molecular Biology, Microbiology, Genetics, and Immunology, and Physiology in the *College of Natural Science* section of this catalog, statements on the programs in Cell and Molecular Biology and Genetics and Genome Sciences in the *College of Natural Science* section of this catalog, and statement on the Department of Pharmacology and Toxicology in the *College of Osteopathic Medicine* section of this catalog.

BIOMEDICAL LABORATORY DIAGNOSTICS PROGRAM

John Gerlach, Director

UNDERGRADUATE PROGRAMS

The Biomedical Laboratory Diagnostics (BLD) Program offers undergraduate degree programs as a foundation for students planning to enter a career in human medicine. The program's majors apply basic science backgrounds in chemistry, biology, mathematics, and physics to medical science. The curriculum focuses on courses with a diagnostic medicine emphasis that include topics in hematology, immunology, transfusion, hemostasis, clinical microbiology, molecular diagnostics, and clinical chemistry. Course work also emphasizes laboratory skills, critical thinking, problem solving, and case-based learning. As a result, students enrolled in the BLD program have a unique diagnostic background and skillset as they prepare for careers in medical science, research, graduate school, medical school, dental school, veterinary sciences, physician assistant school, forensics, and other health care related fields.

There are two undergraduate programs offered in the Biomedical Laboratory Diagnostics Program. They are Biomedical Laboratory Science and Medical Laboratory Science. All students initially select the Biomedical Laboratory Science major.

Students interested in a career as a certified Medical Laboratory Scientist may choose to apply to the limited-enrollment Medical Laboratory Science degree. Medical Laboratory Science, historically called Medical Technology, is the health profession focused on providing medical laboratory testing on human samples for patient screening, disease diagnosis and monitoring of human health. Medical laboratory test results have a significant impact in healthcare and are utilized in patient treatment decisions. Medical Laboratory Scientists carry out the testing process from sample collection to reporting results to the health care provider. This includes test method selection, development, assay performance, quality assurance, instrument management, and result analysis in a highly automated and computerized environment.

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Medical Laboratory Scientists also manage laboratory operations including marketing, personnel management, regulatory compliance, and finances. Our Medical Laboratory Science program is designed to meet the professional needs of graduates entering a highly regulated and rapidly changing environment driven by medical discovery. Our Program also prepares students for continuing professional education and advanced study beyond the bachelor's degree. Students desiring such a career should plan to obtain national certification as a Medical Laboratory Scientist (MLS). Biomedical Laboratory Diagnostics Program advisors will assist students in this process.

Employment in medical diagnostic laboratories is just one of the many career opportunities available to graduates from the Biomedical Laboratory Diagnostics Program. The skills needed in a medical laboratory also translate readily into public health, clinical and biomedical research and other laboratory testing settings. Graduates may additionally find employment in pharmaceutical, laboratory instrument and medical devices sales and development, and technical support. Alumni successfully compete for admission to graduate and graduate professional schools such as medical school, dental school, veterinary sciences and physician assistant school.

BIOMEDICAL LABORATORY SCIENCE

The biomedical laboratory science (BLS) academic program (major) is designed to prepare students for careers in a variety of applied biomedical sciences. These include careers in the medical laboratory, public health, research, industry, human medicine, dentistry, veterinary medicine, graduate school or other human health professional education. The BLD courses are focused in curricular spirals within six disciplines: Clinical Chemistry, Molecular Diagnostics, Immunology and Immunohematology, Hematology and Hemostasis, Medical Microbiology and Professional Writing (with a research and laboratory medicine emphasis). The medical laboratory experience required for national certification as a medical laboratory scientist is not included in this program, though BLS program advisors help students plan their career pathways. Students desiring Medical Laboratory Science certification are recommended to complete the medical laboratory science concentration and are responsible for securing accredited clinical experiences subsequent to completion of the degree. The Biomedical Laboratory Diagnostics Program will advise students in securing clinical practicum experiences. The program will also provide advising and career support for students pursuing career pathways in public health, research, industry, human medicine, dentistry, veterinary medicine, or graduate school.

Requirements for the Bachelor of Science Degree in Biomedical Laboratory Science

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 Biomedical Laboratory Science.

The University's Tier II writing requirement for the Biomedical Laboratory Science major is met by completing Biomedical Laboratory Diagnostics 456. 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 Biomedical Laboratory Science: (44 to 51 credits)

- (1) All of the following courses (27 credits):

BS 161	Cell and Molecular Biology	3
BS 171	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
MGI 365	Medical Microbiology	3
MGI 365L	Medical Microbiology Laboratory	1
PHY 231	Introductory Physics I	3
PHY 232	Introductory Physics II	3
- (2) One of the following courses (3 credits):

MTH 124	Survey of Calculus 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 Engineering	3
STT 421	Statistics I	3
- (4) One of the following, either (a) or (b) (4 or 6 credits):

(a)BMB 401	Comprehensive Biochemistry	4
(b)BMB 461	Advanced Biochemistry I	3
BMB 462	Advanced Biochemistry II	3
- (5) One of the following, either (a) or (b) (4 or 8 credits):

(a)PSL 310	Physiology for Pre-Health Professionals	4
(b)PSL 431	Human Physiology I	4
PSL 432	Human Physiology II	4
- (6) One of the following courses (3 credits):

MGI 201	Fundamentals of Microbiology	3
MGI 301	Introductory Microbiology	3

b. All of the following Biomedical Laboratory Diagnostics courses: (24 credits)

- | | | |
|----------|---|---|
| BLD 121 | Survive and Thrive Freshman Seminar | 1 |
| BLD 204 | Mechanisms of Disease | 3 |
| BLD 213L | Clinical Laboratory Methods | 2 |
| BLD 302 | Clinical Chemistry | 2 |
| BLD 313 | Quality in Clinical Laboratory Practice | 3 |
| BLD 314L | Advanced Clinical Laboratory Methods | 1 |
| BLD 324 | Hematology and Hemostasis | 3 |
| BLD 430 | Molecular Laboratory Diagnostics | 2 |
| BLD 434 | Clinical Immunology | 3 |
| BLD 435 | Immunohematology | 2 |
| BLD 456 | Medical Laboratory Professionalism (W) | 2 |

c. One of the following concentrations:

Clinical Chemistry (12 or 13 credits)

- (1) All of the following courses (7 credits):

BLD 402	Advanced Clinical Chemistry	4
CEM 333	Instrumental Methods and Applications	3
- (2) Two of the following courses (5 or 6 credits):

BE 230	Engineering Analysis of Biological Systems	3
CEM 255	Organic Chemistry Laboratory	2
CEM 262	Quantitative Analysis	3
CEM 311	Inorganic Chemistry	3
CEM 383	Introductory Physical Chemistry I	3
PHM 350	Introductory Human Pharmacology	3
PHM 321	Common Drugs	3
PHM 430	Human Pharmacology	3
PHM 450	Introduction to Chemical Toxicology	3

Medical Microbiology (10 to 12 credits)

- (1) All of the following courses (8 credits):

MGI 465	Advanced Medical Microbiology	3
MGI 465L	Advanced Medical Microbiology Laboratory	2
MGI 461	Molecular Pathogenesis	3
- (2) One of the following courses (2 to 4 credits):

BE 230	Engineering Analysis of Biological Systems	3
BLD 366	Infectious Diseases of East Africa	4

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BLD 461	Advanced Biomedical Technologies	3
BLD 861	Emerging Infections, Emerging Technology	2
EPI 390	Disease in Society: Introduction to Epidemiology and Public Health	4
MGI 413	Virology	3
MGI 421	Prokaryotic Cell Physiology	3
MGI 431	Microbial Genetics	3
PH 801	Introduction to Public Health	3
Hematology and Hemostasis (7 to 9 credits)		
(1) All of the following courses (3 credits):		
BLD 424	Advanced Hematology and Hemostasis	2
BLD 424L	Advanced Hematology, Hemostasis and Urinalysis Laboratory	1
(2) Two of the following courses (2 credits):		
BLD 439	Histocompatibility and Immunogenetics	1
BLD 446	Immunobiology of Neoplasia	1
BLD 447	Immunomodulation and Immunotherapy	1
(3) One of the following courses (2 to 4 credits):		
BLD 815	Cell Biology in Health and Disease I	2
IBIO 341	Fundamental Genetics	4
IBIO 408	Histology	4
IBIO 425	Cells and Development (W)	4
IBIO 450	Cancer Biology (W)	3
MGI 409	Eukaryotic Cell Biology	3
PHM 350	Introductory Human Pharmacology	3
Medical Laboratory Science (13 credits)		
All of the following courses:		
BLD 402	Advanced Clinical Chemistry	4
BLD 424	Advanced Hematology and Hemostasis	2
BLD 424L	Advanced Hematology, Hemostasis and Urinalysis Laboratory	1
BLD 435L	Immunohematology Laboratory	1
MGI 465	Advanced Medical Microbiology	3
MGI 465L	Advanced Medical Microbiology Laboratory	2

MEDICAL LABORATORY SCIENCE

The medical laboratory science major is designed to prepare students for certification in medical laboratory science. The program includes courses in biomedical laboratory sciences, communications, mathematics and statistics, and medical laboratory sciences coupled with clinical practicum experiences. It is designed to prepare graduates for certification and immediate employment in medical laboratories upon graduation by including a six-month hospital laboratory experience.

The Bachelor of Science degree program in medical laboratory science has been accredited by the National Accrediting Agency for Clinical Laboratory Sciences, 5600 N. River Road, Suite 720, Rosemont, Illinois 60018; phone (773) 714-8880.

Admission

Enrollment in the medical laboratory science major is limited. A new cohort is admitted at the end of the spring semester of the junior year. Applications for admission are due by the end of fall semester of the junior year. Applicant interviews are conducted during the spring semester of junior year. Admission decisions for students admitted to the medical laboratory science major are made following review of final grades from spring semester of junior year.

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

1. Have an overall grade-point average of 2.50 or better including courses taken at other institutions.

2. Have a grade-point average of 2.50 or better in the following courses: BLD 204, BLD 213L, BLD 313, and BLD 314L.
3. Have completed BMB 401, MGI 365, MGI 365L, BLD 324, and BLD 434.

Students who present other exceptional credentials, but do not meet the grade-point criterion noted above, may be considered for admission on a provisional basis.

Applications for admission to the medical laboratory science major are reviewed by a committee of faculty. Factors considered by the Admission Committee in the applicant's review and admission action are: (1) academic record including grade-point averages in science and non-science courses; (2) grades for selected preclinical courses; (3) laboratory science exposure; (4) interview; and (5) compositions. Students who are admitted provisionally and require additional course work to remedy deficiencies may not count this course work towards the fulfillment of degree requirements.

Requirements for the Bachelor of Science Degree in Medical Laboratory Science

1. A minimum of 134 credits is required for the Bachelor of Science degree in Medical Laboratory Science.
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 Medical Laboratory Science major is met by completing Biomedical Laboratory Science 456. 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 Biomedical Laboratory Diagnostics (52 to 59 credits):	
(1) All of the following courses (35 credits):	
BS 161 Cell and Molecular Biology	3
BS 171 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
CEM 333 Instrumental Methods and Applications	3
MGI 365 Medical Microbiology	3
MGI 365L Medical Microbiology Laboratory	1
MGI 465 Advanced Medical Microbiology	3
MGI 465L Advanced Medical Microbiology Laboratory	2
PHY 231 Introductory Physics I	3
PHY 232 Introductory Physics II	3
(2) One of the following courses (3 credits):	
MTH 124 Survey of Calculus 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 Engineering	3
STT 421 Statistics I	3
(4) One of the following, either (a) or (b) (4 or 6 credits):	
(a)BMB 401 Comprehensive Biochemistry	4
(b)BMB 461 Advanced Biochemistry I	3
BMB 462 Advanced Biochemistry II	3
(5) One of the following, either (a) or (b) (4 or 8 credits):	
(a)PSL 310 Physiology for Pre-Health Professionals	4
(b)PSL 431 Human Physiology I	4

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PSL 432 Human Physiology II	4
(6) One of the following courses (3 credits):	
MGI 201 Fundamentals of Microbiology	3
MGI 301 Introductory Microbiology	3
b. All of the following Biomedical Laboratory Diagnostics courses (47 credits):	
BLD 121 Survive and Thrive Freshman Seminar	1
BLD 204 Mechanisms of Disease	3
BLD 213L Clinical Laboratory Methods	2
BLD 302 Clinical Chemistry	2
BLD 313 Quality in Clinical Laboratory Practice	3
BLD 314L Advanced Clinical Laboratory Methods	1
BLD 324 Hematology and Hemostasis	3
BLD 402 Advanced Clinical Chemistry	4
BLD 424 Advanced Hematology and Hemostasis	2
BLD 424L Advanced Hematology, Hemostasis and Urinalysis Laboratory	1
BLD 430 Molecular Diagnostics	2
BLD 434 Clinical Immunology	3
BLD 435 Immunohematology	2
BLD 435L Immunohematology Laboratory	1
BLD 445 Medical Laboratory Management	1
BLD 456 Medical Laboratory Professionalism (W)	2
BLD 471L Advanced Clinical Chemistry Laboratory	3
BLD 473L Advanced Clinical Hematology and Body Fluids Laboratory	3
BLD 475L Advanced Clinical Immunology and Immunohematology Laboratory	2
BLD 477L Advanced Clinical Microbiology Laboratory	3
BLD 479 Professional Behavior in Medical Laboratory Science	1
BLD 480 Medical Laboratory Science Examinations I	1
BLD 481 Medical Laboratory Science Examinations II	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.	

Academic Standards

To progress to the clinical phase of the curriculum, students must earn a grade-point average of 2.50 or higher in MGI 465, MGI 465L, BLD 402, BLD 424, BLD 424L, BLD 430, BLD 435, and BLD 435L. Students who do not meet this progression standard will be dismissed from the medical laboratory science degree and can graduate with a biomedical laboratory science degree.

A specific statement of the policies for the clinical phase is provided in the Student Policies for Medical Laboratory Science Students. These policies are provided to all students upon acceptance to the major, but may be obtained earlier from the Biomedical Laboratory Diagnostics Program, 354 Farm Lane, Room N322, East Lansing, MI 48824. Admitted students are responsible for knowing and adhering to these program policies.

GRADUATE STUDY

Three master's degree programs are available. The Master of Arts degree in Biomedical Laboratory Science program for working professionals is available as a non-thesis option. The Master of Science degree in Clinical Laboratory Science program is a traditional science-oriented degree with both thesis and non-thesis options. The Master of Science in Biomedical Laboratory Operations program is a blending of business management with the science needed to prepare managers for positions in regulated research, industry and medical settings. All three master's degrees are available in an online format.

BIOMEDICAL LABORATORY SCIENCE

The Master of Arts degree in Biomedical Laboratory Science is administered by the Biomedical Laboratory Diagnostics Program. The program is designed to enhance the student's knowledge base and broaden their perspectives across the profession. In addition to meeting the requirements of the university and of the College of Natural Science, students must meet all requirements specified below.

Admission

Regular admission to the Master of Arts degree in Biomedical Laboratory Science requires completion of a bachelor's degree in a relevant field, with a grade-point average that is indicative of success in the program, including the following course work:

1. Completion of 16 credits of biological science including one semester of microbiology.
2. Completion of 16 credits of chemistry including organic chemistry and/or biochemistry.
3. Completion of 3 credits of statistics.

Applicants must:

1. Submit official transcripts.
2. Submit three letters of recommendation on official letterhead paper from professional references such as supervisors, professors, or project leaders, people who have overseen your work and can speak to your ability to think critically, work independently, and succeed in graduate work. The letter must include the recommender's credentials and contact information.
3. Submit a letter of intent or purpose statement that addresses why you want to enter graduate education, including career goals and educational goals. Highlight exceptional achievements or explain low performance or withdrawal from undergraduate courses.
4. Submit a brief resume.
5. Submit General Record Examination (GRE) scores. The GRE exam score can be waived in lieu of a professional credential.
6. Submit scores from the Test of English as a Foreign Language (TOEFL) if English is not the first language. Scholastic record, experience, personal qualifications and career goals will be taken into consideration to determine the applicant's acceptability.

Applicants who fail to meet the criteria for regular admission, may apply for provisional admission if they have demonstrated a high probability of success and will be provided other options to obtain a post-baccalaureate clinical laboratory education. For additional information on admission, contact the Graduate Program Director, 322 North Kedzie Hall, 354 Farm Lane, Michigan State University, East Lansing, Michigan 48824.

Requirements for the Master of Arts Degree in Biomedical Laboratory Science

The program is available online and only under Plan B (without thesis). The student must complete a total of 30 credits from the following:

	CREDITS
1. All of the following courses (10 or 11 credits):	
BLD 801 Biomedical Laboratory Diagnostics Seminar	2
BLD 805 Communication in the Sciences	2
BLD 811 Fundamentals of Scientific Research	1

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BLD 890	Selected Problems in Clinical Laboratory Science	2 or 3
PHM 830	Experimental Design and Analysis	3
2.	Complete at least 14 credits from the following courses:	
BLD 815	Cell Biology in Health and Disease I	2
BLD 816	Cell Biology in Health and Disease II	2
BLD 821	Advanced Clinical Laboratory Practice	1
BLD 830	Concepts in Molecular Biology	2
BLD 831	Clinical Application of Molecular Biology	2
BLD 832	Molecular Pathology Laboratory	2
BLD 835	Hemostasis, Thrombosis and Effective Resource Management	3
BLD 836	Adverse Transfusion Outcomes: Detection, Monitoring and Prevention	2
BLD 837	Transfusion Service Operations and Management	1
BLD 838	Clinical Context of Blood Product Management	1
BLD 842	Managing Biomedical Laboratory Operations	2
BLD 844	Topics in Biomedical Laboratory Operations	1
BLD 846	Decision Processes for Biomedical Laboratory Operations	2
BLD 850	Concepts in Immunodiagnostics	2
BLD 851	Clinical Application of Immunodiagnostic Principles	2
BLD 852	Immunodiagnostics Laboratory	2
BLD 853	Advanced Flow Cytometry	2
BLD 861	Emerging Infections, Emerging Technology	2
BLD 870	Clinical Mass Spectrometry Theory	2
BLD 871	Applied Clinical Mass Spectrometry	2
BLD 872	Clinical Mass Spectrometry Laboratory	2
3.	Complete 5 credits of electives as approved by the guidance committee.	
4.	Successfully complete a capstone project.	

CLINICAL LABORATORY SCIENCES

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

The curriculum is customized to the student's interests and to supporting the project each student identifies. 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

Regular admission to the Master of Science degree in Clinical Laboratory Sciences requires completion of a bachelor's degree in a relevant field, with a grade-point average that is indicative of success in the program, including the following course work:

1. Completion of 16 credits of biological science including one semester of microbiology.
2. Completion of 16 credits of chemistry including organic chemistry and/or biochemistry.
3. Completion of 3 credits of statistics.

Applicants must:

1. Submit official transcripts.
2. Submit three letters of recommendation on official letterhead paper from professional references such as supervisors, professors, or project leaders, people who have overseen your work and can speak to your ability to think critically, work independently, and succeed in graduate work. The letter must include the recommender's credentials and contact information.
3. Submit a letter of intent or purpose statement that addresses why you want to enter graduate education,

including career goals and educational goals. Highlight exceptional achievements or explain low performance or withdrawal from undergraduate courses.

4. Submit a brief resume.
5. Submit General Record Examination (GRE) scores. The GRE exam score can be waived in lieu of a professional credential.
6. Submit scores from the Test of English as a Foreign Language (TOEFL) if English is not the first language. Certification as a medical technologist/clinical laboratory scientist is preferred, but not required for admission. Scholastic record, experience, personal qualifications and career goals will be taken into consideration to determine the applicant's acceptability.

For additional information on admission, contact the Graduate Program Director, 322 North Kedzie Hall, 354 Farm Lane, Michigan State University, East Lansing, Michigan 48824.

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 advisor.

CREDITS

Requirements for Both Plan A and Plan B:

1. All of the following courses:

BLD 801	Biomedical Laboratory Diagnostics Seminar	2
BLD 805	Communication in the Sciences	2
BLD 811	Fundamentals of Scientific Research	1
2. At least 4 credits of 800-level Biomedical Laboratory Diagnostics courses approved by the student's academic advisor.
3. One course in biochemistry or cell biology as approved by the guidance committee.
4. One 400-level or 800-level course in statistics as approved by the guidance committee.
5. Not more than 9 credits in 400-level courses. All 400-level courses must be approved by the guidance committee.

Additional Requirements for Plan A:

BLD 899	Master's Thesis Research	7
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Additional Requirements for Plan B:

BLD 890	Selected Problems in Clinical Laboratory Science	3
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BIOMEDICAL LABORATORY OPERATIONS

Master of Science

The master's degree program in biomedical laboratory operations is designed for individuals with previous clinical laboratory experience who seek career advancement as managers, administrators, researchers, entrepreneurs and policymakers in the field. The core of this program resides in three major components: science, management and practice. The science component focuses on post-baccalaureate courses planned to develop a high level of competence within the student's chosen biomedical laboratory discipline. The management component provides a solid foundation in general business including resource management, communication skills, organizational structures, decision making, and essential aspects of working in a regulated industry. The degree is intended to expose individuals to real-life problems with an expectation of generating positive, realistic solutions.

COLLEGE OF NATURAL SCIENCE

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

Admission

Regular admission to the Master of Science degree in Biomedical Laboratory Operations requires completion of a bachelor's degree in a relevant field, with a grade-point average that is indicative of success in the program, including the following course work:

1. Completion of 16 credits of biological science including one semester of microbiology.
2. Completion of 16 credits of chemistry including organic chemistry and/or biochemistry.
3. Completion of 3 credits of statistics.
4. A minimum of two years' experience in a clinical laboratory setting beyond the clinical internship.

Applicants must:

1. Submit official transcripts.
2. Submit three letters of recommendation on official letterhead paper from professional references such as supervisors, professors, or project leaders, people who have overseen your work and can speak to your ability to think critically, work independently, and succeed in graduate work. The letter must include the recommender's credentials and contact information.
3. Submit a letter of intent or purpose statement that addresses why you want to enter graduate education, including career goals and educational goals. Highlight exceptional achievements or explain low performance or withdrawal from undergraduate courses.
4. Submit a brief resume.
5. Submit General Record Examination (GRE) scores. The GRE exam score can be waived in lieu of a professional credential.
6. Submit scores from the Test of English as a Foreign Language (TOEFL) if English is not the first language.

Scholastic record, experience, personal qualifications and career goals will be taken into consideration to determine the applicant's acceptability.

For additional information on admission, contact the Graduate Program Director, 322 North Kedzie Hall, 354 Farm Lane, Michigan State University, East Lansing, Michigan 48824.

Requirements for the Master of Science Degree in Biomedical Laboratory Operations

The student must complete 31 credits under Plan B (without thesis). The specific program of study includes competence in statistics and completion of a project in biomedical laboratory operations as determined in consultation with the student's guidance committee. The final oral examination, which covers both course work and research, is administered by the student's guidance committee.

CREDITS

1. The following courses (9 credits):

BLD 801	Biomedical Laboratory Diagnostics Seminar	1
BLD 805	Communication in the Sciences	2
BLD 811	Fundamentals of Scientific Research	1
BLD 842	Managing Biomedical Laboratory Operations	2
BLD 844	Topics in Biomedical Laboratory Operations	1
BLD 846	Decision Processes for Biomedical Laboratory Operations	2
2. Complete a minimum of 13 credits in courses with a science focus.

3. Complete a minimum of 3 credits of BLD 895 Projects in Biomedical Laboratory Operations. The project will be determined in consultation with the student's guidance committee.
4. Complete 6 credits of electives as approved by the guidance committee.
5. Pass a final oral examination.

DEPARTMENT of CHEMISTRY

Timothy H. Warren, Chairperson

Chemistry is the science concerned with the composition, structure, properties, and reactivity of matter. Synthesis of new organic and inorganic compounds and materials is central to chemistry and is complemented by efforts to develop analytical methods and instrumentation needed to identify and characterize these substances. Studies of reaction rates, thermodynamics, and molecular structure contribute to a deeper understanding of chemical transformations, providing a basis for optimization of known reactions and discovery of new reactions. The work of chemists is not limited to laboratory experiments. Computational approaches are increasingly important tools in understanding molecular structure and reactivity, designing new materials, and discovering new drugs. The molecular-level understanding provided by chemistry plays an important role in interdisciplinary research to solve complex problems in biology, medicine, energy capture and storage, advanced materials, and environmental science. Chemists find employment in education, government, and diverse industries including but not limited to pharmaceuticals, agrichemicals, consumer products, polymers, electronics, food, and biotechnology. Study of chemistry at the undergraduate and graduate level also provides an excellent foundation for post-graduate study in health-related fields, public policy, business, and patent law.

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 intended for students planning careers in industry or in governmental laboratories and for those planning graduate study in chemistry. The Bachelor of Science degree program in chemistry is approved 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 of Chemistry.

COLLEGE OF NATURAL SCIENCE

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 395, 415, 435, and 495. 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: (28 to 33 credits)

- | | |
|---|---|
| (1) One of the following courses (3 or 5 credits): | |
| BS 161 Cell and Molecular Biology | 3 |
| BS 181H Honors Cell and Molecular Biology | 3 |
| LB 145 Biology II: Cellular and Molecular Biology | 5 |
| (2) One of the following courses (3 or 4 credits): | |
| LB 118 Calculus I | 4 |
| MTH 132 Calculus I | 3 |
| MTH 152H Honors Calculus I | 3 |
| (3) One of the following courses (4 credits): | |
| LB 119 Calculus II | 4 |
| MTH 133 Calculus II | 4 |
| MTH 153H Honors Calculus II | 4 |
| (4) One of the following courses (4 credits): | |
| LB 220 Calculus III | 4 |
| MTH 234 Multivariable Calculus | 4 |
| MTH 254H Honors Multivariable Calculus | 4 |
| (5) One of the following courses (3 credits): | |
| MTH 235 Differential Equations | 3 |
| MTH 340 Ordinary Differential Equations I | 3 |
| MTH 347H Honors Ordinary Differential Equations | 3 |
| (6) One of the following groups of courses (8 or 10 credits): | |
| (a) 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) PHY 191 Physics Laboratory for Scientists I | 1 |
| PHY 192 Physics Laboratory for Scientists II | 1 |
| PHY 193H Honors Physics I – Mechanics | 4 |
| PHY 294H Honors Physics II – Electromagnetism | 4 |
| (c) LB 273 Physics I | 4 |
| LB 274 Physics II | 4 |
| (d) PHY 173 Studio Physics for Scientists and Engineers I/5 | |
| PHY 174 Studio Physics for Scientists and Engineers II | 5 |
| (7) The following course (3 credits): | |
| BMB 461 Advanced Biochemistry I | 3 |

b. The following courses in the Department of Chemistry: (46 or 47 credits)

- | | |
|---|---|
| (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 |
| (c) LB 171 Principles of Chemistry I | 4 |
| LB 172 Principles of Chemistry II | 3 |
| (2) One of the following groups of courses (5 credits): | |
| (a) CEM 161 Chemistry Laboratory I | 1 |
| CEM 162 Chemistry Laboratory II | 1 |
| CEM 262 Quantitative Analysis | 3 |
| (b) CEM 185H Honors Chemistry Laboratory I | 2 |
| CEM 262 Quantitative Analysis | 3 |
| (c) CEM 262 Quantitative Analysis | 3 |
| LB 171L Introductory Chemistry Laboratory I | 1 |
| LB 172L Principles of Chemistry II - Reactivity Laboratory | 1 |

(3) All of the following courses (31 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 395 Analytical/Physical Chemistry Laboratory	2
CEM 411 Advanced Inorganic Chemistry	4
CEM 434 Advanced Analytical Chemistry	3
CEM 435 Analytical Chemistry Laboratory	3
CEM 444 Chemistry Safety	1
CEM 483 Quantum Chemistry	3
CEM 484 Molecular Thermodynamics	3
CEM 495 Molecular Spectroscopy	2

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

CEM 415 Advanced Synthesis Laboratory	3
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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 while pursuing programs in prehealth, prelaw, or education, 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 writers, technical librarians, technical sales personnel, and patent lawyers. 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 425. Those courses are referenced in item 3. b. (5) 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 Chemistry: (21 to 27 credits)

- | | |
|---|---|
| (1) One of the following courses (3 to 5 credits): | |
| BS 161 Cell and Molecular Biology | 3 |
| BS 162 Organismal and Population Biology | 3 |
| BS 181H Honors Cell and Molecular Biology | 3 |
| BS 182H Honors Organismal and Population Biology | 3 |
| ENT 205 Pests, Society and Environment | 3 |
| IBIO 150 Integrating Biology: From DNA to Populations | 3 |
| LB 144 Biology I: Organismal Biology | 4 |
| LB 145 Biology II: Cellular and Molecular Biology | 5 |
| MMG 141 Introductory Human Genetics | 3 |
| MMG 201 Fundamentals to Microbiology | 3 |
| PLB 105 Plant Biology | 3 |
| PSL 250 Introductory Physiology | 4 |
| (2) One of the following courses (3 or 4 credits): | |
| LB 118 Calculus I | 4 |
| MTH 132 Calculus I | 3 |
| MTH 152H Honors Calculus I | 3 |

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- (3) One of the following courses (4 credits):
- | | | |
|----------|--------------------|---|
| LB 119 | Calculus II | 4 |
| MTH 133 | Calculus II | 4 |
| MTH 153H | Honors Calculus II | 4 |
- (4) One of the following groups of courses (8 or 10 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 |
| | PHY 191 | Physics Laboratory for Scientists I | 1 |
| | PHY 192 | Physics Laboratory for Scientists II | 1 |
| (c) | LB 273 | Physics I | 4 |
| | LB 274 | Physics II | 4 |
| (d) | PHY 173 | Studio Physics for Scientists and Engineers I | 5 |
| | PHY 174 | Studio Physics for Scientists and Engineers II | 5 |
| (e) | PHY 221 | Studio Physics for Life Scientists I | 4 |
| | PHY 222 | Studio Physics for Life Scientists II | 4 |
- (5) One of the following courses (3 or 4 credits):
- | | | |
|---------|----------------------------|---|
| BMB 401 | Comprehensive Biochemistry | 4 |
| BMB 461 | Advanced Biochemistry I | 3 |
- b. The following courses in the Department of Chemistry: (36 or 37 credits)
- (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 |
| (d) | LB 171 | Principles of Chemistry I | 4 |
| | LB 172 | Principles of Chemistry II | 3 |
- (2) One of the following groups of courses (5 credits):
- | | | | |
|-----|----------|--|---|
| (a) | CEM 161 | Chemistry Laboratory I | 1 |
| | CEM 162 | Chemistry Laboratory II | 1 |
| | CEM 262 | Quantitative Analysis | 3 |
| (b) | CEM 185H | Honors Chemistry Laboratory I | 2 |
| | CEM 262 | Quantitative Analysis | 3 |
| (c) | CEM 262 | Quantitative Analysis | 3 |
| | LB 171L | Introductory Chemistry Laboratory I | 1 |
| | LB 172L | Principles of Chemistry II - Reactivity Laboratory | 1 |
- (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 (2 credits):
- | | | |
|---------|--------------------------------|---|
| CEM 255 | Organic Chemistry Laboratory | 2 |
| CEM 355 | Organic Chemistry Laboratory I | 2 |
- (5) All of the following courses (13 credits):
- | | | |
|---------|--|---|
| CEM 333 | Instrumental Methods and Applications | 3 |
| CEM 383 | Introductory Physical Chemistry I | 3 |
| CEM 384 | Introductory Physical Chemistry II | 3 |
| CEM 425 | Chemistry Communication and Professional Development (W) | 3 |
| CEM 444 | Chemical Safety | 1 |
- (6) The following capstone course (3 credits):
- | | | |
|---------|---------------------|---|
| CEM 311 | Inorganic 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 or physical chemistry.

A detailed description of this program may be obtained from 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 two enrollments of Chemistry 499. That course is referenced in item 3. b. (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.

3. The following requirements for the major:

CREDITS

a. The following courses outside the Department of Chemistry: (51 to 60 credits)

(1) One of the following courses (3 to 5 credits):

BS 161	Cell and Molecular Biology	3
BS 162	Organismal and Population Biology	3
BS 181H	Honors Cell and Molecular Biology	3
BS 182H	Honors Organismal and Population Biology	3
ENT 205	Pests, Society and Environment	3
IBIO 150	Integrating Biology: From DNA to Populations	3
LB 144	Biology I: Organismal Biology	4
LB 145	Biology II: Cellular and Molecular Biology	5
MMG 141	Introductory Human Genetics	3
MMG 201	Fundamentals of Microbiology	3
PLB 105	Plant Biology	3
PSL 250	Introductory Physiology	4

(2) The following courses (4 credits):

CMSE201	Computational Modeling and Data Analysis I	4
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(3) One of the following courses (3 or 4 credits):

LB 118	Calculus I	4
MTH 132	Calculus I	3
MTH 152H	Honors Calculus I	3

(4) One of the following courses (4 credits):

LB 119	Calculus II	4
MTH 133	Calculus II	4
MTH 153H	Honors Calculus II	4

(5) One of the following courses (4 credits):

LB 220	Calculus III	4
MTH 234	Multivariable Calculus	4
MTH 254H	Honors Multivariable Calculus	4

(6) One of the following courses (3 credits):

MTH 235	Differential Equations	3
MTH 340	Ordinary Differential Equations I	3
MTH 347H	Honors Ordinary Differential Equations	3

(7) One of the following sets of courses (4 to 7 credits):

(a)	MTH 299	Transitions	4
	MTH 309	Linear Algebra I	3
(b)	MTH 299	Transitions	4
	MTH 314	Matrix Algebra with Computational Applications	3
(c)	MTH 317H	Honors Linear Algebra	4

(8) One of the following courses (3 credits):

MTH 310	Abstract Algebra I and Number Theory	3
MTH 320	Analysis I	3
MTH 327H	Honors Introduction to Analysis	3
MTH 415	Applied Linear Algebra	3
MTH 418H	Honors Algebra I	3
MTH 441	Ordinary Differential Equations II	3
MTH 442	Partial Differential Equations	3
MTH 451	Numerical Analysis I	3

(9) One of the following groups of courses (8 or 10 credits):

(a)	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)	PHY 191	Physics Laboratory for Scientists I	1
	PHY 192	Physics Laboratory for Scientists II	1

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	PHY 193H Honors Physics I–Mechanics	3
	PHY 294H Honors Physics II–Electromagnetism	3
(c)	LB 273 Physics I	4
	LB 274 Physics II	4
(d)	PHY 173 Studio Physics for Scientists and Engineers I	5
	PHY 174 Studio Physics for Scientists and Engineers II	5
(10)	All of the following courses (12 credits):	
	PHY 215 Thermodynamics and Modern Physics	3
	PHY 321 Classical Mechanics I	3
	PHY 471 Quantum Physics I	3
	PHY 481 Electricity and Magnetism I	3
(11)	One of the following courses (3 or 4 credits):	
	PHY 410 Thermal and Statistical Physics	3
	PHY 415 Methods of Theoretical Physics	4
	PHY 422 Classical Mechanics II	3
	PHY 431 Optics I	3
	PHY 472 Quantum Physics II	3
	PHY 480 Computational Physics	3
	PHY 482 Electricity and Magnetism II	3
	PHY 491 Introduction to Condensed Matter Physics	3
	PHY 492 Introduction to Nuclear Physics	3
	PHY 493 Introduction to Elementary Particle Physics	3
b.	The following courses in the Department of Chemistry:	
	(29 to 31 credits)	
(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
(c)	LB 171 Principles of Chemistry I	4
	LB 172 Principles of Chemistry II	3
(2)	One of the following groups of courses (5 credits):	
(a)	CEM 161 Chemistry Laboratory I	1
	CEM 162 Chemistry Laboratory II	1
	CEM 262 Quantitative Analysis	3
(b)	CEM 185H Honors Chemistry Laboratory	2
	CEM 262 Quantitative Analysis	3
(c)	CEM 262 Quantitative Analysis	3
	LB 171L Introductory Chemistry Laboratory I	1
	LB 172L Principles of Chemistry II - Reactivity Laboratory	1
(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 (2 or 3 credits):	
	CEM 333 Instrumental Methods and Applications	3
	CEM 395 Analytical/Physical Laboratory	2
	CEM 495 Molecular Spectroscopy	3
(5)	All of the following courses (7 credits):	
	CEM 444 Chemical Safety	1
	CEM 483 Quantum Chemistry	3
	CEM 484 Molecular Thermodynamics	3
(6)	The following capstone course (2 credits):	
	CEM 499 Chemical Physics Seminar	2
	The completion of Chemistry 499 fulfills the department's capstone course requirement. Two enrollments in Chemistry 499 are required, 1 credit per enrollment.	

TEACHER CERTIFICATION OPTIONS

The chemistry disciplinary major leading to the Bachelor of Science degree is 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

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

CHEMICAL PHYSICS

Doctor of Philosophy

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

Admission

Only those persons who are enrolled in a Doctor of Philosophy degree program in the Department of Chemistry or the Department of Physics and Astronomy at Michigan State University 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, chemical education, 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. 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, chemical education, inorganic, organic and physical. 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.

Requirements for the Doctor of Philosophy Degree in Chemistry

1. Complete a minimum of one year of teaching requirement.
2. Complete a minimum of 12 to 18 credits of 800-900 level courses through a minimum of 6 courses. Credits earned in requirements 3. and 4. may not be used to fulfill this requirement.
3. Complete the following courses (2 credits):
CEM 890 Chemical Problems and Reports 1 (section 1 Faculty Seminar)
CEM 890 Chemical Problems and Reports 1 (section 2 Second Year Oral)
4. Complete 2 credits of seminar course work from one of the following areas: Analytical, Inorganic, Nuclear, Organic, or Physical to demonstrate research preparedness and as a defense of the dissertation. The student's course work must be planned and approved by their academic advisor.
5. 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.
6. Complete at least 24 credits and no more than 36 credits of CEM 999 Doctoral Dissertation Research.
7. All students must complete Responsible Conduct of Research Training – <https://grad.msu.edu/recr>
8. Additional details on applicable course work can be found in the CEM graduate handbook at www.chemistry.msu.edu.

DEPARTMENT of COMPUTATIONAL MATHEMATICS, SCIENCE and ENGINEERING

Edward Brown, Chairperson

Computational Mathematics, Science and Engineering is the multidisciplinary field concerned with using advanced computing to solve complex problems pertaining to computational modeling and data science. Areas of interest include the development and analysis of algorithms, high performance computing, including both parallel computing and heterogeneous architectures, and the application of both algorithms and high-performance computing to modeling and data analysis, exploration, and visualization. The department offers a wide range of courses in computational and data science. Graduates will use their skills in large-scale computing and data science to address a wide variety of problems in science, engineering, and other fields.

The Department of Computational Mathematics, Science and Engineering is administered jointly by the colleges of Natural Science and Engineering.

UNDERGRADUATE PROGRAMS

DATA SCIENCE

The Bachelor of Science degree in Data Science provides students with a strong background in data science using a broad range of computational techniques, practice in statistical thinking, as well as in-depth exposure to topics in data science. Students in the program participate in a wide range of cutting-edge courses to develop mastery of modern data science tools and techniques allowing them to manipulate, visualize, and extract meaning from complex datasets. Students in the program have the opportunity to align their degree with their personal interests and career goals through individual selection of upper-level course work.

Requirements for the Bachelor of Science Degree in Data Science

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 Data Science.
The University's Tier II writing requirement for the Data Science major is met by completing Computational Mathematics, Science and Engineering 495, referenced in item 3. below.
2. The requirements of the College of Natural Science for the Bachelor of Science degree.
3. The following requirements for the major:

		CREDITS
a. One course from each of the following groups (8 or 10 credits):		
(1)	CEM 141 General Chemistry	4
	CEM 151 General and Descriptive Chemistry	4
	CEM 181H Honors Chemistry I	4
	LB 171 Principles of Chemistry I	4
(2)	CEM 142 General and Inorganic Chemistry	3
	CEM 152 Principles of Chemistry	3
	CEM 182H Honors Chemistry II	4

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	LB 172 Principles of Chemistry II	3
(3)	CEM 161 Chemistry Laboratory I	1
	CEM 185H Honors Chemistry Laboratory I	2
	LB 171L Introductory Chemistry Laboratory I	1
b.	One course from each of the following groups (8 or 10 credits):	
(1)	LB 273 Physics I	4
	PHY 173 Studio Physics for Scientists and Engineers I	5
	PHY 183 Physics for Scientists and Engineers I	4
(2)	LB 274 Physics II	4
	PHY 174 Studio Physics for Scientists and Engineers II	5
	PHY 184 Physics for Scientists and Engineers II	4
c.	One course from each of the following groups (14 or 15 credits):	
(1)	LB 118 Calculus I	4
	MTH 132 Calculus I	3
	MTH 152H Honors Calculus I	3
(2)	LB 119 Calculus II	4
	MTH 133 Calculus II	4
	MTH 153H Honors Calculus II	4
(3)	LB 220 Calculus III	4
	MTH 234 Multivariable Calculus	4
	MTH 254H Honors Multivariable Calculus	4
(4)	MTH 314 Matrix Algebra with Computational Applications	3
d.	One of the following groups (4 or 6 credits):	
(1)	STT 380 Probability and Statistics for Data Science	4
(2)	STT 441 Probability and Statistics I: Probability	3
	STT 442 Probability and Statistics I: Statistics	3
e.	All of the following courses (31 credits):	
	CMSE 201 Introduction to Computational Modeling and Data Analysis	4
	CMSE 202 Computational Modeling Tools and Techniques	4
	CMSE 381 Fundamentals of Data Science Methods	4
	CMSE 382 Optimization Methods in Data Science	4
	CMSE 495 Experiential Learning in Data Science	4
	CSE 232 Introduction to Programming II	4
	CSE 331 Algorithms and Data Structures	3
	STT 180 Introduction to Data Science	4
f.	A minimum of 12 credits of approved 400-level courses or above. The following courses are eligible to fulfill this requirement. Other may be substituted with advisor approval.	
	CMSE 401 Methods for Parallel Computing	4
	CMSE 402 Data Visualization Principles and Techniques	3
	CMSE 410 Computational Biology and Bioinformatics	3
	CMSE 411 Computational Medicine	3
	CMSE 492 Special Topics in Data Science	1 to 4
	CSE 402 Biometrics and Pattern Recognition	3
	CSE 404 Introduction to Machine Learning	3
	CSE 440 Introduction to Artificial Intelligence	3
	CSE 480 Database Systems	3
	CSE 482 Big Data Analysis	3
	MTH 468 Predictive Analytics	3
	STT 464 Statistics for Biologists	3
	STT 465 Bayesian Statistical Methods	3
	A maximum of 12 credits may count towards the degree for enrollments in CMSE 492 with advisor approval.	

MINOR IN COMPUTATIONAL MATHEMATICS, SCIENCE, AND ENGINEERING

The Minor in Computational Mathematics, Science, and Engineering complements a student's major by providing a strong background in computational modeling of a variety of systems using a broad range of computational techniques, functional and object-oriented computer programming, practice in computational thinking, as well as in-depth exposure to some subset of discipline-focused or methodology-focused topics in computational and/or data science.

The minor is available as an elective to students who are enrolled in bachelor's degree programs at Michigan State University with the exception of the Bachelor of Science Degree in Data Science and the Bachelor of Science Degree

in Computational Data Science. With the approval of the department and college that administer the student's degree program, the courses that are used to satisfy the minor may also be used to satisfy the requirements for the bachelor's degree.

Students who plan to complete the requirements of the minor should consult the undergraduate advisor in the Department of Computational Mathematics, Science and Engineering.

Requirements for the Minor in Computational Mathematics, Science, and Engineering

	CREDITS
Complete 17 credits from the following:	
1. Both of the following courses (8 credits):	
CMSE 201 Computational Modeling and Data Analysis I	4
CMSE 202 Computational Modeling and Data Analysis II	4
2. Complete a minimum of 9 credits from the following courses:	
CMSE 401 Methods for Parallel Computing	4
CMSE 402 Visualization of Scientific Datasets	3
CMSE 410 Bioinformatics and Computational Biology	3
CMSE 411 Computational Medicine	3
CSE 232 Introduction to Programming II	4
CSE 404 Introduction to Machine Learning	3
CSE 415 Introduction to Parallel Computing	3
CSE 482 Big Data Analysis	3
MTH 314 Matrix Algebra with Computational Applications	3
MTH 451 Numerical Analysis I	3
MTH 452 Numerical Analysis II	3
PHY 480 Computational Physics	3
PLB 400 Introduction to Bioinformatics	3
STT 461 Computations in Probability and Statistics	3
STT 465 Bayesian Statistical Methods	3
Additional courses may be used with approval of the program advisor including additional CMSE 300-400 level courses. Courses outside of CMSE with a strong focus on the applications of computational methods or on discipline-related computational techniques will be considered.	

MINOR IN DATA SCIENCE

The Minor in Data Science, which is administered by the Department of Computational Mathematics, Science and Engineering, provides students with a strong background in data science using a broad range of computational techniques, practice in statistical thinking, as well as in-depth exposure to topics in data science.

The minor is available as an elective to students enrolled in bachelor's degree programs at Michigan State University with the exception of the Bachelor of Science degree in Data Science and the Bachelor of Science Degree in Computational Data Science. With the approval of the department and college that administer the student's degree program, the courses that are used to satisfy the minor may also be used to satisfy the requirements for the bachelor's degree.

Students who plan to apply to the program should consult the undergraduate advisor in the Department of Computational Mathematics, Science and Engineering.

Requirements for the Minor in Data Science

Complete a minimum of 23 credits from the following:	CREDITS
1. All of the following courses (19 credits):	
CMSE 201 Introduction to Computational Modeling and Data Analysis	4
CMSE 202 Computational Modeling Tools and Techniques	4
CMSE 381 Fundamentals of Data Science Methods	4
MTH 314 Matrix Algebra with Computational Applications	3
STT 180 Introduction to Data Science	4

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2. One of the following groups (4 or 6 credits):
- | | | |
|------------|---|---|
| a. STT 380 | Probability and Statistics for Data Science | 4 |
| b. STT 441 | Probability and Statistics I: Probability | 3 |
| STT 442 | Probability and Statistics I: Statistics | 3 |

GRADUATE STUDY

The Department of Computational Mathematics, Science and Engineering offers the programs listed below:

Master of Science

Computational Mathematics, Science and Engineering

Doctor of Philosophy

Computational Mathematics, Science and Engineering

Graduate Certificates

Computational Modeling

High-Performance Computing

Study for the department's graduate degree programs is administered by the College of Engineering.

DEPARTMENT of EARTH and ENVIRONMENTAL SCIENCES

Jeffrey Freymueller, Chairperson

Earth and Environmental Sciences (EES) aim to understand planets as an integrated system of physical, biological, and chemical processes and materials that shape our past, present, and future. We work together to study how these geological and environmental processes transform planets over timescales ranging from milliseconds to billions of years and length scales from atoms to solar systems, producing the landscapes, hazards, resources, and environments we encounter today. This knowledge is critical for the stewardship of our planet and understanding Earth's origin and co-evolution with life as an inhabited world.

Earth and Environmental Sciences apply interdisciplinary concepts from biology, chemistry, physics, math, and computational sciences to study the Earth and planets. In addition to supporting curriculum across science and engineering, EES courses supply knowledge and tools relevant to a wide variety of careers in industry, stewardship, and research. Our curriculum provides a foundation in geological and environmental sciences, and allows students to explore a broad range of subdisciplines. This multidisciplinary curriculum provides a unique perspective on issues that impact communities in Michigan and around the globe such as the availability of natural resources, assessment and response to environmental hazards, and the influence of humans on Earth systems. Our goal is to prepare graduates to lead the way in shaping decisions concerning the stewardship of our planet.

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 Geological Sciences 401. 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. The following courses outside the Department of Earth and Environmental Sciences:
- (35 to 38 credits)
- | | | |
|-----|---|---|
| (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 groups of courses (7 credits): | |
| (a) | CEM 141 General Chemistry I | 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 courses (3 or 4 credits): | |
| | MTH 234 Multivariable Calculus | 4 |
| | STT 200 Statistical Methods | 3 |
| | STT 201 Statistical Methods | 4 |
| | STT 231 Statistics for Scientists | 3 |
| | STT 421 Statistics I | 3 |
| (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 |
| (5) | One of the following courses (3 or 4 credits): | |
| | FW 472 Limnology | 3 |
| | GEO 203 Introduction to Meteorology | 3 |
| | IBIO 303 Oceanography | 4 |
| (6) | One of the following courses (3 or 4 credits): | |
| | GEO 324 Remote Sensing of the Environment | 4 |
| | GEO 325 Geographic Information Systems | 3 |
| | STT 464 Statistics for Biologists | 3 |
| (7) | One of the following courses (3 credits): | |
| | GEO 435 Geography of Health and Disease | 3 |
| | IBIO 355 Ecology | 3 |
- b. The following courses in the Department of Earth and Environmental Sciences (31 credits):
- | | | |
|---------|--|---|
| GLG 201 | The Dynamic Earth | 4 |
| GLG 304 | Physical and Biological History of the Earth | 4 |
| GLG 321 | Mineralogy and Geochemistry | 4 |
| GLG 401 | Global Tectonics and Earth Structure (W) | 4 |
| GLG 411 | Hydrogeology 3 | |
| GLG 412 | Glacial Geology and the Record of Climate Change | 4 |
| GLG 421 | Environmental Geochemistry | 4 |
| GLG 431 | Sedimentology and Stratigraphy (W) | 4 |
- The completion of GLG 401 satisfies the department's capstone course requirement.

COLLEGE OF NATURAL SCIENCE

- c. One course from each of the following areas (9 or 10 credits):

Hydrogeology Component

CE 421	Engineering Hydrology	3
FW 454	Environmental Hydrology for Watershed Management	3
GEO 306	Environmental Geomorphology	3
GLG 481	Reservoirs and Aquifers	3

Geochemical Component

CEM 251	Organic Chemistry I	3
CEM 311	Inorganic Chemistry	3
CEM 383	Introductory Physical Chemistry I	3
CSS 455	Pollutants in the Soil Environment	3
ENE 481	Environmental Chemistry - Equilibrium Concepts	3
GLG 361	Igneous and Metamorphic Geochemistry and Petrology	4

Geobiological Component

ENE 487	Microbiology for Environmental Science and Engineering	3
FW 420	Stream Ecology	3
GLG 433	Vertebrate Paleontology	4
GLG 434	Evolutionary Paleontology	4
GLG 435	Geomicrobiology	4
IBIO 355	Ecology	3
MMG 425	Microbial Ecology	3

Students may not use IBIO 355 to count towards this requirement if used to fulfill requirement 3. a. (7).

- d. Additional credits in Geological Science courses at the 300-400 level to total 40 credits. 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 these requirements.

Plant Biology 335 and Microbiology and Molecular Genetics 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.

Concentration in Geophysics

A concentration in geophysics is also available. Students must complete all of the following courses. Courses that are used to satisfy the requirements for the concentration may also be used to satisfy the requirements for the Bachelor of Science degree in Environmental Geosciences. The concentration will be noted on the student's transcript.

	CREDITS
GLG 470 Principles of Modern Geophysics	3
GLG 471 Applied Geophysics	4
MTH 234 Multivariable Calculus	4
MTH 235 Differential Equations	3
PHY 183 Physics for Scientists and Engineers I	4
PHY 184 Physics for Scientists and Engineers II	4

GEOLOGICAL SCIENCES

Requirements for the Bachelor of Science Degree in Geological Sciences

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

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

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

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

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

- The following requirements for the major:

CREDITS

- The following courses outside the Department of Earth and Environmental Sciences:
(26 or 27 credits)

- All of the following courses (8 credits):

CEM 161	Chemistry Laboratory I	1
MTH 132	Calculus I	3
MTH 133	Calculus II	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

- 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.	

- 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

- The following courses in the Department of Earth and Environmental Sciences (40 credits):

GLG 201	The Dynamic Earth	4
GLG 304	Physical and Biological History of the Earth	4
GLG 321	Mineralogy and Geochemistry	4
GLG 361	Petrology	4
GLG 401	Global Tectonics and Earth Structure (W)	4
GLG 431	Sedimentology and Stratigraphy	4
GLG 491	Field Geology – Summer Camp (W)	6

Ten additional credits in Geological Sciences courses at the 300-400 level. Plant Biology 335 and Microbiology and Molecular Genetics 426 may be used to satisfy either the requirements for the major or the requirements referenced under the heading Graduation Requirements in the College statement, but not both of those requirements. The credits that are used to satisfy this requirement may be used to satisfy either the requirements for the geological sciences major or the requirements for the environmental geosciences major, but not both of those requirements.

The completion of Geological Sciences 491 fulfills the department's capstone course requirement.

Concentration in Geophysics

A concentration in geophysics is also available. Students must complete all of the following courses. Courses that are used to satisfy the requirements for the concentration may also be used to satisfy the requirements for the Bachelor of Science degree in Geological Sciences. The concentration will be noted on the student's transcript.

	CREDITS
1. All of the following courses (22 credits):	
GLG 470 Principles of Modern Geophysics	3
GLG 471 Applied Geophysics	4
MTH 234 Multivariate 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

MINOR IN ENVIRONMENTAL SCIENCE

The Minor in Environmental Science, administered by the Department of Earth and Environmental Sciences, provides foundational training for students interested in environmental sciences. After a broad introductory course, it offers a menu of courses that focus on the biology/ecology, chemistry, and systems components of environmental science.

The Minor is available as an elective to students outside of the Department of Earth and Environmental Sciences enrolled in bachelor's degree programs at Michigan State University. With the approval of the department and college that administer the student's degree program, the courses that are used to satisfy the Minor may also be used to satisfy the requirements for the bachelor's degree. However, at least 6 credits counted towards the requirements for this Minor must be unique. Unique credits must not be used to fulfill another

COLLEGE OF NATURAL SCIENCE

university, college, or major requirement in the student's program.

Students who plan to complete the requirements for the Minor should consult the undergraduate advisor in the Department of Earth and Environmental Sciences.

Requirements for the Minor in Environmental Science

CREDITS

Students must complete a minimum of 15 credits, with at least 10 credits in GLG:

1. One of the following courses (4 credits):
 - GLG 200 Introduction to Environmental Science and Global Change 4
 - GLG 201 Introduction to Earth and Planetary Sciences 4
2. One of the following environmental biology and ecology courses (3 or 4 credits):
 - FOR 340 Forest Ecology 3
 - FW 410 Upland Ecology and Management 3
 - FW 416 Marine Ecology and Management 3
 - FW 417 Wetland Ecology and Management 3
 - FW 420 Stream Ecology 3
 - GLG 304 Physical and Biological History of the Earth 4
 - GLG 435 Geomicrobiology (W) 4
 - GLG 446 Ecosystems Modeling, Water and Food Security 3
 - IBIO 355 Ecology 3
3. One of the following environmental chemistry courses (4 credits):
 - GLG 321 Mineralogy and Geochemistry 4
 - GLG 421 Environmental Geochemistry 4
4. One of the following environmental systems courses (3 or 4 credits):
 - GEO 306 Environmental Geomorphology 3
 - GLG 303 Oceanography 4
 - GLG 330 Biogeochemistry 3
 - GLG 380 Natural Resources, the Energy Transition and the Environment 3
 - GLG 411 Hydrogeology 3
 - GLG 412 Glacial Geology and the Record of Climate Change 4
 - GLG 431 Sedimentology and Stratigraphy 4

MINOR IN GEOPHYSICS

The Minor in Geophysics, administered by the Department of Earth and Environmental Sciences, provides interdisciplinary training for students interested in applying physical properties of the Earth and Earth materials to planetary and environmental problems.

The minor is available as an elective to students enrolled in bachelor's degree programs at Michigan State University. With the approval of the department and college that administer the student's degree program, the courses that are used to satisfy the minor may also be used to satisfy the requirements for the bachelor's degree. However, at least 6 credits counted towards the requirements for this minor must be unique. Unique credits must not be used to fulfill another university, college, or major requirement in the student's program.

Students who plan to complete the requirements for the minor should consult the undergraduate advisor in the Department of Earth and Environmental Sciences.

Requirements for the Minor in Geophysics

CREDITS

Students must complete a minimum of 27 credits from the following:

1. All of the following courses (12 credits):
 - MTH 234 Multivariate Calculus 4
 - PHY 183 Physics for Scientists and Engineers I 4
 - PHY 184 Physics for Scientists and Engineers II 4
2. One of the following courses (3 or 4 credits):
 - CMSE202 Computational Modeling and Data Analysis II 4
 - MTH 235 Differential Equations 3
 - MTH 314 Matrix Algebra with Computational Applications 3
3. One of the following courses (3 or 4 credits):
 - GLG 201 Introduction to Earth and Planetary Sciences 4

- GLG 203 Geology of the Great Lakes Region 3
- 4. Three of the following courses (9 to 12 credits):
 - GLG 411 Hydrogeology 3
 - GLG 445 Planetary Science 3
 - GLG 470 Solid Earth Geophysics and Geodynamics 3
 - GLG 471 Applied Geophysics 4

TEACHER CERTIFICATION OPTIONS

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

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

Students who elect the earth science—interdepartmental disciplinary major or the earth science disciplinary minor must contact the Department of Earth and Environmental 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 Earth and Environmental Sciences offers programs in environmental geosciences and in geological sciences leading to the Master of Science degree. The department also offers a program in earth and environmental sciences leading to the Doctor of Philosophy degree.

The goal of the graduate programs in the Department of Earth and Environmental Sciences is to develop creative and productive scientists who can develop skills to 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 over time scales ranging from seconds to billions of years.

Areas of active research in the department include experimental mineralogy, geochemistry, geocognition, geodynamics, geomicrobiology, geophysics, hydrology, hydrogeology, land use sustainability, mineral/water interactions, evolutionary paleobiology, petrology, seismology, and tectonics.

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.

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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 Michigan State University, 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:

CREDITS

Requirements for Both Plan A and Plan B

1. Tier I requirements (10 to 12 credits):
 - a. General Component. The following course (1 credit):

GLG 423 Environmental Geosciences	1
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 - b. Soil Component. One of the following courses (3 or 4 credits):

CSS 455 Pollutants in the Soil Environment	3
CSS 825 Clay Mineralogy and Soils Genesis	4
CSS 855 Interfacial Environmental Chemistry	4
 - c. Chemical Component. One of the following courses (3 credits):

GLG 421 Environmental Geochemistry	3
GLG 821 Aqueous Geochemistry	3
GLG 823 Isotope Geochemistry	3
 - d. Hydrogeology Component. One of the following courses (3 or 4 credits):

CE 421 Engineering Hydrology	3
CE 821 Groundwater Hydraulics	3
GLG 411 Hydrogeology	4
2. Tier II requirement. One of the following courses (3 or 4 credits):

GEO 408 Soil Geomorphology Field Study	4
GLG 412 Glacial and Quaternary Geology	3
GLG 422 Organic Geochemistry	3
GLG 471 Applied Geophysics	4
GLG 481 Reservoirs and Aquifers	4
GLG 822 Analytical Applications for Biogeochemical Research	3
GLG 863 Mineral-Water Interactions	4

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

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

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

Additional Requirements for Plan A

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

Additional Requirements for Plan B

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

Doctor of Philosophy

The core of the Doctor of Philosophy degree program in earth and environmental 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 environmental 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 earth and environmental sciences on the basis of their performance during the previous two years of academic work. Satisfactory scores on the GRE General Test are required.

Requirements for the Doctor of Philosophy Degree in Earth and Environmental Sciences

The program of study is determined by mutual agreement between the student and the guidance committee. The student must complete, or have completed prior to admission, 9 credits of course work in earth and environmental sciences and at least 3 credits in 800-level course work. Students must also complete 24 credits of doctoral dissertation research by enrollment in GLG 999.

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.

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GEOLOGICAL SCIENCES

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 Michigan State University, 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.

DEPARTMENT of INTEGRATIVE BIOLOGY

Kevin John McGraw, Chairperson

The Department of Integrative Biology is focused on understanding how complex biological systems evolve, develop, function, interact and respond to environmental change. The systems we study span the tree of life at all levels of biological organization, ranging from molecules to entire ecosystems. We use cutting-edge tools to address questions about genetics, development, physiology, behavior, ecology and evolution in a wide array of "natural" and model systems. Our research and teaching serves national needs related to sustainable biodiversity, ecosystem services, and human and animal welfare in a changing world.

The department's courses, concentrations and degrees span the scope of modern biology. We serve a range of undergraduate interests and prepare students to pursue careers in areas that include academic and non-academic research and teaching, medicine, dentistry, veterinary science and other health professions, biotechnology, environmental science, and animal management and welfare.

UNDERGRADUATE PROGRAMS

Four degree programs are offered: Bachelor of Science in Integrative Biology, Bachelor of Arts or Bachelor of Science in Zoology, and a Bachelor of Science in Environmental Biology/Zoology. Majors are expected to acquire broad background in the sciences fundamental to the understanding of modern zoology. General chemistry and mathematics are normally taken in the freshman year, organic chemistry in the sophomore year, and physics in the junior year. The Biological Science sequence (161/171, 162/172) should be started as soon as possible since these courses are prerequisite to further study in integrative biology. Course electives in integrative biology are to be chosen so that they furnish breath of zoological understanding in animal behavior, cell biology, comparative anatomy, developmental biology, ecology, environmental physiology, evolution, genetics, marine biology, neurobiology, organismal biology, and zoo and aquarium science. The department encourages and supports experiential learning through internships and independent study. These experiences must be approved in advance by an advisor.

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Normally no more than 8 credits of upper-level course work in classes such as directed studies, internship, independent study, study abroad, selected topics, or special topics from any department or college other than integrative biology may be counted as integrative biology electives towards any of the undergraduate degrees. Students may petition the Director of Undergraduate Studies in the department to exceed this 8-credit limit.

ENVIRONMENTAL BIOLOGY/ZOOLOGY

Bachelor of Science

The objective of the Bachelor of Science degree program with a major in environmental biology/zooology 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 integrative biology courses in the program emphasize ecology, systematics, and environmental science.

Students who are enrolled in this program may complete an optional capstone course: Integrative Biology 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 two of the following courses: Integrative Biology 355L and 445. Those courses are referenced in item 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. One of the following groups of courses (9 or 10 credits):	
(1) BS 161 Cell and Molecular Biology	3
BS 162 Organismal and Population Biology	3
BS 171 Cell and Molecular Biology Laboratory	2
BS 172 Organismal and Population Biology Laboratory	2
(2) BS 181H Honors Cell and Molecular Biology	3
BS 182H Honors Organismal and Population Biology	3
BS 191H Honors Cell and Molecular Biology Laboratory	2
BS 192H Honors Organismal and Population Biology Laboratory	2
(3) LB 144 Biology I: Organismal Biology	4
LB 145 Biology II: Cellular and Molecular Biology	5
b. One of the following groups of courses (5 or 6 credits):	
(1) CEM 141 General Chemistry	4
CEM 161 Chemistry Laboratory I	1
(2) CEM 181H Honors Chemistry I	4
CEM 185H Honors Chemistry Laboratory I	2
(3) LB 171 Principles of Chemistry I	4
LB 171L Introductory Chemistry I Laboratory	1
c. One course from each of the following groups of courses (6 credits):	
(1) CEM 251 Organic Chemistry I	3
CEM 351 Organic Chemistry I	3
(2) CEM 252 Organic Chemistry II	3
CEM 352 Organic Chemistry II	3

(3) CEM 255 Organic Chemistry Laboratory	2
CEM 355 Organic Laboratory I	2
d. One of the following groups of courses (8 or 10 credits):	
(1) PHY 221 Studio Physics for Life Scientists I	4
PHY 222 Studio Physics for Life Scientists II	4
(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
(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
(4) LB 273 Physics I	4
LB 274 Physics II	4
(5) PHY 193H Honors Physics I-Mechanics	4
PHY 294H Honors Physics II-Electromagnetism	4
PHY 191 Physics Laboratory for Scientists, I	1
PHY 192 Physics Laboratory for Scientists, II	1
e. One of the following courses (3 or 4 credits):	
MTH 124 Survey of Calculus I	3
MTH 132 Calculus I	3
MTH 152H Honors Calculus I	3
LB 118 Calculus I	4
f. One of the following courses (3 or 4 credits):	
MTH 126 Survey of Calculus II	3
MTH 133 Calculus II	4
MTH 153H Honors Calculus II	3
LB 119 Calculus II	4
STT 201 Statistical Methods	4
STT 224 Introduction to Probability and Statistics for Ecologists	3
STT 231 Statistics for Scientists	3
STT 421 Statistics I	3
g. All of the following courses (21 credits):	
CSS 210 Fundamentals of Soil Science	3
GEO 221 Introduction to Geographic Information	3
GEO 221L Introduction to Geographic Information Laboratory	1
IBIO 341 Fundamental Genetics	4
IBIO 355 Ecology 3	
IBIO 355L Ecology Laboratory (W)	1
IBIO 445 Evolution (W)	3
PLB 441 Plant Ecology	3
Both Geography 221 and 221L must be completed to satisfy this requirement. Forestry 419 may be substituted for GEO 221/221L. Forestry 340 may be substituted for Plant Biology 441.	
h. At least one course from each of the following three groups of courses totaling at least 13 credits:	
(1) FW 471 Ichthyology	4
IBIO 306 Invertebrate Biology	4
IBIO 328 Comparative Anatomy and Biology of Vertebrates	4
IBIO 360 Biology of Birds	4
IBIO 365 Biology of Mammals	4
IBIO 384 Biology of Amphibians and Reptiles (W)	4
(2) PLB 218 Plants of Michigan	3
PLB 418 Plant Systematics	3
(3) FW 416 Marine Ecology and Management	3
FW 420 Stream Ecology	3
FW 444 Conservation Biology	3
FW 472 Limnology	3
GEO 324 Remote Sensing of the Environment	4
IBIO 353 Marine Biology (W)	4
IBIO 357 Global Change Biology (W)	3
IBIO 446 Environmental Issues and Public Policy	3
IBIO 483 Environmental Physiology	3
IBIO 485 Tropical Biology	3
PLB 424 Algal Biology	3

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INTEGRATIVE BIOLOGY

The Bachelor of Science degree in Integrative Biology provides students with an integrated foundation in biology and its underpinnings in chemistry, math, and physics. It prepares students for graduate and professional study and provide the skillsets necessary to enter the workforce.

Requirements for the Bachelor of Science Degree in Integrative 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 Integrative Biology.

The University's Tier II writing requirement for the Integrative Biology major is met by completing two of the following courses: Integrative Biology 355L and 445. Those courses are referenced in item 3. below. These courses may also fulfill requirements in items 3. g. and 3. h. 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 (9 or 10 credits):	
(1) BS 161 Cell and Molecular Biology	3
BS 162 Organismal and Population Biology	3
BS 171 Cell and Molecular Biology Laboratory	2
BS 172 Organismal and Population Biology Laboratory	2
(2) BS 181H Honors Cell and Molecular Biology	3
BS 182H Honors Organismal and Population Biology	3
BS 191H Honors Cell and Molecular Biology Laboratory	2
BS 192H Honors Organismal and Population Biology Laboratory	2
(3) LB 144 Biology I: Organismal Biology	4
LB 145 Biology II: Cellular and Molecular Biology	5
b. One of the following groups of courses (5 or 6 credits):	
(1) CEM 141 General Chemistry	4
CEM 161 Chemistry Laboratory I	1
(2) CEM 151 General and Descriptive Chemistry	4
CEM 161 Chemistry Laboratory	1
(3) CEM 181H Honors Chemistry I	4
CEM 185H Honors Chemistry Laboratory I	2
(4) LB 171 Principles of Chemistry I	4
LB 171L Introductory Chemistry Laboratory I	1
c. All of the following courses (10 credits):	
CEM 251 Organic Chemistry I	4
CEM 252 Organic Chemistry II	4
CEM 255 Organic Chemistry Laboratory	2
d. One of the following groups of courses (8 or 10 credits):	
(1) PHY 221 Studio Physics for Life Scientists I	4
PHY 222 Studio Physics for Life Scientists II	4
(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
(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
(4) LB 273 Physics I	4
LB 274 Physics II	4
(5) PHY 193H Honors Physics I – Mechanics	4
PHY 294H Honors Physics II – Electromagnetism	4
PHY 191 Physics Laboratory for Scientists, I	1
PHY 192 Physics Laboratory for Scientists, II	14
e. One of the following courses (3 or 4 credits):	
MTH 124 Survey of Calculus I	3
MTH 132 Calculus I	3

MTH 152H Honors Calculus I	3
LB 118 Calculus I	4
f. One of the following courses (3 or 4 credits):	
LB 119 Calculus II	4
MTH 126 Survey of Calculus II	3
MTH 133 Calculus II	4
MTH 153H Honors Calculus II	3
STT 201 Statistical Methods	4
STT 224 Introduction to Probability and Statistics for Ecologists	3
STT 231 Statistics for Scientists	3
STT 421 Statistics I	3
g. All of the following courses (14 credits):	
IBIO 341 Fundamental Genetics	4
IBIO 355 Ecology	3
IBIO 355L Ecology Laboratory (W)	1
IBIO 445 Evolution (W)	3
MGI 301 Introductory Microbiology	3
h. One of the following courses (4 credits):	
IBIO 306 Invertebrate Biology	4
IBIO 320 Developmental Biology	4
IBIO 328 Comparative Anatomy and Biology of Vertebrates (W)	4
i. One of the following courses (3 or 4 credits):	
IBIO 425 Cells and Development (W)	4
MGI 409 Eukaryotic Cell Biology	3
j. One of the following courses (3 or 4 credits):	
IBIO 483 Environmental Physiology (W)	3
PLB 301 Introductory Plant Physiology	3
PLB 415 Plant Physiology	3
PSL 310 Physiology for Pre-Health Professionals	4
PSL 431 Human Physiology I	4
k. One of the following options, either (1) or (2):	
(1) BMB 401 Comprehensive Biochemistry	4
(2) BMB 461 Advanced Biochemistry I	3
BMB 462 Advanced Biochemistry II	3
l. Experiential Requirement:	
In addition to courses taken to meet requirements g. and h., one course at the 300-level or above in laboratory bench work or field experience. This course may be chosen from Integrative Biology 306, 320, 328, 355L, 360, 365, 384, 390, 408, 425, 490, 494, 496; Animal Science 313; Fisheries and Wildlife 471; or Microbiology, Genetics, and Immunology 302. Other experiential courses may be chosen through consultation with the student's academic advisor.	
m. Additional credits in 300-400 level Integrative Biology courses as needed to meet the requirement of at least 33 credits. Students may complete more than one course, or pair of courses, from item 3. Additional courses completed from item 3. may be counted as Integrative Biology electives toward the 33 credits. Courses beyond those taken to satisfy item 3. may come from other departments with the approval of the student's academic advisor.	

ZOOLOGY

Bachelor of Arts

The Bachelor of Arts in Zoology degree is designed for students pursuing careers in scientific application areas such as public policy, technical sales, law, and communications. This degree combines study in zoology with a significant amount of course work outside the sciences. Students are strongly encouraged to extend their knowledge and skills through experiential opportunities and a supplemental minor.

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 both of the following courses: Integrative Biology 355L and 445. Those courses are referenced in item 3. 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

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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 groups of courses (9 or 10 credits):
 - (1) BS 161 Cell and Molecular Biology 3
 - BS 162 Organismal and Population Biology 3
 - BS 171 Cell and Molecular Biology Laboratory 2
 - BS 172 Organismal and Population Biology Laboratory 2
 - (2) BS 181H Honors Cell and Molecular Biology 3
 - BS 182H Honors Organismal and Population Biology 3
 - BS 191H Honors Cell and Molecular Biology Laboratory 2
 - BS 192H Honors Organismal and Population Biology Laboratory 2
 - (3) LB 144 Biology I: Organismal Biology 4
 - LB 145 Biology II: Cellular and Molecular Biology 5
- b. One of the following groups of courses (5 or 6 credits):
 - (1) CEM 141 General Chemistry 4
 - CEM 161 Chemistry Laboratory I 1
 - (2) CEM 181H Honors Chemistry I 4
 - CEM 185H Honors Chemistry Laboratory I 2
 - (3) LB 171 Principles of Chemistry I 4
 - LB 171L Introductory Chemistry Laboratory I 1
- c. Complete the following course (4 credits):

CEM 143 Survey of Organic Chemistry 4
- d. One of the following courses (3 or 4 credits):

PHY 183 Physics for Scientists and Engineers I 4

PHY 221 Studio Physics for Life Scientists I 4

PHY 231 Introductory Physics I 3

LB 273 Physics I 4

PHY 193H Honors Physics I-Mechanics 4
- e. One of the following courses (3 or 4 credits):

LB 118 Calculus I 4

MTH 124 Survey of Calculus I 3

MTH 132 Calculus I 3

MTH 152H Honors Calculus I 3
- f. One of the following courses (3 or 4 credits):

LB 119 Calculus II 4

MTH 126 Survey of Calculus II 3

MTH 133 Calculus II 4

MTH 153H Honors Calculus II 4

STT 201 Statistical Methods 4

STT 224 Introduction to Probability and Statistics for Ecologists 3

STT 231 Statistics for Scientists 3

STT 421 Statistics I 3
- g. All of the following courses (11 credits):

IBIO 341 Fundamental Genetics 4

IBIO 355 Ecology 3

IBIO 355L Ecology Laboratory (W) 1

IBIO 445 Evolution (W) 3
- h. Three additional courses in 300-400 level Integrative Biology courses. Students are encouraged to consult with their academic advisor to identify courses which match their career goals. Courses from other departments may be applied to this requirement with the approval of the student's academic advisor.
- i. Complete one course from each of the following three groups of courses (9 to 11 credits):
 - (1) **Writing** (3 credits):

CSUS 433 Grant Writing and Fund Development (W) 3

WRA 320 Technical Communication (W) 3

WRA 331 Writing in the Public Interest (W) 3

WRA 453 Grant and Proposal Writing 3
 - (2) **Communications** (3 or 4 credits):

COM 100 Human Communication 3

COM 225 An Introduction to Interpersonal Communication 3

COM 240 Introduction to Organizational Communication 4

COM 275 Effects of Mass Communication 3

COM 300 Methods of Communication Inquiry 4
 - (3) **Computer Systems** (3 or 4 credits):

CMSE201 Computational Modeling and Data Analysis I 4

CSE 231 Introduction to Programming I 3

- FW 419 Applications of Geographic Information Systems to Natural Resource Management 4
- GEO 221 Introduction to Geographic Information and 3
- GEO 221L Introduction to Geographic Information Laboratory 1
- GEO 324 Remote Sensing of the Environment 4
- GEO 325 Geographic Information Systems 3
- Both Geography 221 and 221L must be completed to satisfy this requirement.
- j. Six credits in 300-400 level courses offered by the Colleges of Arts and Letters or College of Social Science beyond the credits that are counted toward the University's Integrative Studies requirement. Credits from relevant courses completed from item 3.i. may be counted toward this requirement. Courses used to fulfill this requirement must be approved by the student's academic advisor.
 - k. Additional credits in 300-400 level Integrative Biology courses as needed to meet the requirement of at least 33 credits. Students also may complete more than one course, or pair of courses, from item 3.i. Additional courses completed from item 3.i. may be counted as Integrative Biology electives toward the 33 credits. Courses beyond those taken to satisfy item 3.i. may come from other departments with the approval of the student's academic advisor.

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. The degree contains core courses in biology, chemistry, physics, calculus and statistics. Students will complete a concentration encompassing several branches of modern zoology while allowing focused study in any one of those fields. Concentration options include: animal behavior and neurobiology; cell and developmental biology; ecology, evolution and organismal biology; general zoology; genetics; marine biology; or zoo and aquarium science.

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: Integrative Biology 355L and 445. Those courses are referenced in item 3. below. These courses also fulfill requirements in concentrations 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 (9 or 10 credits):
 - (1) BS 161 Cell and Molecular Biology 3
 - BS 162 Organismal and Population Biology 3
 - BS 171 Cell and Molecular Biology Laboratory 2
 - BS 172 Organismal and Population Biology Laboratory 2
 - (2) BS 181H Honors Cell and Molecular Biology 3
 - BS 182H Honors Organismal and Population Biology 3
 - BS 191H Honors Cell and Molecular Biology Laboratory 2
 - BS 192H Honors Organismal and Population Biology Laboratory 2
 - (3) LB 144 Biology I: Organismal Biology 4
 - LB 145 Biology II: Cellular and Molecular Biology 5

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b. One of the following groups of courses (5 or 6 credits):

(1)	CEM 141 General Chemistry	4
	CEM 161 Chemistry Laboratory I	1
(2)	CEM181H Honors Chemistry I	4
	CEM185H Honors Chemistry Laboratory I	2
(3)	LB 171 Principles of Chemistry I	4
	LB 171L Introductory Chemistry Laboratory I	1

c. One course from each of the following groups (8 credits):

(1)	CEM 251 Organic Chemistry I	3
	CEM 351 Organic Chemistry I	3
(2)	CEM 252 Organic Chemistry II	3
	CEM 352 Organic Chemistry II	3
(3)	CEM 255 Organic Chemistry Laboratory	2
	CEM 355 Organic Laboratory I	2

d. One of the following groups of courses (8 or 10 credits):

(1)	PHY 221 Studio Physics for Life Scientists I	4
	PHY 222 Studio Physics for Life Scientists II	4
(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
(3)	PHY 183 Physics for Scientists and Engineers I	4
	PHY 184 Physics for Scientists and Engineers II	4
(4)	LB 273 Physics I	4
	LB 274 Physics II	4
(5)	PHY 193H Honors Physics I-Mechanics	4
	PHY 294H Honors Physics II-Electromagnetism	4
	PHY 191 Physics Laboratory for Scientists, I	1
	PHY 192 Physics Laboratory for Scientists, II	1

e. One of the following courses (3 or 4 credits):

LB 118	Calculus I	4
MTH 124	Survey of Calculus I	3
MTH 132	Calculus I	3
MTH 152H	Honors Calculus I	3

f. One of the following courses (3 or 4 credits):

LB 119	Calculus II	4
MTH 126	Survey of Calculus II	3
MTH 133	Calculus II 4	3
MTH 153H	Honors Calculus II	4
STT 201	Statistical Methods	4
STT 224	Introduction to Probability and Statistics for Ecologists	3
STT 231	Statistics for Scientists	3
STT 421	Statistics I	3

g. One of the following concentrations:

Animal Behavior and Neurobiology

(1)	All of the following courses (17 credits):	
	IBIO 313 Animal Behavior	3
	IBIO 341 Fundamental Genetics	4
	IBIO 355 Ecology	3
	IBIO 355L Ecology Laboratory (W)	1
	IBIO 415 Ecological Aspects of Animal Behavior (W)	3
	IBIO 445 Evolution (W)	3
(2)	One of the following courses (3 credits):	
	IBIO 300 Neurobiology	3
	IBIO 405 Neural Basis of Animal Behavior	3
(3)	One of the following, either (a) or (b) (4 or 8 credits):	
	(a) One of the following courses (4 credits):	
	IBIO 328 Comparative Anatomy and Biology of Vertebrates	4
	IBIO 306 Invertebrate Biology	4
	(b) Two of the following courses (8 credits):	
	FW 471 Ichthyology	4
	IBIO 360 Biology of Birds	4
	IBIO 365 Biology of Mammals	4
	IBIO 384 Biology of Amphibians and Reptiles (W)	4
(4)	One of the following courses (3 or 4 credits):	
	ANS 305 Applied Animal Behavior	3
	ANS 455 Avian Physiology	4
	FW 364 Ecological Problem Solving	3
	FOR 419 Applications of Geographic Information Systems to Natural Resource Management	4
	GEO 221 Introduction to Geographic Information and	3
	GEO 221L Introduction to Geographic Information Laboratory	1
	IBIO 320 Developmental Biology	4
	IBIO 483 Environmental Physiology	3
	LIN 463 Introduction to Cognitive Science	3
	NEU 310 Psychology and Biology of Human Sexuality	3

NEU 416	Development of the Nervous System Through the Lifespan	3
PSY 301	Cognitive Neuroscience	3
PSY 409	Psychobiology of Behavioral Development (W)	3
PSY 411	Hormones and Behavior (W)	3
PSY 413	Laboratory in Behavioral Neuroscience (W)	4
SOC 412	Animals, People and Nature	3

Both GEO 221 and 221L must be completed to satisfy this requirement.

(5) Additional credits in 300-400 level Integrative Biology courses as needed to meet the requirement of at least 33 credits. Students may complete more than one course, or pair of courses, from items (2), (3) or (4). Additional courses completed from items (2), (3) or (4) may be counted as Zoology electives toward the 33 credits. Courses beyond those taken to satisfy items (1), (2), (3) or (4) may come from other departments with the approval of the student's academic advisor.

Ecology, Evolution, and Organismal Biology

(1)	All of the following courses (11 credits):	
	IBIO 341 Fundamental Genetics	4
	IBIO 355 Ecology	3
	IBIO 355L Ecology Laboratory (W)	1
	IBIO 445 Evolution (W)	3
(2)	Two of the following courses (8 credits):	
	FW 471 Ichthyology	4
	IBIO 306 Invertebrate Biology	4
	IBIO 328 Comparative Anatomy and Biology of Vertebrates	4
	IBIO 360 Biology of Birds	4
	IBIO 365 Biology of Mammals	4
	IBIO 384 Biology of Amphibians and Reptiles (W)	4
(3)	One of the following courses (3 or 4 credits):	
	IBIO 313 Animal Behavior	3
	IBIO 357 Global Change Biology (W)	3
	IBIO 483 Environmental Physiology	3
	IBIO 485 Tropical Biology	3
(4)	One of the following courses, or pair of courses (3 or 4 credits):	
	FW 419 Applications of Geographic Information Systems to Natural Resource Management	4
	GEO 221 Introduction to Geographic Information and	3
	GEO 221L Introduction Geographic Information Laboratory	1
	GLG 434 Evolutionary Paleobiology	4
	IBIO 446 Environmental Issues and Public Policy	3
	PLB 418 Plant Systematics	3

Both GEO 221 and 221L must be completed to satisfy this requirement.

(5) Additional credits in 300-400 level Integrative Biology courses as needed to meet the requirement of at least 33 credits. Students may complete more than one course, or pair of courses, from items (2), (3), or (4). Additional courses completed from items (2), (3), or (4) may be counted as Integrative Biology electives toward the 33 credits. Courses beyond those taken to satisfy items (1), (2), (3), or (4) may come from other departments with the approval of the student's academic advisor.

Marine Biology

(1)	All of the following courses (21 credits):	
	GLG 303 Oceanography	3
	IBIO 341 Fundamental Genetics	4
	IBIO 353 Marine Biology (W)	4
	IBIO 355 Ecology	3
	IBIO 355L Ecology Laboratory (W)	1
	IBIO 445 Evolution (W)	3
	IBIO 483 Environmental Physiology	3
(2)	One course from each of the following groups of courses (7 or 8 credits):	
	(a) FW 471 Ichthyology	4
	IBIO 306 Invertebrate Biology	4
	IBIO 360 Biology of Birds	4
	IBIO 365 Biology of Mammals	4
	IBIO 384 Biology of Amphibians and Reptiles (W)	4
	(b) BMB 401 Comprehensive Biochemistry	4
	CEM 383 Introductory Physical Chemistry I	3
	FW 416 Marine Ecology and Management	3
	FW 424 Wildlife Population Analysis and Management	3
	GEO 221 Introduction to Geographic Information and	3
	GEO 221L Introduction Geographic Information Laboratory	1
	IBIO 357 Global Change Biology (W)	3
	MGI 425 Microbial Ecology	3

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Both GEO 221 and 221L must be completed to satisfy this requirement.

- (3) A minimum of at least 1 credit must be completed in an aquatic biology field experience. Through consultation with their academic advisor, students may determine an appropriate aquatic biology field experience or choose one of the following courses (3 or 4 credits):

PLB 424 Algal Biology	3
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 Courses not listed above must have the approval of the student's academic advisor.
- (4) Additional credits in 300-400 level Integrative Biology courses as needed to meet the requirement of at least 33 credits. Students may complete more than one course, or pair of courses, from item (2). Additional courses completed from item (2) may be counted as Zoology electives toward the 33 credits. Courses beyond those taken to satisfy items (1), (2), or (3) may come from other departments with the approval of the student's academic advisor.

Zoo and Aquarium Science

- (1) All of the following courses (25 credits):

IBIO 313 Animal Behavior	3
IBIO 341 Fundamental Genetics	4
IBIO 355 Ecology	3
IBIO 355L Ecology Laboratory (W)	1
IBIO 368 Zoo Animal Biology and Conservation	3
IBIO 369 Introduction to Zoo and Aquarium Science	3
IBIO 445 Evolution (W)	3
IBIO 489 Seminar in Zoo and Aquarium Science	1
IBIO 498 Internship in Zoo and Aquarium Science	4
- (2) Two of the following courses (8 credits):

FW 471 Ichthyology	4
IBIO 306 Invertebrate Biology	4
IBIO 328 Comparative Anatomy and Biology of Vertebrates	4
IBIO 360 Biology of Birds	4
IBIO 365 Biology of Mammals	4
IBIO 384 Biology of Amphibians and Reptiles (W)	4
- (3) Three additional courses of at least 3 credits selected from a list of approved courses that is available from the Department of Integrative Biology.
- (4) Integrative Biology courses that are not listed above must be approved in advance by the student's academic advisor. Courses offered by other departments may be substituted if approved in advance by the student's academic advisor.

GRADUATE STUDY

The Department of Integrative Biology offers Master of Science and Doctor of Philosophy degree programs in integrative biology. Research areas and opportunities are aligned with faculty research programs at the forefronts of the research areas outlined above. Students interested in graduate study should visit the department website for additional information about these opportunities and how to pursue them.

Students who are enrolled in master's or doctoral degree programs in the Department of Integrative Biology 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 Integrative Biology.

INTEGRATIVE BIOLOGY

The graduate degree programs in integrative biology are designed for students who seek a career in education and research in the biological sciences, and/or application of biological knowledge in the private and public sectors. The objectives of the programs are to train the next generation of

scientists in integrative biology who will tackle some of the major issues of our time including the responses of biological systems to environmental variation and change. The programs provide students with a broad knowledge of the field through courses and seminars and prepare students for independent and original research in one of the various specialized subdisciplines of integrative biology. Faculty and staff work on a wide range of biological systems and emphasize the integration and synthesis of information from various levels of biological organization, from molecules to ecosystems. Areas of active research include genetics, cellular and developmental biology, systematics, paleontology, comparative morphology, physiology, behavior, and ecology and evolutionary biology.

Faculty research interests are available from the department Web site. Interested students are also encouraged to contact the Graduate Program Director 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 integrative biology 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; one year each of chemistry, mathematics, and one semester of college physics. Approval of the department is also 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).

CREDITS

Requirements for Both Plan A and Plan B

1. Complete 3 credits of course work at the 800-level or above in biology chosen in consultation with the student's guidance committee.

Additional Requirements for Plan A

1. Completion of 4 credits of IBIO 899 Master's Thesis Research.
2. Although there is no departmental language requirement, a Guidance Committee may prescribe a language requirement for a particular graduate student.
3. Completion of a final oral examination.
4. Successful defense of the master's research.

Additional Requirements for Plan B

1. Completion of 3 credits of IBIO 890 Special Problems which usually consists of a research project carried out either in a laboratory or the library.
2. Completion of a final oral examination formulated and administered by the student's Guidance Committee. It is the student's responsibility to contact the members of the committee concerning the content of the oral examination.

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Requirements for the Doctor of Philosophy Degree in Integrative Biology

The student's program of study must be developed in cooperation with and approved by the student's guidance committee and must include the requirements specified below:

1. Complete at least 6 credits in two 800-level courses in biology.
2. A minimum of 4 semesters of at least one-half time of supervised teaching, research, or other university service. The specific requirements are to be determined by the student's guidance committee. Students should expect to complete all Ph.D. requirements in no more than 5 years.
3. Complete 24 credits of IBIO 999 Doctoral Dissertation Research.
4. Successful completion of the comprehensive examination, taken no later than the end of the first semester of the second calendar year after completing the master's degree or the end of the first semester of the third calendar year from the time of the student's first enrollment at MSU, if they did not enter with a master's and is working directly toward the doctoral degree.
5. Successfully defend the doctoral dissertation.

W. K. KELLOGG BIOLOGICAL STATION

The W. K. Kellogg Biological Station is administered jointly by the College of Agriculture and Natural Resources and the College of Natural Science. 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 65 miles southwest of East Lansing near Battle Creek and Kalamazoo, the Biological Station's 3,352 acres encompass the Kellogg Bird Sanctuary, Kellogg Farm and Dairy Center, Academic Center and Research Laboratories, and Lux Arbor Reserve. Within this multiple-land use facility, a unique community of scholars conducts research and leads educational programs to increase our understanding of natural and managed ecosystems and their linkage to society.

The teaching and research programs of the Biological Station are closely coordinated with those of the College of Agriculture and Natural Resources and the College of Natural Science. The programs focus on the study of natural and managed ecosystems and 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 and research experience 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 researchers from MSU and other institutions are encouraged throughout the year.

Information concerning the instructional program and research opportunities may be obtained by contacting the Academic Programs Coordinator at kbssummer@kbs.msu.edu or by writing to KBS Academic Programs, 3700 E. Gull Lake Drive, Hickory Corners, Michigan 49060-9516.

DEPARTMENT of MATHEMATICS

Jeffrey Schenker, Chairperson

Mathematics, the identification and classification of structure in the world around us, is vital to all branches of knowledge and all human endeavors. The richness of mathematical structures inspires study both for their intrinsic beauty and for their ability to describe our world. The department offers a wide variety of courses that range from extensions of high school mathematics to the very frontiers of mathematical knowledge.

The department packages its courses into flexible programs that can adapt to many different career paths. Students with an interest in mathematics are encouraged, regardless of their preferred major, to contact the Department of Mathematics prior to registration to discuss course options. Students may benefit from advanced placement, participation in Honors courses designed to prepare motivated students for graduate study, or from pursuit of a degree in Actuarial Science.

UNDERGRADUATE PROGRAMS

The Department of Mathematics offers degree opportunities leading to a Bachelor of Arts or a Bachelor of Science in Mathematics, a Bachelor of Arts or a Bachelor of Science, Mathematics, Advanced, a Bachelor of Science in Mathematics-Secondary Education, a Bachelor of Science in Computational Mathematics, and a Bachelor of Science in Actuarial Science. The Bachelor of Arts degree programs require a higher level of foreign language competency, while the Bachelor of Science degree programs require science proficiency beyond that established by the college.

Graduates with the Bachelor of Art and Bachelor of Science degrees find a wide range of career options in industry and teaching fields. The Bachelor of Arts and Bachelor of Science programs prepare students for continuing study in top graduate schools or for the pursuit of careers in mathematically intensive fields. The Bachelor of Science in Mathematics-Secondary Education prepares students teach mathematics at the secondary level. The Bachelor of Science in Computational Mathematics prepares students for either for

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graduate study or for careers that rely upon computational models and tools.

Students with a Bachelor of Science degree in Actuarial Science are sought after by insurance companies, banks, investment firms, government agencies, and businesses that weigh the financial consequences of risk. Course work prepares students for the Society of Actuaries examinations as well as the Validation by Educational Experience course work necessary to become an Associate of the Society of Actuaries.

A Minor in Mathematics and a Minor in Actuarial Science are also available.

ACTUARIAL SCIENCE

Requirements for the Bachelor of Science Degree in Actuarial Science

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 Actuarial Science.

The University's Tier II writing requirement for the Actuarial Science major is met by completing Mathematics 309 or 496. Those courses are referenced in item 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. One course of at least 3 credits in biological science, entomology, microbiology, physiology, plant biology, or integrative biology.

- b. One of the following groups of courses (8 or 10 credits):

(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
(3)	CEM 181H	Honors Chemistry I	4
	CEM 182H	Honors Chemistry II	4
	CEM 185H	Honors Chemistry Laboratory I	2
(4)	LB 171	Principles of Chemistry I	4
	LB 171L	Introductory Chemistry Laboratory I	1
	LB 172	Principles of Chemistry II	3

- c. One of the following groups of courses (8 or 10 credits):

(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	4
	PHY 294H	Honors Physics II – Electromagnetism	4
(3)	LB 273	Physics I	4
	LB 274	Physics II	4
(4)	PHY 173	Studio Physics for Scientists and Engineers I	5
	PHY 174	Studio Physics for Scientists and Engineers II	5

- d. One of the following groups of courses (7 or 8 credits):

(1)	MTH 132	Calculus I	3
	MTH 133	Calculus II	4
(2)	LB 118	Calculus I	4
	LB 119	Calculus II	4
(3)	MTH 152H	Honors Calculus I	3
	MTH 153H	Honors Calculus II	4

- e. One of the following courses (4 credits):

	LB 220	Calculus III	4
	MTH 234	Multivariable Calculus	4
	MTH 254H	Honors Multivariable Calculus	4

- f. One of the following courses (3 credits):

	MTH 235	Differential Equations	3
	MTH 340	Ordinary Differential Equations I	3

- g. One of the following courses (1 credit):

	MTH 490	Directed Studies	1
	MTH 491B	Teamwork Experience	1
h.	All of the following courses (24 credits):		
	MTH 309	Linear Algebra I	3
	MTH 360	Theory of Mathematical Interest	3
	MTH 361	Financial Mathematics for Actuaries I	3
	MTH 458	Financial Mathematics for Actuaries II	3
	STT 441	Probability and Statistics I: Probability	3
	STT 455	Actuarial Models I	3
	STT 456	Actuarial Models II	3
	STT 459	Construction and Evaluation of Actuarial Models	3
i.	One of the following courses (3 credits):		
	MTH 457	Introduction to Financial Mathematics	3
	STT 442	Probability and Statistics II: Statistics	3
j.	One of the following courses (3 credits):		
	MTH 491A	Actuarial Internship	3
	MTH 496	Capstone in Mathematics (W)	3
k.	All of the following courses (15 credits):		
	ACC 230	Survey of Accounting Concepts	3
	EC 201	Introduction to Microeconomics	3
	EC 202	Introduction to Macroeconomics	3
	FI 311	Financial Management	3
	FI 321	Theory of Investments	3
l.	One of the following courses (4 credits):		
	CSE 231	Introduction to Programming I	4
	CMSE 201	Computational Modeling and Data Analysis I	4
	STT 180	Introduction to Data Science	4

COMPUTATIONAL AND APPLIED MATHEMATICS

Requirements for the Bachelor of Science Degree in Computational and Applied 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 and Applied Mathematics.

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

Students who are 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

(a minimum of 28 credits):

(1)	One course of at least 3 credits in biological science, entomology, microbiology, physiology, plant biology, or integrative biology.			
(2)	One course from each of the following groups (8 or 10 credits):			
	(a)	CEM 141	General Chemistry	4
		CEM 151	General and Descriptive Chemistry	4
		CEM 181H	Honors Chemistry I	4
		LB 171	Principles of Chemistry I	4
	(b)	CEM 142	General and Inorganic Chemistry	3
		CEM 152	Principles of Chemistry	3
		CEM 182H	Honors Chemistry II	4
		LB 172	Principles of Chemistry II	3
	(c)	CEM 161	Chemistry Laboratory I	1
		CEM 185H	Honors Chemistry Laboratory	2
		LB 171L	Introductory Chemistry Laboratory I	1
(3)	One course from each of the following groups (8 or 10 credits):			
	(a)	PHY 183	Physics for Scientists and Engineers I	4
		LB 273	Physics I	4
		PHY 173	Studio Physics for Scientists and Engineers I	5
		PHY 193H	Honors Physics I - Mechanics	4
	(b)	LB 274	Physics II	4
		PHY 184	Physics for Scientists and Engineers I	4
		PHY 174	Physics II	5
		PHY 294H	Honors Physics II – Electromagnetism	4

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- (4) At least 1 credit in laboratory in biological science, chemistry, entomology, microbiology, physiology, plant biology, or integrative biology.
- (5) One of the following groups of courses (8 credits):
- (a) CSE 231 Introduction to Programming I 4
 - CSE 232 Introduction to Programming II 4
 - (b) CMSE201 Computational Modelling and Data Analysis I 4
 - CMSE202 Computational Modelling and Data Analysis II 4
- b. The following courses from the Department of Mathematics:
- (1) One course from each of the following groups (11 or 12 credits):
- (a) MTH 132 Calculus I 3
 - MTH 152H Honors Calculus I 3
 - LB 118 Calculus I 4
 - (b) MTH 133 Calculus II 4
 - MTH 153H Honors Calculus II 4
 - LB 119 Calculus II 4
 - (c) MTH 234 Multivariable Calculus 4
 - MTH 254H Honors Multivariable Calculus 4
 - LB 220 Calculus III 4
- (2) One of the following groups (4 or 7 credits):
- (a) MTH 299 Transitions 4
 - MTH 309 Linear Algebra I 3
 - (b) MTH 299 Transitions 4
 - MTH 314 Matrix Algebra with Computational 3
 - (c) MTH 317H Honors Linear Algebra 4
- (3) Completion of one of the following groups of courses (12 credits):
- (a) **Differential Equations and Numerical Methods**
 - (i) One of the following courses:
 - MTH 235 Differential Equations 3
 - MTH 340 Ordinary Differential Equations I 3
 - MTH 347H Honors Ordinary Differential Equations 3
 - (ii) One of the following courses:
 - MTH 320 Analysis I 3
 - MTH 327H Honors Introduction to Analysis 3
 - (iii) The following course:
 - MTH 451 Numerical Analysis I 3
 - (iv) One of the following courses:
 - MTH 441 Ordinary Differential Equations II 3
 - MTH 442 Partial Differential Equations 3
 - MTH 452 Numerical Analysis II 3
 - (b) **Probability and Discrete Mathematics**
 - (i) The following course:
 - STT 441 Probability and Statistics I: Probability 3
 - (ii) One of the following courses:
 - MTH 320 Analysis I 3
 - MTH 327H Honors Introduction to Analysis 3
 - (iii) Both of the following courses:
 - MTH 481 Discrete Mathematics I 3
 - MTH 482 Discrete Mathematics II 3
 - (c) **Applied Algebra and Discrete Mathematics**
 - (i) One of the following courses:
 - MTH 310 Abstract Algebra I and Number Theory 3
 - MTH 418H Honors Algebra I 3
 - (ii) All of the following courses:
 - MTH 416 Introduction to Algebraic Coding 3
 - MTH 481 Discrete Mathematics I 3
 - MTH 482 Discrete Mathematics II 3
 - (d) **Mathematical Machine Learning**
 - (i) One of the following courses:
 - MTH 320 Analysis I 3
 - MTH 327H Honors Introduction to Analysis 3
 - (ii) All of the following courses:
 - MTH 483 Mathematical Machine Learning 3
 - STT 441 Probability and Statistics I: Probability 3
 - STT 442 Probability and Statistics II: Statistics 3
- (4) Both of the following courses (6 credits):
- MTH 415 Applied Linear Algebra 3
 - MTH 496 Capstone in Mathematics (W) 3
- (5) Complete five elective courses from the following lists of electives with at least two from the **Mathematics Electives** list. All courses listed may only be used if not being used to meet a course requirement in requirement (3) above (15 to 20 credits):
- Mathematics Electives**
- MTH 310 Abstract Algebra 3
 - Or
 - MTH 418H Honors Algebra I 3
 - MTH 320 Analysis I 3
 - or
 - MTH 327H Honors Introduction to Analysis 3

- MTH 411 Abstract Algebra II 3
- or
- MTH 419H Honors Algebra II 3
- MTH 416 Introduction to Algebraic Coding 3
- MTH 417 Topics in Number Theory 3
- MTH 421 Analysis II 3
- or
- MTH 429H Honors Real Analysis 3
- MTH 425 Complex Analysis 3
- MTH 441 Ordinary Differential Equations II 3
- MTH 442 Partial Differential Equations 3
- MTH 451 Numerical Analysis I 3
- MTH 452 Numerical Analysis II 3
- MTH 457 Introduction to Financial Mathematics 3
- MTH 461 Metric and Topological Spaces 3
- MTH 481 Discrete Mathematics I 3
- MTH 482 Discrete Mathematics II 3
- MTH 483 Mathematical Machine Learning 3
- Other 400-level or above MTH courses approved by the Department of Mathematics.

Other Electives

Approval of the College of Engineering is required to enroll in all CSE or ECE courses listed.

- CMSE404 Introduction to Machine Learning 3
- CSE 402 Biometrics and Pattern Recognition 3
- CSE 404 Introduction to Machine Learning 3
- CSE 425 Introduction to Computer Security 3
- CSE 450 Translation of Programming Languages 3
- CSE 460 Computability and Formal Language Theory 3
- CSE 472 Computer Graphics 3
- CSE 482 Big Data Analysis 3
- ECE 305 Electromagnetic Fields and Waves I 4
- ECE 366 Introduction to Signal Processing 3
- ECE 405 Electromagnetic Fields and Waves II 4
- ECE 446 Biomedical Signal Processing 3
- ECE 447 Introduction to Biomedical Imaging 3
- ECE 449 Fundamentals of Acoustics 3
- ECE 457 Communication Systems 3
- PHY 410 Thermal and Statistical Physics 3
- PHY 415 Methods of Theoretical Physics 4
- PHY 422 Classical Mechanics II 3
- PHY 471 Quantum Physics I 3
- PHY 472 Quantum Physics II 3
- PHY 480 Computational Physics 3
- PHY 481 Electricity and Magnetism I 3
- PHY 482 Electricity and Magnetism II 3
- STT 381 Fundamentals of Data Science Methods 4
- STT 441 Probability and Statistics I: Probability 3
- STT 442 Probability and Statistics II: Statistics 3
- STT 455 Actuarial Models I 3
- STT 461 Computations in Probability and Statistics 3
- STT 465 Bayesian Statistical Methods 3
- Other 400-level or above courses approved by the Department of Mathematics.

Requirements for the Bachelor of Arts Degree in Computational and Applied Mathematics

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

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

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

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

CREDITS

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a. The following courses outside the Department of Mathematics

(a minimum of 27 credits):

- (1) One course of at least 3 credits in biological science, entomology, microbiology, physiology, plant biology, or integrative biology.
- (2) One of the following courses (4 credits):

CEM 141	General Chemistry	4
CEM 151	General and Descriptive Chemistry	4
LB 171	Principles of Chemistry I	4
CEM 181H	Honors Chemistry I	4
- (3) One of the following courses (4 or 5 credits):

PHY 183	Physics for Scientists and Engineers I	4
LB 273	Physics I	4
PHY 173	Studio Physics for Scientists and Engineers I	5
PHY 193H	Honors Physics I - Mechanics	4
- (4) At least 2 credits in laboratory in biological science, chemistry, entomology, microbiology, physiology, plant biology, or integrative biology.
- (5) A minimum of 6 credits beyond the university requirements in courses from the College of Arts and Letters or the College of Social Science approved by the student's academic advisor.
- (6) One of the following groups of courses (8 credits):
 - (a) CSE 231 Introduction to Programming I 4
CSE 232 Introduction to Programming II 4
 - (b) CMSE 201 Computational Modelling and Data Analysis I 4
CMSE 202 Computational Modelling and Data Analysis II 4

b. The following courses from the Department of Mathematics:

- (1) One course from each of the following groups (11 or 12 credits):
 - (a) MTH 132 Calculus I 3
MTH 152H Honors Calculus I 3
LB 118 Calculus I 4
 - (b) MTH 133 Calculus II 4
MTH 153H Honors Calculus II 4
LB 119 Calculus II 4
 - (c) MTH 234 Multivariable Calculus 4
MTH 254H Honors Multivariable Calculus 4
LB 220 Calculus III 4
- (2) One of the following groups (4 or 7 credits):
 - (a) MTH 299 Transitions 4
MTH 309 Linear Algebra I 3
 - (b) MTH 299 Transitions 4
MTH 314 Matrix Algebra with Computational 3
 - (c) MTH 317H Honors Linear Algebra 4
- (3) Completion of one of the following groups of courses (12 credits):
 - (a) **Differential Equations and Numerical Methods**
 - (i) One of the following courses:

MTH 235	Differential Equations	3
MTH 340	Ordinary Differential Equations I	3
MTH 347H	Honors Ordinary Differential Equations	3
 - (ii) One of the following courses:

MTH 320	Analysis I	3
MTH 327H	Honors Introduction to Analysis	3
 - (iii) The following course:

MTH 451	Numerical Analysis I	3
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 - (iv) One of the following courses:

MTH 441	Ordinary Differential Equations II	3
MTH 442	Partial Differential Equations	3
MTH 452	Numerical Analysis II	3
 - (b) **Probability and Discrete Mathematics**
 - (i) The following course:

STT 441	Probability and Statistics I: Probability	3
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 - (ii) One of the following courses:

MTH 320	Analysis I	3
MTH 327H	Honors Introduction to Analysis	3
 - (iii) Both of the following courses:

MTH 481	Discrete Mathematics I	3
MTH 482	Discrete Mathematics II	3
 - (c) **Applied Algebra and Discrete Mathematics**
 - (i) One of the following courses:

MTH 310	Abstract Algebra I and Number Theory	3
MTH 418H	Honors Algebra I	3
 - (ii) All of the following courses:

MTH 416	Introduction to Algebraic Coding	3
MTH 481	Discrete Mathematics I	3
MTH 482	Discrete Mathematics II	3
 - (d) **Mathematical Machine Learning**
 - (i) One of the following courses:

MTH 320	Analysis I	3
MTH 327H	Honors Introduction to Analysis	3
 - (ii) All of the following courses:

MTH 483	Mathematical Machine Learning	3
STT 441	Probability and Statistics I: Probability	3
STT 442	Probability and Statistics II: Statistics	3

- (4) Both of the following courses (6 credits):

MTH 415	Applied Linear Algebra	3
MTH 496	Capstone in Mathematics (W)	3
- (5) Complete five elective courses from the following lists of electives with at least two from the **Mathematics Electives** list. All courses listed may only be used if not being used to meet a course requirement in requirement (3) above (15 to 20 credits):

Mathematics Electives

MTH 310	Abstract Algebra	3
Or		
MTH 418H	Honors Algebra I	3
MTH 320	Analysis I	3
or		
MTH 327H	Honors Introduction to Analysis	3
MTH 411	Abstract Algebra II	3
or		
MTH 419H	Honors Algebra II	3
MTH 416	Introduction to Algebraic Coding	3
MTH 417	Topics in Number Theory	3
MTH 421	Analysis II	3
or		
MTH 429H	Honors Real Analysis	3
MTH 425	Complex Analysis	3
MTH 441	Ordinary Differential Equations II	3
MTH 442	Partial Differential Equations	3
MTH 451	Numerical Analysis I	3
MTH 452	Numerical Analysis II	3
MTH 457	Introduction to Financial Mathematics	
MTH 461	Metric and Topological Spaces	3
MTH 481	Discrete Mathematics I	3
MTH 482	Discrete Mathematics II	3
MTH 483	Mathematical Machine Learning	3
Other 400-level or above MTH courses approved by the Department of Mathematics.		

Other Electives

Approval of the College of Engineering is required to enroll in all CSE or ECE courses listed.

CMSE404	Introduction to Machine Learning	3
CSE 402	Biometrics and Pattern Recognition	3
CSE 404	Introduction to Machine Learning	3
CSE 425	Introduction to Computer Security	3
CSE 450	Translation of Programming Languages	3
CSE 460	Computability and Formal Language Theory	3
CSE 472	Computer Graphics	3
CSE 482	Big Data Analysis	3
ECE 305	Electromagnetic Fields and Waves I	4
ECE 366	Introduction to Signal Processing	3
ECE 405	Electromagnetic Fields and Waves II	4
ECE 446	Biomedical Signal Processing	3
ECE 447	Introduction to Biomedical Imaging	3
ECE 449	Fundamentals of Acoustics	3
ECE 457	Communication Systems	3
PHY 410	Thermal and Statistical Physics	3
PHY 415	Methods of Theoretical Physics	4
PHY 422	Classical Mechanics II	3
PHY 471	Quantum Physics I	3
PHY 472	Quantum Physics II	3
PHY 480	Computational Physics	3
PHY 481	Electricity and Magnetism I	3
PHY 482	Electricity and Magnetism II	3
STT 381	Fundamentals of Data Science Methods	4
STT 441	Probability and Statistics I: Probability	3
STT 442	Probability and Statistics II: Statistics	3
STT 455	Actuarial Models I	3
STT 461	Computations in Probability and Statistics	3
STT 465	Bayesian Statistical Methods	3

Other 400-level or above courses approved by the Department of Mathematics.

COLLEGE OF NATURAL SCIENCE

MATHEMATICS

Requirements for the Bachelor of Science Degree in Mathematics

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

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

(21 to 23 credits)

- (1) One course of at least 3 credits in biological science, entomology, microbiology, physiology, plant biology, or integrative biology.
- (2) At least 2 credits in laboratory in biological science, chemistry, entomology, microbiology, physics, physiology, plant biology, or integrative biology.

- (3) One course from each of the following groups (8 or 10 credits):

- | | | | |
|-----|----------|-------------------------------------|---|
| (a) | CEM 141 | General Chemistry | 4 |
| | CEM 151 | General and Descriptive Chemistry | 4 |
| | CEM 181H | Honors Chemistry I | 4 |
| | LB 171 | Principles of Chemistry I | 4 |
| (b) | CEM 142 | General and Inorganic Chemistry | 3 |
| | CEM 152 | Principles of Chemistry | 3 |
| | CEM 182H | Honors Chemistry II | 4 |
| | LB 172 | Principles of Chemistry II | 3 |
| (c) | CEM 161 | Chemistry Laboratory I | 1 |
| | CEM 185H | Honors Chemistry Laboratory I | 2 |
| | LB 171L | Introductory Chemistry Laboratory I | 2 |

- (4) One of the following groups of courses (8 to 10 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 | 4 |
| | PHY 294H | Honors Physics II - Electromagnetism | 4 |
| (c) | LB 273 | Physics I | 4 |
| | LB 274 | Physics II | 4 |

- b. A total of 36 to 43 credits in courses in the Department of Mathematics including (36 to 43 credits):

- (1) One course from each of the following two groups (7 or 8 credits):

- | | | | |
|-----|----------|--------------------|---|
| (a) | MTH 132 | Calculus I | 3 |
| | MTH 152H | Honors Calculus | 3 |
| | LB 118 | Calculus I | 4 |
| (b) | MTH 133 | Calculus II | 4 |
| | MTH 153H | Honors Calculus II | 4 |
| | LB 119 | Calculus II | 4 |

- (2) One of the following courses (4 credits):

- | | | |
|----------|-------------------------------|---|
| MTH 234 | Multivariable Calculus | 4 |
| MTH 254H | Honors Multivariable Calculus | 4 |
| LB 220 | Calculus III | 4 |

- (3) One of the following two groups (4 or 7 credits):

- | | | | |
|-----|----------|-----------------------|---|
| (a) | MTH 299 | Transitions | 4 |
| | MTH 309 | Linear Algebra I | 3 |
| (b) | MTH 317H | Honors Linear Algebra | 4 |

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

- | | | |
|---------|-----------------------------|---|
| MTH 496 | Capstone in Mathematics (W) | 3 |
|---------|-----------------------------|---|
- The completion of Mathematics 496 fulfills the department's capstone course requirement.

- (5) A total of 27 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. One course from a list of approved cognates available in the Department of Mathematics may be used to satisfy this requirement. Statistics and Probability 351 or 430 or 441 may be substituted for one 300-level mathematics course. The 300-400 level courses as referenced in item 3. b. partially satisfy this requirement. Students with credit in MTH 235

prior to entering the Mathematics major, only need 24 credits to fulfill this requirement.

- | | | | |
|----------|---|------------------------------------|---|
| (6) | One of the following courses (3 credits): | | |
| MTH 310 | Abstract Algebra I and Number Theory | 3 | |
| MTH 418H | Honors Algebra I | 3 | |
| (5) | One of the following courses (3 credits): | | |
| MTH 320 | Analysis I | 3 | |
| MTH 327H | Honors Introduction to Analysis | 3 | |
| (8) | One of the following courses (3 credits): | | |
| MTH 330 | Higher Geometry | 3 | |
| MTH 340 | Ordinary Differential Equations I | 3 | |
| MTH 347H | Honors Ordinary Differential Equations | 3 | |
| MTH 432 | Axiomatic Geometry | 3 | |
| (9) | One course selected from two of the following groups (6 credits): | | |
| (a) | MTH 411 | Abstract Algebra II | 3 |
| | MTH 414 | Linear Algebra II | 3 |
| | MTH 416 | Introduction to Algebraic Coding | 3 |
| | MTH 417 | Topics in Number Theory | 3 |
| | MTH 419H | Honors Algebra II | 3 |
| (b) | MTH 421 | Analysis II | 3 |
| | MTH 425 | Complex Analysis | 3 |
| | MTH 428H | Honors Complex Analysis | 3 |
| | MTH 429H | Honors Real Analysis | 3 |
| | MTH 442 | Partial Differential Equations | 3 |
| (c) | MTH 441 | Ordinary Differential Equations II | 3 |
| | MTH 451 | Numerical Analysis I | 3 |
| | MTH 457 | Introduction to Financial Math | 3 |
| | MTH 461 | Metric and Topological Spaces | 3 |
| | MTH 481 | Discrete Mathematics I | 3 |

Students with credit in MTH 418H may not use MTH 411 to satisfy this requirement.

- c. One of the following courses (4 credits):

- | | | |
|----------|--|---|
| CMSE 201 | Computational Modeling and Data Analysis I | 4 |
| CSE 231 | Introduction to Programming I | 4 |

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 309 or 310 or 418H. Those courses are referenced in items 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 or 12 credits)

- (1) One course of at least 3 credits in biological science, entomology, microbiology, physiology, plant biology, or integrative biology.
- (2) At least 2 credits in laboratory in biological science, chemistry, entomology, microbiology, physics, physiology, plant biology, or integrative biology.

- (3) One of the following courses (4 or 5 credits):

- | | | |
|----------|--|---|
| LB 273 | Physics I | 4 |
| PHY 183 | Physics for Scientists and Engineers I | 4 |
| PHY 193H | Honors Physics I - Mechanics | 4 |

- (4) One of the following courses (4 credits):

- | | | |
|----------|-----------------------------------|---|
| CEM 141 | General Chemistry | 4 |
| CEM 151 | General and Descriptive Chemistry | 4 |
| CEM 181H | Honors Chemistry I | 4 |
| LB 171 | Principles of Chemistry I | 4 |

- (5) A minimum of 6 credits beyond the university requirements in courses from the College of Arts and Letters or the College of Social Science approved by the student's academic advisor.

- b. A total of 36 to 43 credits in courses in the Department of Mathematics including:

- (1) One course from each of the following two groups (6 to 8 credits):

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- (a) MTH 132 Calculus I 3
MTH 152H Honors Calculus 3
LB 118 Calculus I 4
- (b) MTH 133 Calculus II 4
MTH 153H Honors Calculus II 3
LB 119 Calculus II 4
- (2) One of the following courses (4 credits):
MTH 234 Multivariable Calculus 4
MTH 254H Honors Multivariable Calculus 4
LB 220 Calculus III 4
- (3) One of the following two groups (4 or 7 credits):
(a) MTH 299 Transitions 4
MTH 309 Linear Algebra I 3
(b) MTH 317H Honors Linear Algebra 4
- (4) The following course (3 credits):
MTH 496 Capstone in Mathematics (W) 3
The completion of Mathematics 496 fulfills the department's capstone course requirement.
- (5) A total of 27 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. Students may use no more than one of MTH 309, 314, 317H to satisfy this requirement. One course from a list of approved cognates available in the Department of Mathematics may be used to satisfy this requirement. Statistics and Probability 351 or 430 or 441 may be substituted for one 300-level mathematics course. The 300-400 level courses referenced in item 3. c. partially satisfy this requirement.
- (6) One of the following courses (3 credits):
MTH 310 Abstract Algebra I and Number Theory 3
MTH 418H Honors Algebra I 3
- (7) One of the following courses (3 credits):
MTH 320 Analysis I 3
MTH 327H Honors Introduction to Analysis 3
- (8) One of the following courses (3 credits):
MTH 330 Higher Geometry 3
MTH 340 Ordinary Differential Equations I 3
MTH 347H Honors Ordinary Differential Equations 3
MTH 432 Axiomatic Geometry 3
- (9) Two courses selected from two of the following three groups (6 credits):
(a) MTH 411 Abstract Algebra II 3
MTH 414 Linear Algebra II 3
MTH 416 Introduction to Algebraic Coding 3
MTH 417 Topics in Number Theory 3
MTH 419H Honors Algebra II 3
(b) MTH 421 Analysis II 3
MTH 425 Complex Analysis 3
MTH 428H Honors Complex Analysis 3
MTH 429H Honors Real Analysis 3
MTH 442 Partial Differential Equations 3
(c) MTH 441 Ordinary Differential Equations II 3
MTH 451 Numerical Analysis I 3
MTH 457 Introduction to Financial Mathematics 3
MTH 461 Metric and Topological Spaces 3
MTH 481 Discrete Mathematics I 3
Students with credit in 418H may not use MTH 411 to satisfy this requirement.
- c. One of the following courses (4 credits):
CSE 231 Introduction to Programming I 4
CMSE 201 Computational Modeling and Data Analysis I 4

MATHEMATICS, ADVANCED

Requirements for the Bachelor of Arts Degree in Mathematics, Advanced

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, Advanced.

The University's Tier II writing requirement for the Mathematics, Advanced major is met by completing Mathematics 418H and 496. Those courses are referenced in item 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 (13 or 14 credits):
(1) One of the following courses (3 or 4 credits):
BS 161 Cell and Molecular Biology 3
ENT 205 Pests, Society, and Environment 3
IBIO 150 Integrating Biology: From DNA to Populations 3
PLB 105 Plant Biology 3
PSL 250 Introductory Physiology 4
(2) One of the following courses (4 credits):
CEM 141 General Chemistry 4
CEM 151 General and Descriptive Chemistry 4
CEM 181H Honors Chemistry I 4
LB 171 Principles of Chemistry I 4
(3) One of the following courses (4 or 5 credits):
PHY 173 Studio Physics for Scientists and Engineers I 5
PHY 183 Physics for Scientists and Engineers I 4
PHY 193H Honors Physics I – Mechanics 4
LB 273 Physics I 4
(4) A minimum of 2 credits in laboratory courses in biological science, chemistry, entomology, microbiology, physics, physiology, plant biology, or integrative biology.
- b. A total of 34 to 37 credits in courses in the Department of Mathematics including:
(1) One of the following courses (3 or 4 credits):
MTH 132 Calculus I 3
MTH 152H Honors Calculus I 3
LB 118 Calculus I 4
(2) One of the following courses (4 credits):
MTH 133 Calculus II 4
MTH 153H Honors Calculus II 4
LB 119 Calculus II 4
(3) One of the following courses (4 credits):
MTH 234 Multivariable Calculus 4
MTH 254H Honors Multivariable Calculus 4
LB 220 Calculus III 4
(4) All of the following courses (22 credits):
MTH 317H Honors Linear Algebra 4
MTH 327H Honors Introduction to Analysis 3
MTH 347H Honors Ordinary Differential Equations 3
MTH 418H Honors Algebra I 3
MTH 419H Honors Algebra II 3
MTH 429H Honors Real Analysis 3
MTH 496 Capstone in Mathematics (W) 3
The completion of Mathematics 496 fulfills the department's capstone course requirement.
- c. A total of 15 credits in electives. Three of the courses (9 credits) are to be selected from any MTH course at the 800-level or above, or any course approved by the Mathematics Advanced program for satisfying this requirement, or any course from the following list:
MTH 416 Introduction to Algebraic Coding 3
MTH 417 Topics in Number Theory 3
MTH 425 Complex Analysis 3
MTH 441 Ordinary Differential Equations II 3
MTH 442 Partial Differential Equations 3
MTH 451 Numerical Analysis I 3
MTH 452 Numerical Analysis II 3
MTH 461 Metric and Topological Spaces 3
MTH 481 Discrete Mathematics I 3
MTH 482 Discrete Mathematics II 3
MTH 492H Undergraduate Thesis (W) 3
Two of the courses (6 credits) are to be selected from any MTH course at the 400 level or above (excluding MTH 411 and 421), or any course approved by the Mathematics Advanced program for satisfying this requirement, or any course from the following list:
CMSE820 Mathematical Foundations of Data Science 3
CMSE821 Numerical Methods for Differential Equations 3
CMSE823 Numerical Linear Algebra 3
CSE 425 Introduction to Computer Security 3
CSE 450 Translation of Programming Languages 3
CSE 460 Computability and Formal Language Theory 3
CSE 472 Computer Graphics 3
CSE 802 Pattern Recognition and Analysis 3
CSE 803 Computer Vision 3

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CSE 814	Computer Aided Verification	3
CSE 830	Design and Theory of Algorithms	3
CSE 835	Algorithmic Graph Theory	3
CSE 847	Machine Learning	3
CSE 860	Foundations of Computing	3
CSE 881	Data Mining	3
PHL 432	Logic and its Metatheory	4
PHY 410	Thermal and Statistical Physics	3
PHY 415	Methods of Theoretical Physics	4
PHY 422	Classical Mechanics II	3
PHY 471	Quantum Physics I	3
PHY 472	Quantum Physics II	3
PHY 480	Computational Physics	3
PHY 481	Electricity and Magnetism I	3
PHY 482	Electricity and Magnetism II	3
STT 861	Theory of Probability and Statistics I	3
STT 862	Theory of Probability and Statistics II	3
STT 881	Theory of Probability I	3
STT 882	Theory of Probability II	3
STT 886	Stochastic Processes and Applications	3

Requirements for the Bachelor of Science Degree in Mathematics, Advanced

- 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, Advanced.

The University's Tier II writing requirement for the Mathematics, Advanced major is met by completing Mathematics 418H and 496. Those courses are referenced in item 3. below.

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

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

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

- The following requirements for the major:

CREDITS

- The following courses outside the Department of Mathematics (20 to 25 credits):

- One of the following courses (3 or 4 credits):

BS 161	Cell and Molecular Biology	3
ENT 205	Pests, Society, and Environment	3
IBIO 150	Integrating Biology: From DNA to Populations	3
PLB 105	Plant Biology	3
PSL 250	Introductory Physiology	4
- One of the following groups of courses (8 or 10 credits):
 - CEM 141 General Chemistry 4
 - CEM 142 General and Inorganic Chemistry 3
 - CEM 161 Chemistry Laboratory I 1
 - CEM 151 General and Descriptive Chemistry 4
 - CEM 152 Principles of Chemistry 3
 - CEM 161 Chemistry Laboratory I 1
 - CEM 181H Honors Chemistry I 4
 - CEM 182H Honors Chemistry II 4
 - CEM 185H Honors Chemistry Laboratory I 2
 - LB 171 Principles of Chemistry I 4
 - LB 172 Principles of Chemistry II 3
 - LB 171L Introductory Chemistry Laboratory I 1
- One of the following groups of courses (8 or 10 credits):
 - PHY 183 Physics for Scientists and Engineers I 4
 - PHY 184 Physics for Scientists and Engineers II 4
 - PHY 193H Honors Physics I – Mechanics 4
 - PHY 294H Honors Physics II – Electromagnetism 4
 - PHY 173 Studio Physics for Scientists and Engineers I 5
 - PHY 174 Studio Physics for Scientists and Engineers II 5
 - LB 273 Physics I 4
 - LB 274 Physics II 4
- A minimum of 1 credit in laboratory courses in biological science, chemistry, entomology, microbiology, physics, physiology, plant biology, or integrative biology.

- A total of 34 to 37 credits in courses in the Department of Mathematics including:

- One of the following courses (3 or 4 credits):

MTH 132	Calculus I	3
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- | | | |
|----------|-------------------|---|
| MTH 152H | Honors Calculus I | 3 |
| LB 118 | Calculus I | 4 |
- One of the following courses (4 credits):

MTH 133	Calculus II	4
MTH 153H	Honors Calculus II	4
LB 119	Calculus II	4
 - One of the following courses (4 credits):

MTH 234	Multivariable Calculus	4
MTH 254H	Honors Multivariable Calculus	4
LB 220	Calculus III	4
 - All of the following courses (22 credits):

MTH 317H	Honors Linear Algebra	4
MTH 327H	Honors Introduction to Analysis	3
MTH 347H	Honors Ordinary Differential Equations	3
MTH 418H	Honors Algebra I	3
MTH 419H	Honors Algebra II	3
MTH 429H	Honors Real Analysis	3
MTH 496	Capstone in Mathematics (W)	3

 The completion of Mathematics 496 fulfills the department's capstone course requirement.

- A total of 15 credits in electives. Three of the courses (9 credits) are to be selected from any MTH course at the 800-level or above, or any course approved by the Mathematics Advanced program for satisfying this requirement, or any course from the following list:

MTH 416	Introduction to Algebraic Coding	3
MTH 417	Topics in Number Theory	3
MTH 425	Complex Analysis	3
MTH 441	Ordinary Differential Equations II	3
MTH 442	Partial Differential Equations	3
MTH 451	Numerical Analysis I	3
MTH 452	Numerical Analysis II	3
MTH 461	Metric and Topological Spaces	3
MTH 481	Discrete Mathematics I	3
MTH 482	Discrete Mathematics II	3
MTH 492H	Undergraduate Thesis (W)	3

- Two of the courses (6 credits) are to be selected from any MTH course at the 400 level or above (excluding MTH 411 and 421), or any course approved by the Mathematics Advanced program for satisfying this requirement, or any course from the following list:

CMSE820	Mathematical Foundations of Data Science	3
CMSE821	Numerical Methods for Differential Equations	3
CMSE823	Numerical Linear Algebra	3
CSE 425	Introduction to Computer Security	3
CSE 450	Translation of Programming Languages	3
CSE 460	Computability and Formal Language Theory	3
CSE 472	Computer Graphics	3
CSE 802	Pattern Recognition and Analysis	3
CSE 803	Computer Vision	3
CSE 814	Computer Aided Verification	3
CSE 830	Design and Theory of Algorithms	3
CSE 835	Algorithmic Graph Theory	3
CSE 847	Machine Learning	3
CSE 860	Foundations of Computing	3
CSE 881	Data Mining	3
PHL 432	Logic and its Metatheory	4
PHY 410	Thermal and Statistical Physics	3
PHY 415	Methods of Theoretical Physics	4
PHY 422	Classical Mechanics II	3
PHY 471	Quantum Physics I	3
PHY 472	Quantum Physics II	3
PHY 480	Computational Physics	3
PHY 481	Electricity and Magnetism I	3
PHY 482	Electricity and Magnetism II	3
STT 861	Theory of Probability and Statistics I	3
STT 862	Theory of Probability and Statistics II	3
STT 881	Theory of Probability I	3
STT 882	Theory of Probability II	3
STT 886	Stochastic Processes and Applications	3

COLLEGE OF NATURAL SCIENCE

MATHEMATICS-SECONDARY EDUCATION

The Bachelor of Science Degree in Mathematics-Secondary Education adequately prepares students to teach mathematics at the secondary level. Students gain a thorough foundation of mathematics, both in content and practice, and a comprehensive understanding of educational pedagogy and instructional methods.

Requirements for the Bachelor of Science Degree in Mathematics-Secondary Education

- CREDITS
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-Secondary Education.
The University's Tier II writing requirement for the Mathematics-Secondary Education major is met by completing Mathematics 309 and 396. Those courses are referenced in item 3. below.
Students may substitute Teacher Education 101 and 102 for two ISS requirements.
Students may substitute Teacher Education 341 for one IAH requirement.
 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:
 - a. The following courses outside the Department of Mathematics (19 to 23 credits):
 - (1) One course of at least 3 credits in biological science, entomology, Microbiology, physiology, plant biology, or integrative biology
At least 2 credits in laboratory in biological science, chemistry, microbiology, physics, physiology, plant biology, or integrative biology.
This requirement is met by fulfilling the course requirements in item 3. a. (2) (c) below and 1 additional credit if not taking CEM 185H.
 - (2) One course from each of the following groups (8 or 10 credits):
 - (a) CEM 141 General Chemistry 4
CEM 151 General and Descriptive Chemistry 4
CEM 181H Honors Chemistry I 4
LB 171 Principles of Chemistry I 4
 - (b) CEM 142 General and Inorganic Chemistry 3
CEM 152 Principles of Chemistry 3
CEM 182H Honors Chemistry II 4
LB 172 Principles of Chemistry II 3
 - (c) CEM 161 Chemistry Laboratory I 1
CEM 185H Honors Chemistry Laboratory I 2
LB 171L Introductory Chemistry Laboratory I 1
 - (d) One of the following groups of courses (8 to 10 credits):
 - (i) PHY 183 Physics for Scientists and Engineers I 4
PHY 184 Physics for Scientists and Engineers II 4
 - (ii) PHY 193H Honors Physics I – Mechanics 4
PHY 294H Honors Physics II – Electromagnetism 4
(iii) LB 273 Physics I 4
LB 274 Physics II 4
 - (iv) PHY 173 Physics I 5
PHY 174 Physics II 5
 - b. The following courses in the Department of Mathematics (33 to 37 credits):
 - (1) One course from each of the following two groups (7 or 8 credits):
 - (a) MTH 132 Calculus I 3
MTH 152H Honors Calculus 3
LB 118 Calculus I 4
 - (b) MTH 133 Calculus II 4
MTH 153H Honors Calculus II 4
LB 119 Calculus II 4
 - (2) One of the following courses (4 credits):
MTH 234 Multivariable Calculus 4
MTH 254H Honors Multivariable Calculus 4
LB 220 Calculus III 4
 - (3) One of the following two groups of courses (4 or 7 credits):
 - (a) MTH 299 Transitions 4
MTH 309 Linear Algebra I 3
 - (b) MTH 317H Honors Linear Algebra 4
 - (4) All of the following courses (12 credits):
MTH 304 Algebra and Calculus for Secondary Education 3

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|----------|--|---|
| MTH 305 | Discrete and Computational Mathematics for Secondary Education | 3 |
| MTH 330 | Higher Geometry | 3 |
| MTH 396 | Capstone in Mathematics for Secondary Education (W) | 3 |
| (5) | One of the following courses (3 credits): | |
| MTH 310 | Abstract Algebra I and Number Theory | 3 |
| MTH 418H | Honors Algebra I | 3 |
| (6) | One of the following courses (3 credits): | |
| MTH 320 | Analysis I | 3 |
| MTH 327H | Honors Introduction to Analysis | 3 |
| c. | The following computational and statistics courses from outside the Department of Mathematics (7 credits): | |
| (1) | One of the following courses (4 credits): | |
| CMSE 201 | Computational Modeling and Data Analysis I | 4 |
| CSE 231 | Introduction to Programming I | 4 |
| (2) | The following course (3 credits): | |
| STT 430 | Introduction to Probability and Statistics | 3 |
| d. | The following Professional Education Courses in the Department of Teacher Education (36 credits): | |
| (1) | All of the following courses from the shared professional sequence (18 credits): | |
| CEP 240 | Diverse Learners in Multicultural Perspective | 3 |
| TE 101 | Social Foundations of Justice and Equity in Education | 3 |
| TE 102 | Pedagogy and Politics of Justice and Equity in Education | 3 |
| TE 150 | Reflections on Learning | 3 |
| TE 302 | Literacy and Adolescent Learners in School and Community Contexts | 3 |
| TE 341 | Teaching and Learning of (Bi)Multilingual Learners | 3 |
| (2) | All of the following courses from the subject-specific professional sequence (18 credits): | |
| TE 314 | Clinical Experiences in Mathematics Education I | 3 |
| TE 414 | Clinical Experiences in Mathematics Education II | 3 |
| TE 415 | Seminar in Mathematics Education I | 3 |
| TE 416 | Seminar in Mathematics Education II | 3 |
| TE 417 | Student Teaching Internship in Mathematics Education | 6 |

MINOR IN MATHEMATICS

The Minor in Mathematics, which is administered by the Department of Mathematics, will broaden students' understanding and application of mathematical concepts to their chosen field of study.

The minor is available as an elective to students who are enrolled in bachelor's degree programs at Michigan State University other than the Bachelor of Arts and Bachelor of Science Degree in Mathematics. With the approval of the department and college that administer the student's degree program, the courses that are used to satisfy the minor may also be used to satisfy the requirements for the bachelor's degree.

Students who plan to complete the requirements of the minor should consult the undergraduate advisor in the Department of Mathematics.

Requirements for the Minor in Mathematics

- CREDITS
- Complete the following (21 to 28 credits):
1. One of the following courses (3 or 4 credits):

LB 118	Calculus I	4
MTH 132	Calculus I	3
MTH 152H	Honors Calculus I	3
 2. One of the following courses (3 or 4 credits):

LB 119	Calculus II	4
MTH 133	Calculus II	4
MTH 153H	Honors Calculus II	3
 3. One of the following courses (3 or 4 credits):

LB 220	Calculus III	4
MTH 234	Multivariable Calculus	4

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MTH 254H Honors Multivariable Calculus	3
4. One of the following groups of courses (3 to 7 credits):	
(a) MTH 299 Transitions	4
MTH 309 Linear Algebra I	3
(b) MTH 317H Advanced Linear Algebra	3
5. All of the following courses (9 credits):	
MTH 310 Abstract Algebra I and Number Theory	3
MTH 320 Analysis I	3
One 400-level mathematics course approved by the student's advisor	3

MINOR IN ACTUARIAL SCIENCE

The Minor in Actuarial Science, which is administered by the Department of Mathematics within the College of Natural Science, is available as an elective to students who are enrolled in any bachelor's degree program at Michigan State University. This minor complements a number of major fields such as mathematics, statistics and probability, finance, and economics. It is intended to prepare students for work in insurance companies, banks, investment firms, government work, hospitals and business firms where there is a need to weigh the financial consequences of risk. The Minor in Actuarial Science prepares students for two of the examinations of the Society of Actuaries (SOA): Exam P/1 and Exam FM/2. With the approval of the department that administers the student's degree program, courses that are used to satisfy the requirements for the minor may also be used to satisfy the requirements for the bachelor's degree.

Requirements for the Minor in Actuarial Science

The student must complete all of the following courses (21 credits):	CREDITS
1. All of the following courses (18 credits):	
FI 311 Financial Management	3
FI 321 Theory of Investments	3
MTH 360 Theory of Mathematical Interest	3
MTH 361 Financial Mathematics for Actuaries I	3
STT 441 Probability and Statistics I: Probability	3
STT 455 Actuarial Models I	3
2. One of the following courses (3 credits):	
MTH 457 Introduction to Financial Mathematics	3
STT 442 Probability and Statistics II: Statistics	3

TEACHER CERTIFICATION OPTIONS

The mathematics-secondary education disciplinary major leading to the Bachelor of Science degree is available for teacher certification.

A mathematics-secondary education disciplinary minor is also available for teacher certification.

Students who elect the mathematics-secondary education major or the mathematics-secondary 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 is ranked a tier-one program by the National Research Council rankings and conducts world-class research in a broad spectrum of mathematical endeavors. At the highest level, the department offers the graduate degrees of Doctor of Philosophy in Mathematics and Doctor of Philosophy in Applied Mathematics, which open the door to research careers in universities, national laboratories,

and industry. We also offer graduate work leading to Master of Science degrees in Mathematics and in Applied Mathematics. Our Professional Master's program in Industrial Mathematics has an exemplary record of preparing students for careers in industry.

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 advisor and must include:

1. At least 24 credits in mathematics courses including:
 - a. At least 6 credits from the following courses: Mathematics 818, 819, 828, 829, 848, 849, 868, 869.
 - b. At least 12 credits in 800-level applied mathematics courses including 6 credits in one of the following groups of courses: Mathematics 841, 842; 848, 849; 850, 851; or 880, 881.The completion of Mathematics 848 and 849 may be used to satisfy either the requirement referenced in item 1 a. or the requirement referenced in item 1 b., but not both of those requirements.
2. At least 18 credits in 800–900 level courses.

Doctor of Philosophy

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

Admission

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

COLLEGE OF NATURAL SCIENCE

Requirements for the Doctor of Philosophy Degree in Applied Mathematics

The student must:

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

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

INDUSTRIAL MATHEMATICS

Master of Science

The degree of Master of Science in Industrial Mathematics is designed to produce generalized problem solvers of great versatility, capable of moving within an organization from task to task. The graduate will have acquired not only the standard mathematical and statistical tools and computer science principles to strengthen data analytic skills, 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 designed 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, statistics, economics, physics or engineering, (2) courses at the senior level in mathematical analysis, linear algebra and differential equations, and (3) have some familiarity with mathematical software programs such as Mathematica, Matlab, etc.

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

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 30 credits for the degree under Plan B (without thesis). The student's program of study must be approved by the student's academic advisor, including:

1. The following requirements for the major (30 credits):

- a. Both of the following courses:

MTH 843	Survey of Industrial Mathematics	3
MTH 844	Projects in Industrial Mathematics	3

- b. A minimum of two of the following courses:

MTH 810	Error-Correcting Codes	3
MTH 841	Boundary Value Problems I	3
MTH 842	Boundary Value Problems II	3
MTH 847	Partial Differential Equations I	3
MTH 848	Ordinary Differential Equations	3
MTH 849	Partial Differential Equations	3
MTH 850	Numerical Analysis I	3
MTH 851	Numerical Analysis II	3
MTH 852	Numerical Methods for Ordinary Differential Equations	3
MTH 880	Combinatorics I	3
MTH 881	Graph Theory	3

- c. A minimum of two of the following courses:

STT 801	Design of Experiments	3
STT 802	Statistical Computation	3
STT 843	Multivariate Analysis	3
STT 844	Time Series Analysis	3
STT 847	Analysis of Survival Data	3
STT 861	Theory of Probability and Statistics I	3
STT 862	Theory of Probability and Statistics II	3
STT 863	Statistics Methods I	3
STT 864	Statistics Methods II	3
STT 866	Spatial Data Analysis	3
STT 875	R Programming for Data Sciences	3
STT 886	Stochastic Processes and Applications	4
STT 888	Stochastic Models in Finance	3

- d. At least two of the following courses:

CMSE 801	Introduction to Computational Modeling	3
CMSE 802	Methods in Computational Modeling	3
CMSE 820	Mathematical Foundations of Data Science	3
CMSE 821	Numerical Methods for Differential Equations	3
CMSE 822	Parallel Computing	3
CMSE 823	Numerical Linear Algebra	3
CSE 802	Pattern Recognition and Analysis	3
CSE 803	Computer Vision	3
CSE 830	Design and Theory of Algorithms	3
CSE 835	Algorithmic Graph Theory	3
CSE 836	Probabilistic Models and Algorithms in Computational Biology	3
CSE 841	Artificial Intelligence	3
CSE 847	Machine Learning	3
CSE 860	Foundations of Computing	3
CSE 872	Advanced Computer Graphics	3
CSE 880	Advanced Database Systems	3
CSE 881	Data Mining	3
CSE 885	Artificial Neural Networks	3
EC 811A	Mathematical Applications in Economics	2
EC 811B	The Structure of Economic Analysis	2
EC 812A	Microeconomics I	3
EC 812B	Microeconomics II	3
EC 813A	Macroeconomics I	3
EC 813B	Macroeconomics II and its Mathematical Foundations	4
EC 820A	Econometrics IA	3
EC 820B	Econometrics IB	3
EC 821A	Cross Section and Panel Data Econometrics I	3
EC 821B	Cross Section and Panel Data Econometrics II	3
EC 822A	Time Series Econometrics I	3
EC 822B	Time Series Econometrics II	3
ECE 848	Evolutionary Computation	3
ECE 863	Analysis of Stochastic Systems	3
ME 830	Fluid Mechanics I	3
ME 840	Computational Fluid Dynamics and Heat Transfer	3
ME 872	Finite Element Method	3
MKT 805	Marketing Management	2
MKT 806	Marketing Research for Decision Making	3
MKT 816	Marketing Analysis	3
MKT 819	Advanced Marketing Research	3
MKT 864	Data Mining in Marketing	3
SCM 800	Supply Chain Management	3
SCM 815	Emerging Topics in Supply Management	3
SCM 826	Manufacturing Design and Analysis	1.5
SCM 833	Decision Support Models	2
SCM 843	Sustainable Supply Chain Management	2
SCM 853	Operations Strategy	2
SCM 854	Integrated Logistics Systems	1.5

- e. Completion of a Certificate Program in Project Management. This requires completion of PHM 857 Project Management, covering such topics as

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formal project management culture, principles, knowledge areas, and terminology. It will normally be undertaken during the first year of enrollment with the opportunity to use the credit-no credit grading system. Certification will also require participation in Industrial Mathematics-specific discussion sessions. After the completion of the certificate program is approved by the instructors, the Industrial Mathematics Program, and 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.

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 advisor and must include:

1. At least 24 credits in mathematics courses including at least 6 credits from the following courses: Mathematics 818, 819, 828, 829, 848, 849, 868, 869.
2. At least 18 credits in 800–900 level courses.

Doctor of Philosophy

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

Admission

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

Requirements for the Doctor of Philosophy Degree in Mathematics

The student must:

1. Pass the qualifying examination.
2. Complete at least 30 credits in approved 800–900 level mathematics courses excluding courses taken in preparation for the qualifying examination and Mathematics 999.
3. Present at least two seminars acceptable to the faculty.

4. Pass the comprehensive examination.
5. Demonstrate a reading knowledge of one foreign language, normally from among French, German, and Russian, sufficient to read the mathematical literature written in that language.

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

GRADUATE CERTIFICATE IN SPORTS ANALYTICS

The Sports Analytics graduate certificate provides students with quantitative and applicable skills in support of the analysis of sports performance. Students develop analytic techniques in stochastic and statistical analysis with written and verbal communication skills. They will be able to transfer data on player performance into metrics, develop analytical models to differentiate player performance, and communicate effectively with non-quantitative decision makers. The applications draw from quantitative issues in management of day-to-day operations, player developing and assessment, and player recruitment. The certificate is targeted at professionals in the sports industry or college athletics, former athletes transitioning into sports analytics, and quantitatively literate people who are transitioning into sports analytics. The certificate is available online only.

Admission

Students must:

Complete an application with approval from both the Department of Mathematics and Department of Statistics and Probability.

Have background in mathematical and statistical foundations normally acquired through course work in multivariable calculus, linear algebra, and statistics and probability.

Requirements for the Graduate Certificate in Sports Analytics

Students must complete 12 credits from the following:

MTH 801	Machine Learning Algorithms: Mathematical Analysis	3
MTH 803	Sports Decision Analytics	3
STT 832	Data Visualization and Programming in R	3
STT 834	Sports Analytics Capstone	3

DEPARTMENT of MICROBIOLOGY, GENETICS, and IMMUNOLOGY

Victor DiRita, Chairperson

The Department of Microbiology, Genetics, and Immunology 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 research on the interaction of pathogenic and beneficial microbes with their hosts. Microbiology also includes the study of complex communities of microbes, such as those found in soil or within humans and animals.

Molecular genetics and genomics includes study of the basis of heredity and the mechanisms by which genes exert their effects as well as genetic engineering and gene manipulation. Much of this study originates in microbial systems or employs microbiology-based technologies, but these approaches can be applied to larger organisms as well. The microbial sciences influence nearly every area of biology. Microbes are not only key in disease, industrial processes, and the environment, but they are among the best studied model systems in biology.

The microbiologist today may specialize in one or more of the diverse aspects of the science. At the undergraduate level, students may pursue their interests by completing a course of study leading to a bachelor's degree in microbiology, genomics and molecular genetics, or environmental biology/microbiology.

Employment opportunities for microbiologists and molecular geneticists 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 or molecular genetics offer a broad overview of biology, they are excellent choices for students who are interested in fundamental and applied biological science and also for students who plan to apply for admission to graduate professional programs, such as human or veterinary medicine.

Students who are enrolled in bachelor's degree programs in the Department of Microbiology, Genetics, and Immunology may elect the Minor in Food Processing and Technology. For additional information, refer to the *Minor 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.

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

UNDERGRADUATE PROGRAMS

ENVIRONMENTAL BIOLOGY/MICROBIOLOGY

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

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

The educational objectives of the program are to:

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

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, Genetics, and Immunology 408 or 494L. 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 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, Genetics, and Immunology (58 to 68 credits):
 - (1) One of the following, either a. or b. (4 or 6 credits):

(a) BMB 461 Advanced Biochemistry I	3
BMB 462 Advanced Biochemistry II	3
(b) BMB 401 Comprehensive Biochemistry	4
 - (2) All of the following courses (15 credits):

CSS 210 Fundamentals of Soil Science	3
GLG 201 The Dynamic Earth	4
GLG 421 Environmental Geochemistry	4
IBIO 355 Ecology	3
IBIO 355L Ecology Laboratory (W)	1
 - (3) One of the following groups of courses (6 or 9 credits):

(a) BS 161 Cell and Molecular Biology	3
BS 162 Organismal and Population Biology	3
(b) LB 144 Biology I: Organismal Biology	4
LB 145 Biology II: Cell and Molecular Biology	5
(c) BS 181H Honors Cell and Molecular Biology	3
BS 182H Honors Organismal and Population Biology	3
 - (4) One of the following courses (2 credits):

BS 171 Cell and Molecular Biology Laboratory	2
BS 172 Organismal and Population Biology Laboratory	2
BS 191H Honors Cell and Molecular Biology Laboratory	2
BS 192H Honors Organismal and Population Biology Laboratory	2

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This requirement is waived for students who selected item (3) (b) above.

- (5) One of the following groups of courses (9 or 10 credits):
- (a) CEM 141 General Chemistry 4
 - CEM 142 General and Inorganic Chemistry 3
 - CEM 161 Chemistry Laboratory I 1
 - CEM 162 Chemistry Laboratory II 1
 - (b) LB 171 Principles of Chemistry I 4
 - LB 172 Principles of Chemistry II 3
 - LB 171L Introductory Chemistry Laboratory I 1
 - LB 172L Principles of Chemistry II - Reactivity Laboratory 1
 - (c) 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
 - (d) CEM 181H Honors Chemistry I 4
 - CEM 182H Honors Chemistry II 4
 - CEM 185H Honors Chemistry Laboratory 2
- (6) One of the following groups of courses (8 credits):
- (a) CEM 251 Organic Chemistry I 3
 - CEM 252 Organic Chemistry II 3
 - CEM 255 Organic Chemistry Laboratory 2
 - (b) CEM 351 Organic Chemistry I 3
 - CEM 352 Organic Chemistry II 3
 - CEM 355 Organic Chemistry Laboratory I 2
 - (c) LB 271 Organic Chemistry 3
 - CEM 252 Organic Chemistry II 3
 - CEM 255 Organic Chemistry Laboratory 2
- (7) One of the following courses (3 or 4 credits):
- MTH 124 Survey of Calculus I 3
 - MTH 132 Calculus I 3
 - LB 118 Calculus I 3
 - MTH 152H Honors Calculus I 3
- (8) One of the following courses (3 or 4 credits):
- STT 231 Statistics for Scientists 3
 - STT 421 Statistics I 3
 - MTH 133 Calculus II 3
 - MTH 126 Survey of Calculus II 3
 - MTH 153H Honors Calculus II 4
 - LB 119 Calculus II 4
- (9) One of the following groups of courses (8 or 10 credits):
- (a) PHY 221 Studio Physics for Life Scientists, I 4
 - PHY 222 Studio Physics for Life Scientists, II 4
 - (b) LB 273 Physics I 4
 - LB 274 Physics II 4
 - (c) 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
 - (d) PHY 193H Honors Physics I-Mechanics 4
 - PHY 294H Honors Physics II-Electromagnetism 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 Microbiology, Genetics, and Immunology (19 credits):
- (1) All the following courses (13 credits):
 - MGI 301 Introductory Microbiology 3
 - MGI 302 Introductory Laboratory for General and Allied Health Microbiology 1
 - MGI 421 Prokaryotic Cell Physiology 3
 - MGI 425 Microbial Ecology 3
 - MGI 431 Microbial Genetics 3
 - (2) One of the following courses (3 credits):
 - MGI 408 Advanced Microbiology Laboratory (W) 3
 - MGI 494L Summer Undergraduate Research Institute in Genomics (W) 3
 - (3) One of the following three options (3 credits):
 - (a) MGI 491 Current Topics in Microbiology, Genetics, and Immunology 3
 - (b) MGI 492 Undergraduate Research Seminar 1
 - One of the following courses:
 - MGI 499 Undergraduate Research 2
 - MGI 499H Honors Research 2
 - (c) MGI 493 Professional Internship in Microbiology, Genetics, and Immunology 3
 - The completion of either of these three options fulfills the department's capstone course requirement.
- c. One course from two of the following areas (6 to 8 credits):

- (1) CSS 455 Environmental Pollutants in Soil and Water 3
- (2) FOR 340 Forest Ecology 3
- PLB 402 Biology of Fungi 4
- (3) FSC 440 Food Microbiology 3
- (4) GEO 206 Physical Geography 3
- GEO 221 Introduction to Geographic Information 3
- (5) GLG 435 Geomicrobiology (W) 4
- (6) FOR 466 Natural Resource Policy 3
- IBIO 446 Environmental Issues and Public Policy 3
- (7) FW 420 Stream Ecology 3
- FW 472 Limnology 3
- (8) MGI 433 Genomics (W) 3
- CMSE410 Bioinformatics and Computational Biology 3
- (9) IBIO 357 Global Change Biology (W) 3

GENETICS AND GENOMICS

The objective of the Bachelor of Science degree program with a major in genetics and genomics is to provide a broad foundation in science, with emphasis in genetics and genomics. Although the majority of the course work is prescribed, students have an opportunity to tailor their degree program to their own interests within the field by choosing a suitable course combination from a slate of options.

In addition to the general degree requirements of the College of Natural Science, the undergraduate program in genetics and genomics encompasses fundamental training in chemistry, mathematics, physics, and biology. This foundation provides the prerequisites for undertaking the basic courses in genetics and genomics. In order to increase the flexibility of the program, and to provide additional intellectual stimulation, students are encouraged to participate in mentored 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 or a presentation or seminar by the student. This research may fulfill part of the department's capstone course requirement for the bachelor's degree with a major in genetics and genomics.

Requirements for the Bachelor of Science Degree in Genetics and Genomics

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 Genetics and Genomics.

The University's Tier II writing requirement for the Genetics and Genomics major is met by completing Microbiology, Genetics, and Immunology 434 or 494L. 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.

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

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

The following requirements for the major:

CREDITS

- a. The following courses outside the Department of Microbiology, Genetics, and Immunology (45 to 55 credits):
- (1) One of the following, either a. or b. (4 or 6 credits):
- (a) BMB 461 Advanced Biochemistry I 3
- BMB 462 Advanced Biochemistry II 3
- (b) BMB 401 Comprehensive Biochemistry 4
- (2) One of the following groups of courses (6 or 9 credits):
- (a) BS 161 Cell and Molecular Biology 3
- BS 162 Organismal and Population Biology 3

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- (b) LB144 Biology I: Organismal Biology 4
LB145 Biology II: Cell and Molecular Biology 5
- (c) BS 181H Honors Cell and Molecular Biology 3
BS 182H Honors Organismal and Population Biology 3
- (3) One of the following courses (2 credits):
BS 171 Cell and Molecular Biology Laboratory 2
BS 172 Organismal and Population Biology Laboratory 2
BS 191H Honors Cell and Molecular Biology Laboratory 2
BS 192H Honors Organismal and Population Biology Laboratory 2
- This requirement is waived for students who selected item (2) (b) above.
- (4) One of the following groups of courses (9 or 10 credits):
- (a) CEM 141 General Chemistry 4
CEM 142 General and Inorganic Chemistry 3
CEM 161 Chemistry Laboratory I 1
CEM 162 Chemistry Laboratory II 1
- (b) LB 171 Principles of Chemistry I 4
LB 172 Principles of Chemistry II 4
LB 171L Introductory Chemistry Laboratory I 1
LB 172L Principles of Chemistry II – Reactivity Laboratory 1
- (c) 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
- (d) CEM 181H Honors Chemistry I 4
CEM 182H Honors Chemistry II 4
CEM 185H Honors Chemistry Laboratory I 2
- (5) One of the following groups of courses (8 credits):
- (a) CEM 251 Organic Chemistry I 3
CEM 252 Organic Chemistry II 3
CEM 255 Organic Chemistry Laboratory 2
- (b) CEM 351 Organic Chemistry I 3
CEM 352 Organic Chemistry II 3
CEM 355 Organic Laboratory I 2
- (c) LB 271 Organic Chemistry 3
CEM 252 Organic Chemistry II 3
CEM 255 Organic Chemistry Laboratory 2
- (6) The following course (4 credits):
IBIO 341 Fundamental Genetics 4
- (7) One of the following groups of courses (6 to 8 credits):
- (a) PHY 221 Studio Physics for Life Scientists, I 4
PHY 222 Studio Physics for Life Scientists, II 4
- (b) LB 273 Physics I 4
LB 274 Physics II 4
- (c) 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
- (d) PHY 191 Physics Laboratory for Scientists, I 1
PHY 192 Physics Laboratory for Scientists, II 1
PHY 193H Honors Physics I - Mechanics 4
PHY 294H Honors Physics II - Electromagnetism 4
- (8) Both of the following courses (6 to 8 credits):
- (a) One of the following courses (3 or 4 credits):
LB 118 Calculus I 4
MTH 124 Survey of Calculus I 3
MTH 132 Calculus I 3
MTH 152H Honors Calculus I 3
- (b) One of the following courses (3 or 4 credits):
LB 119 Calculus II 4
MTH 126 Survey of Calculus II 3
MTH 133 Calculus II 4
MTH 153H Honors Calculus II 4
STT 231 Statistics for Scientists 3
STT 421 Statistics I 3
- b. The following courses in the Department of Microbiology, Genetics, and Immunology (20 credits):
- (1) All of the following courses (13 credits):
MGI 301 Introductory Microbiology 3
MGI 302 Introductory Laboratory for General and Allied Health Microbiology 1
MGI 409 Eukaryotic Cell Biology 3
MGI 431 Microbial Genetics 3
MGI 433 Genomics (W) 3
- (2) One of the following courses (3 or 4 credits):
MGI 408 Advanced Microbiology Laboratory (W) 3
MGI 434 Laboratory in Genetics and Genomics (W) 4

- MGI 494L Summer Undergraduate Research Institute in Genomics (W) 3
- (3) One of the following three options (3 credits):
- (a) MGI 491 Current Topics in Microbiology, Genetics, and Immunology 3
- (b) MGI 492 Undergraduate Research Seminar 1
One of the following courses:
MGI 499 Undergraduate Research 2
MGI 499H Honors Research 2
- (c) MGI 493 Professional Internship in Microbiology, Genetics, and Immunology 3
The completion of Microbiology, Genetics, and Immunology 491, 493; or Microbiology, Genetics, and Immunology 492 and 499 or 499H, fulfills the department's capstone course requirement.
- c. Two of the following courses (6 to 8 credits):
- ANS 314 Genetic Improvement of Domestic Animals (W) 4
ANS 404 Introduction to Quantitative Genetics 3
ANS 425 Animal Biotechnology 3
CMSE201 Computational Modeling and Data Analysis I 4
CMSE202 Computational Modeling and Data Analysis II 4
CMSE410 Bioinformatics and Computational Biology 3
CMSE411 Computational Medicine 3
CSE 231 Introduction to Programming I 4
CSE 232 Introduction to Programming II 4
CSS 350 Introduction to Plant Genetics 3
CSS 451 Biotechnology Applications for Plant Breeding and Genetics 3
IBIO 445 Evolution (W) 3
MGI 404 Human Genetics 3
MGI 413 Virology 3

MICROBIOLOGY

The objective of the Bachelor of Science degree program with a major in microbiology is to provide a broad foundation in science, with emphasis in microbiology. In order to assist students in planning a course of study, elective microbiology courses are organized by interest group (cell and molecular biology, immunology and medical microbiology, microbe biology, and microbial biotechnology) and students are advised in personal consultations to select a set of electives according to their interests. Thus, different emphases may be chosen 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.

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.

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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, Genetics, and Immunology 408 or 494L. 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 Microbiology, Genetics, and Immunology (41 to 51 credits):	
(1) One of the following, either a. or b. (4 or 6 credits):	
(a) BMB 461 Advanced Biochemistry I	3
BMB 462 Advanced Biochemistry II	3
(b) BMB 401 Comprehensive Biochemistry	4
(2) One of following groups of courses (6 or 9 credits):	
(a) BS 161 Cell and Molecular Biology	3
BS 162 Organismal and Population Biology	3
(b) LB 144 Biology I: Organismal Biology	4
LB 145 Biology II: Cell and Molecular Biology	5
(c) BS 181H Honors Cell and Molecular Biology	3
BS 182H Honors Organismal and Population Biology	3
(3) One of the following courses (2 credits):	
BS 171 Cell and Molecular Biology Laboratory	2
BS 172 Organismal and Population Biology Laboratory	2
BS 191H Honors Cell and Molecular Biology Laboratory	2
BS 192H Honors Organismal and Population Biology Laboratory	2
This requirement is waived for students who selected item (2) (b) above.	
(4) One of the following groups of courses (9 or 10 credits):	
(a) CEM 141 General Chemistry	4
CEM 142 General and Inorganic Chemistry	3
CEM 161 Chemistry Laboratory I	1
CEM 162 Chemistry Laboratory II	1
(b) LB 171 Principles of Chemistry I	4
LB 172 Principles of Chemistry II	4
LB 171L Introductory Chemistry Laboratory I	1
LB 172L Principles of Chemistry II – Reactivity Laboratory	1
(c) 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
(d) CEM 181H Honors Chemistry I	4
CEM 182H Honors Chemistry II	4
CEM 185H Honors Chemistry Laboratory I	2
(5) One of the following groups of courses (8 credits):	
(a) CEM 251 Organic Chemistry I	3
CEM 252 Organic Chemistry II	3
CEM 255 Organic Chemistry Laboratory	2
(b) CEM 351 Organic Chemistry I	3
CEM 352 Organic Chemistry II	3
CEM 355 Organic Laboratory I	2
(c) LB 271 Organic Chemistry	3
CEM 252 Organic Chemistry II	3
CEM 255 Organic Chemistry Laboratory	2
(6) One of the following groups of courses (6 to 8 credits):	
(a) PHY 221 Studio Physics for Life Scientists, I	4
PHY 222 Studio Physics for Life Scientists, II	4
(b) LB 273 Physics I	4
LB 274 Physics II	4

(c) PHY 183 Physics for Scientists and Engineers I	4
PHY 184 Physics for Scientists and Engineers II	4
(d) PHY 193H Honors Physics I - Mechanics	4
PHY 294H Honors Physics II - Electromagnetism	4
(7) Both of the following courses (6 to 8 credits):	
(a) One of the following courses (3 or 4 credits):	
LB 118 Calculus I	4
MTH 124 Survey of Calculus I	3
MTH 132 Calculus I	3
MTH 152H Honors Calculus I	3
(b) One of the following courses (3 or 4 credits):	
LB 119 Calculus II	4
MTH 126 Survey of Calculus II	3
MTH 133 Calculus II	4
MTH 153H Honors Calculus II	4
STT 231 Statistics for Scientists	3
STT 421 Statistics I	3
b. The following courses in the Department of Microbiology, Genetics, and Immunology (16 credits):	
(1) All of the following courses (10 credits):	
MGI 301 Introductory Microbiology	3
MGI 302 Introductory Laboratory for General and Allied Health Microbiology	1
MGI 421 Prokaryotic Cell Physiology	3
MGI 431 Microbial Genetics	3
(2) One of the following courses (3 credits):	
MGI 408 Advanced Microbiology Laboratory (W)	3
MGI 494L Summer Undergraduate Research Institute in Genomics (W)	3
(3) One of the following, either (a), (b), or (c) (3 credits):	
(a) MGI 491 Current Topics in Microbiology, Genetics, and Immunology	3
(b) MGI 492 Undergraduate Research Seminar and One of the following courses:	1
MGI 499 Undergraduate Research	2
MGI 499H Honors Research	2
(c) MGI 493 Professional Internship in Microbiology, Genetics, and Immunology	3
The completion of Microbiology, Genetics, and Immunology 491, 493, or Microbiology 492 and 499 or 499H, fulfills the department's capstone course requirement.	
c. Complete four of the following courses (12 or 13 credits):	
EPI 390 Disease in Society: Introduction to Epidemiology and Public Health	4
FSC 440 Food Microbiology	3
GLG 435 Geomicrobiology (W)	4
MGI 365 Medical Microbiology	3
MGI 413 Virology	3
MGI 425 Microbial Ecology	3
MGI 433 Genomics (W)	3
MGI 445 Microbial Biotechnology (W)	3
MGI 451 Immunology	3
MGI 461 Molecular Pathogenesis	3
MGI 465 Advanced Medical Microbiology	3

GRADUATE STUDY

The Department of Microbiology, Genetics, and Immunology is administered jointly by the colleges of Natural Science, Human Medicine, Osteopathic Medicine, and Veterinary Medicine. Study for the Master of Science degree in microbiology, genetics, and immunology or the Doctor of Philosophy degree in microbiology, genetics, and immunology may be administered by any one of the four colleges referenced above.

COLLEGE OF NATURAL SCIENCE

MICROBIOLOGY, GENETICS, and IMMUNOLOGY

The objective of the graduate programs in microbiology, genetics, and immunology 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. Financial subsidy may be available on a limited basis in the form of teaching assistantships.

A new graduate student in microbiology, genetics, and immunology is advised by the Director of Graduate Studies until a major professor is chosen. 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, Genetics, and Immunology* 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.

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

In general, applicants should have had the equivalent of two semesters 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. Scores on the Graduate Record Examination General Test are not required, however a personal letter of professional intent and objectives should be submitted. 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, Genetics, and Immunology

The student must complete 30 credits under Plan A (with thesis) or Plan B (without thesis). The student's program of study must be approved by the student's guidance committee.

Requirements for Both Plan A and Plan B

1. Complete the following course (1 credit):
MGI 892 Seminar 1
2. Complete the following course (1 to 3 credits):
MGI 991 Topics in Microbiology 1 to 3
3. Complete four courses at the 800-level, covering areas of genetics, microbiology, and biochemistry. At least two of these courses must be offered by the Department of Microbiology, Genetics, and Immunology. Students may select from the following courses:

BMB	801	Molecular Biology	3
BMB	802	Metabolic Regulation and Signal Transduction	3
BMB	805	Protein Structure, Design, and Mechanism	3
MGI	801	Integrative Microbial Biology	4
MGI	803	Topics in Integrative Microbial Biology	2
MGI	813	Molecular Virology	3
MGI	825	Cell Structure and Function	3
MGI	833	Microbial Genetics	3
MGI	835	Eukaryotic Molecular Genetics	3
MGI	852	Molecular Immunology	1
MGI	853	Cellular Immunology	1
MGI	854	Applied Immunology	1
MGI	861	Advanced Microbial Pathogenesis	3

- Other courses may be used if approved by the Director of Graduate Studies.
4. Present and pass an oral examination in defense of the master's degree that covers both course work and thesis, research, or project.

Additional Requirements for Plan A

1. Complete a minimum of 7 credits of MGI 899 Master's Thesis Research.
2. Successfully complete the oral examination in defense of thesis.

Additional Requirements for Plan B

1. Complete a minimum of 7 credits of MGI 890 Special Problems in Microbiology.
2. Preparation and presentation of the final research report.

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

Admission to the Doctor of Philosophy degree in Microbiology, Genetics, and Immunology is through the BioMolecular Science Gateway – First Year (BMS). The successful applicant will typically have: a bachelor's degree (four-year or equivalent) or Master of Science degree that includes course work that demonstrates proficiency in math and science; a grade point average of 3.50 or above; significant research experience equivalent to a minimum of one full-time summer research experience or four semesters of part-time research experience; and strong letters of reference.

Requirements for the Doctor of Philosophy Degree in Microbiology, Genetics, and Immunology

The student must:

1. Complete a minimum of four 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, Genetics, and Immunology.
 - a. One course must focus on Molecular Biology or Genetics and include one of the following courses or an approved equivalent as approved by the Director of Graduate Studies.

BMB	801	Molecular Biology	3
MGI	833	Microbial Genetics	3
MGI	835	Eukaryotic Molecular Genetics	3
 - b. One course must focus on Cell Biology or Cell Physiology and include one of the following courses or an approved equivalent as approved by the Director of Graduate Studies.

BMB	802	Metabolic Regulation and Signal Transduction	3
MGI	801	Integrative Microbial Biology	4
MGI	825	Cell Structure and Function	3
 - c. Other approved course electives include:

BMB	803	Protein Structure and Function	2
BMB	805	Protein Structure, Design, and Mechanism	3
MGI	813	Molecular Virology	3

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- | | | |
|--|---|---|
| | MGI 851 Immunology | 3 |
| | MGI 861 Advanced Microbial Pathogenesis | 3 |
2. Complete three special topics graduate seminar courses (MGI 803, MGI 991 or other departmental seminar courses as approved by the Director of Graduate Studies chosen to increase the breadth and depth of knowledge in your field.
 3. Pass a comprehensive examination that includes a written research proposal, public seminar and oral examination with the student's guidance committee.
 4. Complete 24 credits of MGI 999 Doctoral Dissertation Research.
 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, genetics, and immunology are required to participate in laboratory teaching through enrollment of 1 credit of MGI 892 and are expected to attend departmental seminars through enrollment in 4 credits of MGI 892. In addition, all students must participate in the Work in Progress (WiPs) seminar series.

Academic Standards

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

BIOMOLECULAR SCIENCE GATEWAY - FIRST YEAR

Students seeking a doctoral degree in biochemistry and molecular biology, cell and molecular biology, genetics and genome sciences, microbiology, genetics and immunology, pharmacology and toxicology, or molecular, cellular, and integrative physiology should apply through the BioMolecular Science Gateway—First Year for admission to any of these Ph.D. programs. Students should select the Ph.D. program in which they have the greatest interest. During the first two semesters of enrollment, students will have the opportunity to choose and complete at least four courses in appropriate disciplinary subjects. In the spring semester of the first year, they will have the opportunity to continue with the Ph.D. program initially selected or change to one of the other five programs that aligns most closely with their educational goals.

For additional information about the individual Ph.D. programs, refer to the statements in the Departments of Biochemistry and Molecular Biology, Microbiology, Genetics, and Immunology, and Physiology in the *College of Natural Science* section of this catalog, statements on the programs in Cell and Molecular Biology and Genetics and Genome Sciences in the *College of Natural Science* section of this catalog, and statement on the Department of Pharmacology and Toxicology in the *College of Osteopathic Medicine* section of this catalog.

DEPARTMENT of PHYSICS and ASTRONOMY

Stephen E. Zeph, Chairperson

Physics is the study of the physical universe. By means of observation, experiment, theoretical constructions and computer simulations this science attempts to find the principles which describe the universe. Among the topics of physics are motion and force, energy, sound, electricity and magnetism, light, atomic and nuclear structure, nuclear

reactions, electronic properties of conductors and semiconductors, materials important for energy applications, elementary particles and their interactions, particle accelerators, and the physics of living systems. The study of physics provides the basic understanding of nature and develops the analytical skills which are essential for progress in science and technology, e.g., conducting scientific research, solving environmental problems, advancing biomedical systems, and inventing cutting-edge technology.

Astronomy is the study of the universe beyond Earth. The laws of physics, as they are known from laboratory experiments, are applied to stars, interstellar gas, galaxies, and space itself in an attempt to understand the detailed physical states of these entities. Astrophysics frequently involves a study of matter under extreme conditions that cannot be duplicated in the laboratory. From this point of view the universe becomes a laboratory in which naturally occurring phenomena subject matter to very large ranges of physical parameters. Cosmology, a branch of physics and astronomy, attempts to use theory and current observations to comprehend the history and evolution of the universe.

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

UNDERGRADUATE PROGRAMS

Bachelor of Science

PHYSICS

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

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

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

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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. (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 Physics and Astronomy (35 to 40 credits):

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|---|---|
| (1) One of the following courses (3 to 5 credits): | |
| BS 161 Cell and Molecular Biology | 3 |
| BS 162 Organismal and Population Biology | 3 |
| BS 181H Honors Cell and Molecular Biology | 3 |
| BS 182H Honors Organismal and Population Biology | 3 |
| ENT 205 Pests, Society and Environment | 3 |
| IBIO 150 Integrating Biology: From DNA to Populations | 3 |
| LB 144 Biology I: Organismal Biology | 4 |
| LB 145 Biology II: Cellular and Molecular Biology | 5 |
| MMG 141 Introductory Human Genetics | 3 |
| MMG 201 Fundamentals of Microbiology | 3 |
| PLB 105 Plant Biology | 3 |
| PSL 250 Introductory Physiology | 4 |

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|---|---|
| (2) One of the following groups of courses (8 to 10 credits): | |
| (a) CEM 141 General Chemistry | 4 |
| CEM 142 General and Inorganic Chemistry | 3 |
| CEM 161 Chemistry Laboratory I | 1 |
| (b) CEM 151 General and Descriptive Chemistry | 4 |
| CEM 152 Principles of Chemistry | 3 |
| CEM 161 Chemistry Laboratory I | 1 |
| (c) CEM 181H Honors Chemistry I | 4 |
| CEM 182H Honors Chemistry II | 4 |
| CEM 185H Honors Chemistry Laboratory I | 2 |
| (d) LB 171 Principles of Chemistry I | 4 |
| LB 171L Introductory Chemistry Laboratory I | 1 |
| LB 172 Principles of Chemistry II | 3 |

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| (3) One of the following groups of Mathematics courses (14 or 15 credits): | |
| (a) MTH 132 Calculus I | 3 |
| MTH 133 Calculus II | 4 |
| MTH 234 Multivariable Calculus | 4 |
| MTH 235 Differential Equations | 3 |
| (b) MTH 152H Honors Calculus I | 3 |
| MTH 153H Honors Calculus II | 4 |
| MTH 254H Honors Multivariable Calculus | 4 |
| MTH 235 Differential Equations | 3 |
| or | |
| MTH 340 Ordinary Differential Equations I | 3 |
| (c) LB 118 Calculus I | 4 |
| LB 119 Calculus II | 4 |
| LB 220 Calculus III | 4 |
| MTH 235 Differential Equations | 3 |
| or | |
| MTH 340 Ordinary Differential Equations I | 3 |

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|--|---|
| (4) The following course (4 credits): | |
| CMSE 201 Computational Modeling and Data Analysis I | 4 |
| (5) Two additional mathematics courses at the 300-level or above of at least 3 credits each. PHY 415 Methods of Theoretical Physics may be used towards the fulfillment of this requirement. | |

b. The following courses in the Department of Physics and Astronomy: (33 to 38 credits)

- | | |
|---|---|
| (1) One of the following groups of courses (8 to 10 credits): | |
| (a) 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) PHY 191 Physics Laboratory for Scientists, I | 1 |

- | | |
|---|---|
| PHY 192 Physics Laboratory for Scientists, II | 1 |
| PHY 193H Honors Physics I - Mechanics | 4 |
| PHY 294H Honors Physics II - Electromagnetism | 4 |
| (c) PHY 173 Studio Physics for Scientists and Engineers I | 5 |
| PHY 174 Studio Physics for Scientists and Engineers II | 5 |
| (d) LB 273 Physics I | 4 |
| LB 274 Physics II | 4 |
| (2) All of the following courses (18 credits): | |
| PHY 215 Thermodynamics and Modern Physics | 3 |
| PHY 321 Classical Mechanics I | 3 |
| PHY 410 Thermal and Statistical Physics | 3 |
| PHY 451 Advanced Laboratory | 3 |
| PHY 471 Quantum Physics I | 3 |
| PHY 481 Electricity and Magnetism I | 3 |
| (3) One of the following courses (3 or 4 credits): | |
| PHY 431 Optics I | 3 |
| PHY 440 Electronics | 4 |
| (4) One of the following groups of courses (4 or 6 credits): | |
| (a) PHY 490 Physics Senior Thesis | 4 |
| Students must complete two enrollments of this course for a total of 4 credits. | |
| (b) Two of the following courses: | |
| PHY 491 Introduction to Condensed Matter Physics | 3 |
| PHY 492 Introduction to Nuclear Physics | 3 |
| PHY 493 Introduction to Elementary Particle Physics | 3 |
| PHY 494 Survey of Physics Education Research (W) | 3 |

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 4 credits of Astronomy and Astrophysics 410. 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 Physics and Astronomy (33 to 39 credits):

- | | |
|---|---|
| (1) One of the following courses (3 to 5 credits): | |
| BS 161 Cell and Molecular Biology | 3 |
| BS 162 Organismal and Population Biology | 3 |
| BS 181H Honors Cell and Molecular Biology | 3 |
| BS 182H Honors Organismal and Population Biology | 3 |
| ENT 205 Pests, Society and Environment | 3 |
| IBIO 150 Integrating Biology: from DNA to Populations | 3 |
| LB 144 Biology I: Organismal Biology | 4 |
| LB 145 Biology II: Cellular and Molecular Biology | 5 |
| MMG 141 Introductory Human Genetics | 3 |
| MMG 201 Fundamentals of Microbiology | 3 |
| PLB 105 Plant Biology | 3 |
| PSL 250 Introductory Physiology | 4 |
| (2) One of the following groups of courses (8 to 10 credits): | |
| (a) CEM 141 General Chemistry | 4 |
| CEM 142 General and Inorganic Chemistry | 3 |
| CEM 161 Chemistry Laboratory I | 1 |

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- (b) CEM 151 General and Descriptive Chemistry 4
- CEM 152 Principles of Chemistry 3
- CEM 161 Chemistry Laboratory I 1
- (c) CEM 181H Honors Chemistry I 4
- CEM 182H Honors Chemistry II 4
- CEM 185H Honors Chemistry Laboratory I 2
- (d) LB 171 Principles of Chemistry I 4
- LB 171L Introductory Chemistry Laboratory I 1
- LB 172 Principles of Chemistry II 3
- (3) One of the following groups of Mathematics courses (12 to 14 credits):
 - (a) MTH 132 Calculus I 3
 - MTH 133 Calculus II 4
 - MTH 234 Multivariable Calculus 4
 - MTH 235 Differential Equations 3
 - (b) MTH 152H Honors Calculus I 3
 - MTH 153H Honors Calculus II 4
 - MTH 254H Honors Multivariable Calculus 4
 - MTH 235 Differential Equations 3
 - or
 - MTH 340 Ordinary Differential Equations I 3
 - (c) LB 118 Calculus I 4
 - LB 119 Calculus II 4
 - LB 220 Calculus III 4
 - MTH 235 Differential Equations 3
 - or
 - MTH 340 Ordinary Differential Equations I 3
 - (d) The following course (4 credits):
 - CMSE 201 Introduction to Computational Modeling 4
- b. The following courses in the Department of Physics and Astronomy: (39 to 41 credits)
 - (1) All of the following Astronomy courses (16 credits):
 - AST 207 The Science of Astronomy 3
 - AST 208 Planets and Telescopes 3
 - AST 304 Stars 3
 - AST 308 Galaxies and Cosmology 3
 - AST 410 Senior Thesis 4
 - Students must enroll for a total of 4 credits of AST 410. This is normally split over two semesters.
 - (2) One of the following groups of Physics courses (8 to 10 credits):
 - (a) 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) PHY 193H Honors Physics I - Mechanics 4
 - PHY 294H Honors Physics II - Electromagnetism 4
 - PHY 191 Physics Lab for Scientists I 1
 - PHY 192 Physics Lab for Scientists II 1
 - (c) LB 273 Physics I 4
 - LB 274 Physics II 4
 - (3) All of the following courses (15 credits):
 - PHY 215 Thermodynamics and Modern Physics 3
 - 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

Bachelor of Arts

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

Requirements for the Bachelor of Arts Degree in Physics

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. (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.

3. The following requirements for the major:

CREDITS

- a. The following courses outside the Department of Physics and Astronomy (29 to 33 credits):

- (1) One of the following courses (3 to 5 credits):

- BS 161 Cell and Molecular Biology 3
- BS 162 Organismal and Population Biology 3
- BS 181H Honors Cell and Molecular Biology 3
- BS 182H Honors Organismal and Population Biology 3
- ENT 205 Pests, Society and Environment 3
- IBIO 150 Integrating Biology: From DNA to Populations 3
- LB 144 Biology I: Organismal Biology 4
- LB 145 Biology II: Cellular and Molecular Biology 5
- MMG 141 Introductory Human Genetics 3
- MMG 201 Fundamentals of Microbiology 3
- PLB 105 Plant Biology 3
- PSL 250 Introductory Physiology 4

- (2) One of the following groups of courses (5 to 6 credits):

- (a) CEM 141 General Chemistry 4
- CEM 161 Chemistry Laboratory I 1
- (b) CEM 151 General and Descriptive Chemistry 4
- CEM 161 Chemistry Laboratory I 1
- (c) CEM 181H Honors Chemistry I 4
- CEM 185H Honors Chemistry Laboratory I 2
- (d) LB 171 Principles of Chemistry I 4
- LB 171L Introductory Chemistry Laboratory I 1

- (3) One of the following groups of Mathematics courses (14 or 15 credits):

- (a) MTH 132 Calculus I 3
- MTH 133 Calculus II 4
- MTH 234 Multivariable Calculus 4
- MTH 235 Differential Equations 3
- (b) MTH 152H Honors Calculus I 3
- MTH 153H Honors Calculus II 4
- MTH 254H Honors Multivariable Calculus 4
- MTH 235 Differential Equations 3
- or
- MTH 340 Ordinary Differential Equations I 3
- (c) LB 118 Calculus I 4
- LB 119 Calculus II 4
- LB 220 Calculus III 4
- MTH 235 Differential Equations 3
- or
- MTH 340 Ordinary Differential Equations I 3

- (4) The following course (4 credits):

- CMSE 201 Computational Modeling and Data Analysis I 4

- (5) One additional mathematics courses at the 300-level or above of at least 3 credits. PHY 415 Methods of Theoretical Physics may be used towards the fulfillment of this requirement.

- b. The following courses in the Department of Physics and Astronomy (33 to 38 credits):

- (1) One of the following groups of courses (8 to 10 credits):

- (a) 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) PHY 193H Honors Physics I - Mechanics 4
- PHY 294H Honors Physics II - Electromagnetism 4
- PHY 191 Physics Laboratory for Scientists, I 1
- PHY 192 Physics Laboratory for Scientists, II 1
- (c) PHY 173 Studio Physics for Scientists and Engineers I 5
- PHY 174 Studio Physics for Scientists and Engineers II 5
- (d) LB 273 Physics I 4
- LB 274 Physics II 4

- (2) All of the following courses (12 credits):

- PHY 215 Thermodynamics and Modern Physics 3
- PHY 321 Classical Mechanics I 3
- PHY 410 Thermal and Statistical Physics 3
- PHY 471 Quantum Physics I 3

- (3) One of the following courses (3 or 4 credits):

- PHY 431 Optics I 3
- PHY 440 Electronics 4

- (4) One of the following groups of courses (4 or 6 credits):

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|-----|---|---|---|
| (a) | PHY 490 | Physics Senior Thesis | 4 |
| | Students must complete two enrollments of this course for a total of 4 credits. | | |
| (b) | Two of the following courses: | | |
| | PHY 491 | Introduction to Condensed Matter Physics | 3 |
| | PHY 492 | Introduction to Nuclear Physics | 3 |
| | PHY 493 | Introduction to Elementary Particle Physics | 3 |
| | PHY 494 | Survey of Physics Education Research (W) | 3 |

MINOR IN PHYSICS

The Minor in Physics provides students with a deep understanding of the discipline of physics and to the fundamental physical laws at play in the world around us – and in the universe as a whole. The minor complements other majors where additional physics knowledge beyond the introductory level is beneficial. It prepares students to apply scientific methodology, to think critically and quantitatively, and to understand the experimental and theoretical methods used in modern physics.

The minor is available as an elective to students who are enrolled in bachelor's degree programs at Michigan State University other than the Bachelor of Arts and Bachelor of Science Degrees in Physics, the Bachelor of Science Degree in Chemical Physics, and the Bachelor of Science Degree in Astrophysics. The minor is not available to students pursuing teacher certification through the Disciplinary Teaching Minor in Physics.

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

Students who plan to complete the requirements of the minor should consult the undergraduate advisor in the Department of Physics and Astronomy. Admission to the minor requires approval by the Physics and Astronomy undergraduate program director to ensure students are informed of the minor requirements, and have adequate preparation, including the math prerequisites.

Requirements for the Minor in Physics

- | | CREDITS |
|--|---------|
| Students must complete a minimum of 18 credits from the following: | |
| 1. One of the following (5 credits): | |
| (a) PHY 173 Studio Physics for Scientists and Engineers I | 5 |
| (b) PHY 183 Physics for Scientists and Engineers I | 4 |
| PHY 191 Physics Laboratory for Scientists, I | 1 |
| (c) PHY 191 Physics Laboratory for Scientists, I | 1 |
| PHY 193H Honors Physics I – Mechanics | 4 |
| (d) LB 273 Physics I | 4 |
| 2. One of the following (5 credits): | |
| (a) PHY 174 Studio Physics for Scientists and Engineers II | 5 |
| (b) PHY 184 Physics for Scientists and Engineers II | 4 |
| PHY 192 Physics Laboratory for Scientists, II | 1 |
| (c) PHY 192 Physics Laboratory for Scientists, II | 1 |
| PHY 294H Honors Physics II – Electromagnetism | 4 |
| (d) LB 274 Physics II | 4 |
| 3. The following course (3 credits): | |
| PHY 215 Thermodynamics and Modern Physics | 3 |
| 4. One of the following courses (3 or 4 credits): | |
| PHY 431 Optics I | 3 |
| PHY 440 Electronics | 4 |
| PHY 451 may be substituted for PHY 431 or PHY 440. | |
| 5. The following course (4 credits): | |
| CMSE 201 Computational Modeling and Data Analysis I | 4 |

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 in both physics and astrophysics. A Master of Science degree and Graduate Certificate in Accelerator Science and Engineering and Instrumentation in High Energy Physics are also available.

Current experimental and theoretical research programs include work in the general fields of accelerator physics, acoustics, atomic, molecular and optical physics, biological physics, computational physics, condensed matter physics, elementary particles, low-temperature physics, nanoscience, nuclear physics, physics education, and quantum computing. Students who are enrolled in doctoral degree programs in the Department of Physics and Astronomy may elect joint programs with many partnering departments including Biochemistry, Chemical Engineering, Chemistry, Computational Mathematics, Science and Engineering, Electrical and Computer Engineering, Materials Science, and Mathematics.

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, visit <http://www.pa.msu.edu> or contact the Department of Physics and Astronomy.

ACCELERATOR SCIENCE AND ENGINEERING

The Master of Science degree in Accelerator Science and Engineering provides graduate students the opportunity to further their understanding of accelerator science and technology. Graduates will be certified, well trained, and ready for productive careers in Accelerator Science and Engineering. Research is supported by the Accelerator Science and Engineering Traineeship (ASET) Program. Students will gain a broad understanding of physics and engineering of large accelerators; superconducting radio frequency accelerator physics and engineering; radio frequency power engineering; and large-scale cryogenic systems, and their role in accelerator science and engineering. Upon completion of the program, students are able to contribute to the research and development of accelerator

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systems and associated technologies and support operations of accelerator systems, primarily, but not limited to accelerator systems at National Laboratories and industries.

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 accelerator science and engineering on regular status, the student must have:

1. Completed mathematics and physics 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.
3. General GRE and Physics GRE examinations are required for admission to the program. Scores should be sent electronically, directly to Michigan State University.
4. For international students, except those with a 4-year degree from a U.S. institution, TOEFL examination scores must be submitted with a total average score of 100 or higher on the iBT.

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. Collateral course work will not count towards the requirements for the degree.

Requirements for the Master of Science Degree in Accelerator Science and Engineering

CREDITS

The student must complete a total of 30 credits for the degree with a grade-point average of 3.00 under Plan A (with thesis). A minimum of 16 credits must be at the 800-level or above.

Requirements for Plan A:

1. The following course (3 credits):
PHY 862 Accelerator Systems 3
2. At least two courses from the following or any other 800 or 900-level accelerator science-focused courses as approved by the Physics and Astronomy Graduate Program Director (6 credits):
ECE 837 Computational Methods in Electromagnetics 3
ECE 850 Electrodynamics of Plasmas 3
ECE 989 Advanced Topics in Plasmas 3
PHY 861 Beam Physics 3
PHY 864 Accelerator Technology 3
PHY 905 Special Problems 3
PHY 961 Nonlinear Beam Dynamics 3
PHY 962 Particle Accelerators 3
PHY 963 U.S. Particle Accelerator School 3
PHY 964 Seminar in Beam Physics Research 3

Additional courses may be used to fulfill this requirement if approved by the Director of Graduate Studies. Up to 14 credits of undergraduate senior-level courses that have not been used towards any other degree may be used to fulfill this requirement with the exception of PHY 405 and PHY 490.

Additional Requirements for Plan A

1. Complete 5 to 10 credits of PHY 899 Master's Thesis Research.
2. Pass a final oral examination in defense of the thesis.

GRADUATE CERTIFICATE IN INSTRUMENTATION IN HIGH ENERGY PHYSICS

The Graduate Certificate in Instrumentation in High Energy Physics complements a graduate students' degree in the field of instrumentation applicable to high energy physics.

The TRAIN-MI program will bring together MSU's strengths to formulate a curriculum addressing three major areas: (1) advanced sensors for particle and radiation detection, including quantum devices; (2) application-specific front-end electronics and data acquisition' and (3) systems design and engineering for complex instrumentation, including in extreme radiation, temperature, and low-background environments.

Requirements for the Graduate Certificate in Instrumentation in High Energy Physics

CREDITS

Students must complete 9 credits from the following:

1. One of the following courses that includes instruction on particle interactions with matter. The topic must be approved by the Physics and Astronomy Graduate Program Director.
CEM 985 Selected Topics in Nuclear Chemistry 3
PHY 959 Special Topics in High Energy Physics 3
2. Complete 6 credits from the following list of approved courses, or any other 800 or 900-level accelerator science-focused courses as approved by the Physics and Astronomy Graduate Program Director.
CEM 985 Selected Topics in Nuclear Chemistry 3
HRT 860 Scientific Writing Workshop 3
PHY 905 Special Problems 3
PHY 959 Special Topics in High Energy Physics 3
Topics in CEM 985 and PHY 959 must be different than the topic used to fulfill requirement 1. above and must be approved by the Physics and Astronomy Graduate Program Director.

Students are expected to maintain a minimum cumulative grade-point average of 3.0 in all courses in the certificate.

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.

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Requirements for the Master of Science Degree in Astrophysics and Astronomy

CREDITS

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 a qualifying master's exam that tests basic knowledge of undergraduate physics with a grade of B or above before the end of the student's first semester of the second year. A maximum of three attempts is allowed on this exam.
3. Complete the following core physics courses or their subject examinations, and the following core of astronomy courses, with a grade-point average of 3.0 or higher.

Physics

Two of the following:

- | | | |
|---------|-----------------------------|---|
| PHY 820 | Classical Mechanics | 3 |
| PHY 831 | Statistical Mechanics | 3 |
| PHY 841 | Classical Electrodynamics I | 3 |

Astronomy

All of the following:

- | | | |
|---------|-------------------------|---|
| AST 810 | Radiation Astrophysics | 3 |
| AST 825 | Galactic Astronomy | 3 |
| AST 835 | Extragalactic Astronomy | 3 |
| AST 840 | Stellar Astrophysics | 3 |
4. Complete a minimum of 6 credits of additional course work in physics, astrophysics or computation, with a grade-point average of 3.0 or higher at the 800-level or above as chosen in consultation with the student's guidance committee.
 5. Complete training in Responsible Conduct of Research (RCR).

Additional Requirements for Plan A

1. Complete 4 to 10 credits of Astronomy 899 Master's Thesis Research.
2. The student must form a guidance committee of three regular faculty members: the student's master's thesis advisor, one additional member of the astronomy group and one faculty member from outside the astronomy group.
3. Pass a final oral examination in defense of the thesis.

Additional Requirements for Plan B

1. Complete 6 credits in Astronomy 805 Research Project. This research project is taken over two semesters and will be graded on the basis of a written paper and oral examination.
2. Pass a final examination or evaluation.

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

CREDITS

The student must:

1. Pass the doctoral qualifying exam that tests basic knowledge of undergraduate physics with a grade of A before the end of the student's first semester of the second year. A maximum of three attempts is allowed on this exam.

2. Complete the following core graduate physics courses or their subject examinations, and the following core of astronomy courses, with a grade-point average of 3.375 or higher.

Physics

Two of the following:

- | | | |
|---------|---------------------------|---|
| PHY 820 | Classical Mechanics | 3 |
| PHY 831 | Statistical Mechanics | 3 |
| PHY 841 | Classical Electrodynamics | 3 |
| PHY 851 | Quantum Mechanics | 3 |

Astronomy

All of the following:

- | | | |
|---------|-------------------------|---|
| AST 810 | Radiation Astrophysics | 3 |
| AST 825 | Galactic Astronomy | 3 |
| AST 835 | Extragalactic Astronomy | 3 |
| AST 840 | Stellar Astrophysics | 3 |
3. Satisfactorily complete 6 credits in Astronomy 805 Research Project. This research project is taken over two semesters and will be graded on the basis of a written paper and oral examination that also serves as the student's comprehensive examination.
 4. Complete a minimum of 6 credits of additional course work in physics, astrophysics or computation, with a grade-point average of 3.375 or higher at the 800-level or above as chosen in consultation with the student's guidance committee.
 5. Complete training in Responsible Conduct of Research (RCR).
 6. Complete one semester as a Teaching Assistant (TA). International students who are not native English speakers must pass the SPEAK test in order to be a TA.
 7. Complete 24 credits of doctoral dissertation research in AST 999.
 8. Complete a doctoral dissertation on original research, followed by an oral examination in defense of the dissertation.

CHEMICAL PHYSICS

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

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) including:

1. A minimum of 16 credits of approved course work at the 800-900 level.
2. A maximum of 14 credits of 400-level Physics and Astronomy courses approved by the Director of Graduate Studies. These courses may not have been used previously towards another degree. Courses outside of

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the department may be used with approval by the Director of Graduate Studies.

Concentration in Beam Physics. Students pursuing a concentration in beam physics must satisfy the regular requirements for the master's degree. Credits for the concentration may be earned through courses including PHY 861, PHY 961, PHY 962, PHY 963, and PHY 964.

Additional Requirements for Plan A

1. Complete 5 to 10 credits of course work from PHY 800 Research Methods and PHY 899 Master's Thesis Research combined. At least 4 credits must be in PHY 899.
2. Successfully complete the oral examination in defense of the thesis.

Additional Requirements for Plan B

1. Complete at least 5 credits of research course work normally met by completing PHY 800 Research Methods.
2. Completion of a final evaluation.

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.

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

CREDITS

Students must:

1. pass the comprehensive examination requirement, which is fulfilled by passing a series of subject examinations (see item 2.) and an oral subject examination (see item 3.).
2. select three of the following courses, in coordination with an initial mentoring committee consisting of the graduate program director, an initial faculty advisor, and another faculty member with expertise in the research area of interest. These three courses will serve as the subject examination courses that count toward the comprehensive examination requirements. The subject examination grade is determined by the higher of the course grade and the final examination grade. A student may demonstrate their ability in the material by scoring a 3.0 on the final examination in lieu of taking the course.

PHY 820	Classical Mechanics	3
PHY 831	Statistical Mechanics	3
PHY 841	Classical Electrodynamics I	3
PHY 851	Quantum Mechanics I	3
3. pass the oral subject examination which consists of a research presentation that is evaluated by the students' guidance committee based on a published rubric. A 3.5 or 4.0 grade constitutes a passing grade. The oral subject exam shall be held by the beginning of the third year after entering the program if

the Subject Exam requirement is fulfilled by the end of the fall semester of the second year. If the Subject Exam requirement is fulfilled later than fall of the second year, the Guidance Committee should be formed no later than six months after that happens.

4. complete the following course with a grade of 3.0 if they have not taken an equivalent course previously or demonstrated that they acquired the necessary skills:

PHY 810	Methods of Theoretical Physics	3
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Course equivalency is determined by the Graduate Program Director.
5. complete one of the courses listed under item 2. that was not selected as one of the three subject exam courses if the student's initial mentoring committee or guidance committee determines the background is required for the research.

PHY 842	Classical Electrodynamics II	3
PHY 852	Quantum Mechanics II	3
6. complete a minimum of 24 credits of PHY 999 Doctoral Dissertation Research.
7. submit a dissertation proposal or evaluation to the guidance committee based on the PHY 999 Doctoral Dissertation Research.
8. successfully defend the doctoral dissertation in a meeting with the guidance committee following a public presentation about the PHY 999 Doctoral Dissertation Research.

Concentration in Beam Physics. Students are exempt from enrolling in the core courses mentioned in item 2., 4., and 5. above, and acquire the corresponding knowledge through equivalent studies and courses at local universities. All other requirements must be met. Written examinations can be administered by mutually agreeable local proctors upon prior arrangements with the Director of Graduate Studies. The final student thesis defense must be at MSU.

Changes to, or a waiver for certain program elements of the above requirements are, within the requirements set by the University and the College of Natural Science, subject to the approval by the Graduate Program Director.

GRADUATE CERTIFICATE IN ACCELERATOR SCIENCE AND ENGINEERING

The Graduate Certificate in Accelerator Science and Engineering provides graduate students the opportunity to further their understanding of accelerator science and technology. Graduates will be certified, well trained, and ready for productive careers in Accelerator Science and Engineering. Research is supported by the Accelerator Science and Engineering Traineeship (ASET) Program. The certificate is available to masters or doctoral students at Michigan State University. Students can apply for the certificate at any time prior to receiving their graduate degree. Students who wish to complete the certificate must consult with the Graduate Program Director in Accelerator Science and Engineering prior to beginning course work in the program.

Requirements for the Graduate Certificate in Accelerator Science and Engineering

CREDITS

Complete a minimum of 9 credits from the following with a grade-point average of 3.0:

1. The following course (3 credits):

PHY 862	Accelerator Systems	3
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2. At least two courses from the following or any other 800 or 900-level accelerator science-focused courses as approved by the Physics and Astronomy Graduate Program Director (6 credits):

ECE 835	Advanced Electromagnetic Fields and Waves I	3
ECE 837	Computational Methods in Electromagnetics	3
ECE 850	Electrodynamics of Plasmas	3
ECE 989	Advanced Topics in Plasmas	3
ME 814	Convective Heat Transfer	3
ME 840	Computational Fluid Dynamics and Heat Transfer	3
ME 842	Advanced Turbomachinery	3
ME 940	Selected Topics in Thermal Science	3
PHY 861	Beam Physics	3
PHY 905	Special Problems	3

PHY 961	Nonlinear Beam Dynamics	3
PHY 962	Particle Accelerators	3
PHY 963	U.S. Particle Accelerator School	3
PHY 964	Seminar in Beam Physics Research	3

Students who enroll in ME 940 and PHY 905 must obtain approval of the Physics and Astronomy Graduate Program Director to ensure appropriate content. PHY 905 may be taken more than once as long as the topic taken is different.

DEPARTMENT of PHYSIOLOGY

Karl Olson, Chairperson

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

The Department of Physiology seeks to prevent and cure diseases through basic research on genes, proteins, and the regulatory signaling systems that control fundamental processes of cellular life.

Medical research in the modern era has enabled society to conquer many bacterial, viral, and parasitic diseases, including polio, diphtheria, small pox, and pneumonia. Much of medical research today focuses on diseases that result from alterations of fundamental molecular mechanisms within cells and tissues and include cancer, heart disease, kidney disease, bone and joint disorders, and diabetes. DNA carries in its sequence the genes that encode vast numbers of different proteins that are synthesized throughout the life cycle. It also encodes the regulatory instructions that determine exactly when and where each of those genes will be expressed. The Department of Physiology's research on genes and gene regulatory mechanisms includes explorations of both the normal expression of genetic information in development and abnormal expression in diseases such as cancer, diabetes, heart and pulmonary disease, and neuro-degenerative diseases.

Genomics at the Systems Level. The Department of Physiology conducts basic research aimed at understanding how the genes and proteins of multicellular organisms work. The basic goal is to understand the flow of genetic information during life and the translation of this information into functioning proteins, organized in complex systems that act as signaling ensembles to govern how cells multiply, differentiate, migrate, and die. Research conducted in pursuit of this goal is widely acknowledged to be crucial to the advancement of medical science.

The Department of Physiology seeks to provide fundamental information into the way genes, their regulation and dysregulation, determine our biological fate and how they can cause disease. The department takes a multidisciplinary approach that requires the scientific skills of a variety of disciplines, including many non-traditionally associated with biomedicine, and focuses on determining how genes and proteins signal cells in the processes of multiplication, differentiation, metabolism, migration, and cell death in the context of complex organisms. With a commitment to use the latest in cellular and molecular technologies, the Department of Physiology promotes an environment in which questions of

fundamental importance to medicine and biology can be addressed.

The Department of Physiology's approach is to promote research that probes the molecular mechanisms of particular medical problems, to investigate the interaction between environment and genes especially in causing disease, and to discover the role of many genes that are involved in particular diseases. Departmental scientists seek critical information into how specific genes are controlled and expressed by factors both internal and external to the organism. An ultimate aim is to achieve the ability to manipulate the expression of genes involved in disease such that illness can be ameliorated, prevented or cured.

For the most part, departmental scientists do not concentrate directly on treating patients or developing drug therapies, but instead focus on filling critical information gaps in understanding the molecular origins of a disease, and consequently serving as a knowledge bridge that is essential for other scientists and physicians, generally in collaboration, to translate that basic research into effective treatments and cures.

UNDERGRADUATE PROGRAMS

NEUROSCIENCE

The Bachelor of Science degree in Neuroscience is for students who wish to pursue a career in which a broad-based knowledge of the structure and function of the nervous system is necessary, including careers in research, education, healthcare or business. It is also intended for those students who seek admission to graduate study in neuroscience or health-related professional schools.

Several colleges and departments within Michigan State University cooperate in offering the interdepartmental Master of Science and 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 Master of Science and Doctor of Philosophy degree in neuroscience.

Students who are enrolled in the master's or 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.

Bachelor of Science

Requirements for the Bachelor of Science Degree in Neuroscience

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 Neuroscience.

The University's Tier II writing requirement for the Neuroscience major is met by completing Neuroscience 311L. That course is referenced in item 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

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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) BS 161 Cell and Molecular Biology 3
 - BS 162 Organismal and Population Biology 3
 - BS 171 Cell and Molecular Biology Laboratory 2
 - (2) BS 181H Honors Cell and Molecular Biology 3
 - BS 182H Honors Organismal and Population Biology 3
 - BS 191H Honors Cell and Molecular Biology Laboratory 2
 - (3) LB 144 Biology I: Organismal Biology 4
 - LB 145 Biology II: Cellular and Molecular Biology 5
- b. One of the following groups of courses (7 or 8 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
 - (3) CEM 181H Honors Chemistry I 4
 - CEM 182H Honors Chemistry II 4
 - (4) LB 171 Principles of Chemistry I 4
 - LB 172 Principles of Chemistry II 3
- c. One of the following courses (1 or 2 credits):
 - CEM 161L Chemistry Laboratory I 1
 - LB 171L Introductory Chemistry Laboratory 1
 - CEM 185H Honors Chemistry Laboratory I 2
- d. Both of the following courses (6 credits):
 - CEM 251 Organic Chemistry I 3
 - CEM 252 Organic Chemistry II 3
- e. One of the following groups of courses (6 or 8 credits):
 - (1) PHY 221 Studio Physics for Life Scientists I 4
 - PHY 222 Studio Physics for Life Scientists II 4
 - (2) PHY 231 Introductory Physics I 3
 - PHY 232 Introductory Physics II 3
 - (3) PHY 183 Physics for Scientists and Engineers I 4
 - PHY 184 Physics for Scientists and Engineers II 4
 - (4) PHY 193H Honors Physics I-Mechanics 4
 - PHY 294H Honors Physics II-Electromagnetism 4
 - (5) LB 273 Physics I 4
 - LB 274 Physics II 4
- f. One of the following courses (3 or 4 credits):
 - MTH 124 Survey of Calculus I 3
 - MTH 132 Calculus I 3
 - MTH 152H Honors Calculus I 3
 - LB 118 Calculus I 4
- g. One of the following courses (3 or 4 credits):
 - STT 201 Statistical Methods 4
 - STT 231 Statistics for Scientists 3
 - STT 421 Statistics I 3
 - STT 464 Statistics for Biologists 3
- h. Both of the following courses (8 credits):
 - BMB 401 Comprehensive Biochemistry 4
 - PSY 101 Introductory Psychology 4
- i. One of the following groups of courses (4 or 8 credits):
 - (1) PSL 310 Physiology for Pre-Health Professionals 4
 - (2) PSL 431 Human Physiology I 4
 - PSL 432 Human Physiology II 4
- k. All of the following courses (15 credits):
 - NEU 101 Frontiers in Neuroscience 1
 - NEU 301 Introduction to Neuroscience I 3
 - NEU 302 Introduction to Neuroscience II 3
 - NEU 311L Neuroscience Laboratory (W) 2
 - NEU 401 Cellular and Molecular Neuroscience 3
 - NEU 402 Behavioral and Cognitive Neuroscience 3
- l. One of the following courses (3 or 4 credits):
 - NEU 403 Communication in Neuroscience (W) 3
 - LB 492 Senior Seminar (W) 4
- m. Complete a minimum of 3 credits from the following:
 - NEU 310 Psychology and Biology of Human Sexuality 3
 - NEU 416 Development of the Nervous System Through the Lifespan 3
 - NEU 417 Instrumental Methods of Analysis in Neuroscience 3
 - NEU 420 Neurobiology of Disease 3
 - NEU 440 Synaptic Transmission 3
 - NEU 450 The Autonomic Nervous System 3

NEU 460	Current Approaches in Molecular and Cellular Neuroscience	3
NEU 492	Special Topics in Neuroscience	1 to 3
PHM 422	Fundamentals of Neuropharmacology	2
PHM 431	Pharmacology of Drug Addiction	3
n. One of the following courses (3 or 4 credits):		
IBIO 341	Fundamental Genetics	4
MMG 409	Eukaryotic Cell Biology	3

PHYSIOLOGY

The Bachelor of Science degree program in Physiology is intended primarily for students who wish to pursue careers in medicine or other health-related fields, research, and industry, for which a thorough knowledge of physiology is necessary. The physiology major is particularly suitable for students in the life sciences who plan advanced study at the graduate or professional level. It combines comprehensive study of physiology, including molecular, cellular, and organ systems physiology with courses in biology, chemistry, physics, and mathematics. Students may complete the requirements for the Bachelor of Science degree in Physiology either within the College of Natural Science or as a Lyman Briggs College coordinate major. Students are encouraged to complete their preparatory biology, chemistry, mathematics, and physics courses early during their collegiate study in order to meet prerequisites for the required upper division courses in the major.

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 Physiology 460. 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 completion of the Biological Science, Chemistry, Mathematics, and Physics courses referenced in requirement 3. below satisfies the requirements referenced in 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: (62 to 71 credits)
 - (1) One course from each of the following groups of courses (6 to 8 credits):
 - (a) MTH 124 Survey of Calculus I 3
 - MTH 132 Calculus I 3
 - MTH 152H Honors Calculus I 3
 - LB 118 Calculus I 4
 - (b) MTH 126 Survey of Calculus II 3
 - MTH 133 Calculus II 4
 - MTH 153H Honors Calculus II 4
 - LB 119 Calculus II 4
 - STT 200 Statistical Methods 3
 - STT 201 Statistical Methods 4
 - STT 231 Statistics for Scientists 3
 - STT 421 Statistics I 3
 - STT 464 Statistics for Biologists 3
 - (2) One of the following groups of courses (7 or 8 credits):
 - (a) CEM 141 General Chemistry 4
 - CEM 142 General and Inorganic Chemistry 3

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- | | | | |
|------|--|---|---|
| (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 |
| (d) | LB 171 | Principles of Chemistry I | 4 |
| | LB 172 | Principles of Chemistry II | 3 |
| (3) | One of the following groups of courses (2 credits): | | |
| (a) | CEM 161 | Chemistry Laboratory I | 1 |
| | CEM 162 | Chemistry Laboratory II | 1 |
| (b) | LB 171L | Introductory Chemistry Laboratory I | 1 |
| | LB 172L | Principles of Chemistry II – Reactivity Laboratory | 1 |
| (c) | CEM 185H | Honors Chemistry Laboratory I | 2 |
| (4) | One of the following groups of courses (9 to 10 credits): | | |
| (a) | BS 161 | Cell and Molecular Biology | 3 |
| | BS 162 | Organismal and Population Biology | 3 |
| | BS 171 | Cell and Molecular Biology Laboratory | 2 |
| | BS 172 | Organismal and Population Biology Laboratory | 2 |
| (b) | LB 144 | Biology I: Organismal Biology | 4 |
| | LB 145 | Biology II: Cellular and Molecular Biology | 5 |
| (c) | BS 181H | Honors Cell and Molecular Biology | 3 |
| | BS 182H | Honors Organismal and Population Biology | 3 |
| | BS 191H | Honors Cell and Molecular Biology Laboratory | 2 |
| | BS 192H | Honors Organismal and Population Biology Laboratory | 2 |
| (5) | All of the following courses (8 credits): | | |
| | CEM 251 | Organic Chemistry I | 3 |
| | CEM 252 | Organic Chemistry II | 3 |
| | CEM 255 | Organic Chemistry Laboratory | 2 |
| (6) | One of the following groups of courses (8 or 10 credits): | | |
| (a) | PHY 221 | Studio Physics for Life Scientists I | 4 |
| | PHY 222 | Studio Physics for Life Scientists II | 4 |
| (b) | 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) | LB 273 | Physics I | 4 |
| | LB 274 | Physics II | 4 |
| (7) | One of the following courses (3 or 4 credits): | | |
| | ANTR 350 | Human Gross Anatomy for Pre-Health Professionals | 3 |
| | IBIO 320 | Developmental Biology | 4 |
| | IBIO 328 | Comparative Anatomy and Biology of Vertebrates | 4 |
| (8) | One of the following courses or groups of courses (4 to 6 credits): | | |
| (a) | BMB 401 | Comprehensive Biochemistry | 4 |
| (b) | BMB 461 | Advanced Biochemistry I | 3 |
| | BMB 462 | Advanced Biochemistry II | 3 |
| (9) | One of the following courses (3 credits): | | |
| | CEM 383 | Introductory Physical Chemistry I | 3 |
| | PSL 425 | Physiological Biophysics | 3 |
| (10) | Twelve credits in nonscience courses beyond the credits that are counted toward University requirements. | | |
| b. | All of the following courses in the Department of Physiology (16 credits): | | |
| | PSL 101 | Frontiers in Physiology | 1 |
| | PSL 431 | Human Physiology I | 4 |
| | PSL 432 | Human Physiology II | 4 |
| | PSL 450 | Physiology in Health and Disease | 3 |
| | PSL 460 | Topics in Physiology (W) | 2 |
| | PSL 475L | Capstone Laboratory in Physiology | 2 |
| | The completion of Physiology 450 and 475L satisfies the department's capstone course requirement. | | |

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 degree with a major in molecular, cellular, and integrative physiology or Doctor of Philosophy degree with a major in molecular, cellular, and integrative physiology may be

administered by any one of the four colleges referenced above.

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.

MOLECULAR, CELLULAR, AND INTEGRATIVE 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 degree program in physiology and Doctor of Philosophy degree program in molecular, cellular, and integrative 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.

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Requirements for the Master of Science Degree in Molecular, Cellular, and Integrative 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 advisor 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 advisor 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 Molecular, Cellular, and Integrative 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 advisor, and must include one representative from another department. The course work, research program, and overall requirements needed to qualify for candidacy for the degree are planned in consultation with the guidance committee. However, the student's Guidance Committee Report is approved by the committee only after the student has demonstrated the potential to do research. Such potential may be demonstrated by any of the following:

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

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

A dissertation based on original research outlined in the proposal must be submitted to, approved by, and defended in an oral examination before the guidance committee. The dissertation is expected to show evidence of originality in its conception and execution and must be written in a clear and

logical manner. Typically, three or more years of study beyond the bachelor's degree are needed to meet these requirements.

BIOMOLECULAR SCIENCE GATEWAY - FIRST YEAR

Students seeking a doctoral degree in biochemistry and molecular biology, cell and molecular biology, genetics and genome sciences, microbiology, genetics and immunology, pharmacology and toxicology, or molecular, cellular, and integrative physiology should apply through the BioMolecular Science Gateway—First Year for admission to any of these Ph.D. programs. Students should select the Ph.D. program in which they have the greatest interest. During the first two semesters of enrollment, students will have the opportunity to choose and complete at least four courses in appropriate disciplinary subjects. In the spring semester of the first year, they will have the opportunity to continue with the Ph.D. program initially selected or change to one of the other five programs that aligns most closely with their educational goals.

For additional information about the individual Ph.D. programs, refer to the statements in the Departments of Biochemistry and Molecular Biology, Microbiology, Genetics, and Immunology, and Physiology in the *College of Natural Science* section of this catalog, statements on the programs in Cell and Molecular Biology and Genetics and Genome Sciences in the *College of Natural Science* section of this catalog, and statement on the Department of Pharmacology and Toxicology in the *College of Osteopathic Medicine* section of this catalog.

DEPARTMENT of PLANT BIOLOGY

Andrea Case, Chairperson

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

Plant Biology is the branch of natural science that deals with all aspects of the biology of plants, encompassing all levels of biological organization from molecules to the ecosystem. Plant biology concerns itself with the study of the structure, function, evolution, physiology, molecular biology, biochemistry, genetics, and systematics of all taxonomic groups of plants and fungi. Plant biology is central to the wide divergence of disciplines that make up modern plant science at Michigan State University and deals with the relationships between plants and society. Students in this program can study all aspects of plant biology and they are trained to integrate information between different hierarchies of biological organization while at the same time developing a deep understanding of their area of specialization.

COLLEGE OF NATURAL SCIENCE

UNDERGRADUATE PROGRAMS

The Department of Plant Biology offers two Bachelor of Science degree programs: one in plant biology and one in environmental biology/plant biology. In addition to course work, students experience scientific research through an independent research project that is part of the graduation requirements.

PLANT BIOLOGY

The Bachelor of Science degree program with a major in plant biology is designed for students who plan to pursue careers in plant biology or related disciplines.

Requirements for the Bachelor of Science Degree in Plant Biology

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

The University's Tier II writing requirement for the Plant Biology major is met by completing Plant Biology 498 and 499 and Integrative Biology 355L and 445. Those courses are referenced in item 3. below.

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

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

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

- The following requirements for the major:

CREDITS

- One of the following groups of courses (9 or 10 credits):

(1)	BS 161	Cell and Molecular Biology	3
	BS 162	Organismal and Population Biology	3
	BS 171	Cell and Molecular Biology Laboratory	2
	BS 172	Organismal and Population Biology Laboratory	2
(2)	LB 144	Biology I: Organismal Biology	4
	LB 145	Biology II: Cellular and Molecular Biology	5
(3)	BS 181H	Honors Cell and Molecular Biology	3
	BS 182H	Honors Organismal and Population Biology	3
	BS 191H	Honors Cell and Molecular Biology Laboratory	2
	BS 192H	Honors Organismal and Population Biology Laboratory	2

- One of the following groups of courses (8 to 10 credits):

(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
(3)	LB 171	Principles of Chemistry I	4
	LB 171L	Introductory Chemistry Laboratory I	1
	LB 172	Principles of Chemistry II	3
(4)	CEM 181H	Honors Chemistry I	4
	CEM 182H	Honors Chemistry II	4
	CEM 185H	Honors Chemistry Laboratory I	2

- Both of the following courses (6 credits):

	CEM 251	Organic Chemistry I	3
	CEM 252	Organic Chemistry II	3

- One of the following groups of courses (8 or 10 credits):

(1)	PHY 183	Physics for Scientists and Engineers I	4
	PHY 184	Physics for Scientists and Engineers II	4
(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
(3)	LB 273	Physics I	4
	LB 274	Physics II	4

(4)	PHY 221	Studio Physics for Life Scientists I	4
	PHY 222	Studio Physics for Life Scientists II	4
(5)	PHY 241	Physics for Cellular and Molecular Biologists I	4
	PHY 242	Physics for Cellular and Molecular Biologists II	4
(6)	PHY 173	Studio Physics for Scientists and Engineers I	5
	PHY 174	Studio Physics for Scientists and Engineers II	5
e.	One of the following courses (3 or 4 credits):		
	LB 118	Calculus I	4
	MTH 124	Survey of Calculus I	3
	MTH 132	Calculus I	3
	MTH 152H	Honors Calculus I	3
f.	One of the following courses (3 or 4 credits):		
	LB 119	Calculus II	4
	MTH 126	Survey of Calculus II	3
	MTH 133	Calculus II	4
	MTH 153H	Honors Calculus II	4
	STT 231	Statistics for Scientists	3
g.	All of the following courses (27 credits):		
	IBIO 355	Ecology	3
	IBIO 355L	Ecology Laboratory (W)	1
	IBIO 341	Fundamental Genetics	4
	IBIO 445	Evolution (W)	3
	PLB 203	Biology of Plants	4
	PLB 415	Plant Physiology	3
	PLB 416L	Plant Physiology Laboratory	2
	PLB 418	Plant Systematics	3
h.	One of the following options (4 or 6 credits):		
	(1)	BMB 401 Comprehensive Biochemistry	4
	(2)	BMB 461 Advanced Biochemistry I	3
		BMB 462 Advanced Biochemistry II	3
i.	One of the following, either (a) or (b) (4 credits):		
	(a)	PLB 498 Undergraduate Research	3
		PLB 499 Senior Seminar (W)	1
	(b)	PLB 495 Internship in Plant Biology	3
		PLB 499 Senior Seminar (W)	1
j.	Two 300–400 level courses relating to plant biology approved by the Department of Plant Biology (6 to 8 credits)		

ENVIRONMENTAL BIOLOGY/PLANT BIOLOGY

The Bachelor of Science degree program in environmental biology/plant biology 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.

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

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

The University's Tier II writing requirement for the Environmental Biology/Plant Biology major is met by completing the following courses: Plant Biology 498, 499 and Integrative Biology 355L. Those courses are referenced in item 3. a. below.

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

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

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

- The following requirements for the major:

CREDITS

- One of the following groups of courses (8 to 10 credits):

(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
(3)	LB 171	Principles of Chemistry I	4
	LB 171L	Introduction to Chemistry Laboratory I	1
	LB 172	Principles of Chemistry II	3

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- (4) CEM 181H Honors Chemistry I 4
- CEM 182H Honors Chemistry II 4
- CEM 185H Honors Chemistry Laboratory I 2
- b. One of the following groups of courses: (9 or 10 credits)
- (1) BS 161 Cell and Molecular Biology 3
- BS 162 Organismal and Population Biology 3
- BS 171 Cell and Molecular Biology Laboratory 2
- BS 172 Organismal and Population Biology Laboratory 2
- (2) LB 144 Biology I: Organismal Biology 4
- LB 145 Biology II: Cellular and Molecular Biology 5
- (3) BS 181H Honors Cell and Molecular Biology 3
- BS 182H Honors Organismal and Population Biology 3
- BS 191H Honors Cell and Molecular Biology Laboratory 2
- BS 192H Honors Organismal and Population Biology Laboratory 2
- c. One of the following groups of courses (8 or 10 credits):
- (1) PHY 183 Physics for Scientists and Engineers I 4
- PHY 184 Physics for Scientists and Engineers II 4
- (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
- (3) LB 273 Physics I 4
- LB 274 Physics II 4
- (4) PHY 221 Studio Physics for Life Scientists I 4
- PHY 222 Studio Physics for Life Scientists II 4
- (5) PHY 241 Physics for Cellular and Molecular Biologists I 4
- PHY 242 Physics for Cellular and Molecular Biologists II 4
- (6) PHY 173 Studio Physics for Scientists and Engineers I 5
- PHY 174 Studio Physics for Scientists and Engineers II 5
- d. One of the following courses (3 or 4 credits):
- MTH 124 Survey of Calculus I 3
- MTH 132 Calculus I 3
- MTH 152H Honors Calculus I 3
- LB 118 Calculus I 4
- e. One of the following courses (3 credits):
- STT 231 Statistics for Scientists 3
- STT 224 Introduction to Probability and Statistics for Ecologists 3
- f. One of the following, either (1) or (2) (4 or 6 credits):
- (1) CEM 143 Survey of Organic Chemistry 4
- (2) CEM 251 Organic Chemistry I 3
- CEM 252 Organic Chemistry II 3
- g. All of the following courses (23 credits):
- CSS 210 Fundamentals of Soil Science 3
- FW 417 Wetland Ecology and Management 3
- GEO 221 Introduction to Geographic Information 3
- IBIO 355 Ecology 3
- IBIO 355L Ecology Laboratory (W) 1
- PLB 203 Biology of Plants 4
- PLB 415 Plant Physiology 3
- PLB 418 Plant Systematics 3
- h. Both of the following (4 credits):
- (1) One of the following (3 credits):
- PLB 495 Internship in Plant Biology 3
- PLB 498 Undergraduate Research 3
- (2) PLB 499 Senior Seminar (W) 1
- i. One of the following courses (3 or 4 credits):
- CSS 350 Introduction to Plant Genetics 3
- IBIO 341 Fundamental Genetics 4
- j. One of the following courses (3 or 4 credits):
- ENT 404 Fundamentals of Entomology 3
- PLP 405 Plant Pathology 3
- PLP 407 Diseases and Insects of Forest and Shade Trees 4
- k. One of the following courses (3 credits):
- FW 410 Upland Ecosystem Management 3
- FW 444 Conservation Biology 3
- l. Two 300–400 level courses relating to environmental biology approved by the Department of Plant Biology (6 to 8 credits)

GRADUATE STUDY

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

PLANT BIOLOGY

Graduate students in plant biology may emphasize one or more of a number of special areas, including anatomy, bryology, cell biology, ecology, genetics, molecular biology, morphology, mycology, paleobotany, physiology, and taxonomy. 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, 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 Plant Biology

CREDITS

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

For either Plan A or Plan B, the student must complete at least 30 credits including:

1. The following course:
 - PLB 801 Foundations of Plant Biology 3
2. Acquire teaching experience by assisting in at least one course.
3. Completion of the Responsible Conduct of Research Workshop series offered by The Graduate School.

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 Plant Biology

CREDITS

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

1. Complete the following courses:
 - a. The following course:

PLB 801 Foundations of Plant Biology	3
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 - b. Completion of the Responsible Conduct of Research Workshop series offered by The Graduate School.
 - c. One of the following courses:

CMB 800 Cell and Molecular Biology Seminar	1
ENT 812 Graduate Seminar	1
FW 893 Seminar in Fisheries and Wildlife	1
GEN 800 Genetics Seminar	1
GEO 874 Seminar in Geographic Information Science	3
HRT 892 Plant Breeding and Genetics Seminar	1
IBIO 891 Current Topics in Ecology and Evolution	1
IBIO 895 Seminar	1
PLP 894 Seminar in Plant Pathology	1
2. Pass a preliminary examination.
3. Acquire teaching experience by assisting in two courses.
4. Pass a final oral examination in defense of the dissertation.

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

GRADUATE CERTIFICATE IN COMPUTATIONAL PLANT SCIENCE

The Graduate Certificate in Computational Plant Science provides interdisciplinary training that intersects plant biology and computational and data sciences. The certificate address pressing problems in their respective fields and synthesizes these disciplines to address vast challenges in plant biology.

Requirements for the Graduate Certificate in Computational Plant Science

Students must complete a minimum of 9 credits from the following:

1. All of the following courses (7 credits):

CSS 844 Frontiers in Computational and Plant Sciences	3
HRT 841 Foundation in Computational and Plant Sciences	3
PLB 843 Forum in Computational and Plant Sciences	1
2. Complete a minimum of 2 credits from the following courses:

Biologists relevant courses:

CMSE 491 Selected Topics in Computational Mathematics, Science, and Engineering	1 to 4
CMSE 801 Introduction to Computational Modeling	3
CMSE 820 Mathematical Foundations of Data Science	3
CMSE 822 Parallel Computing	3
CMSE 823 Numerical Linear Algebra	3
CMSE 890 Selected Topics in Computational Mathematics, Science, and Engineering	1 to 4

Non-Biologists relevant courses:

BMB 801 Molecular Biology	3
BMB 978 Seminar in Biochemistry	1
HRT 894 Horticulture Seminar	1
IBIO 445 Evolution (W)	3
PLB 400 Introduction to Bioinformatics	3
PLB 801 Foundations of Plant Biology	3

DEPARTMENT of STATISTICS and PROBABILITY

Hao Zhang, Chairperson

Statistics is a foundational discipline that drives data science and provides systematic methods for collecting, summarizing, modeling, and interpreting data. These methods enable individuals across a wide range of fields to make informed decisions based on rigorous analyses and computational techniques. Probability theory underpins many aspects of statistical modeling, guided by practical considerations of computation and scientific interpretability. Advances in statistics and probability have propelled progress in diverse areas including the physical, biological, social, and agricultural sciences, as well as in engineering, medicine and business. They are dynamic areas of theoretical and methodological research that form the intellectual foundation of the modern era of big data and artificial intelligence and play a central role in advancing data-driven discovery.

UNDERGRADUATE PROGRAMS

The Department of Statistics and Probability offers degree opportunities leading to a Bachelor of Arts or Bachelor of Science degree in Statistics and a Bachelor of Science degree in Quantitative Risk Analytics.

The Statistics degree programs provide students with tools and techniques to visualize and analyze data from in a wide variety of areas, and prepares students with mathematical and computational skills that are used in many fields including industry, business, medicine, and social science.

The Bachelor of Science degree in Quantitative Risk Analytics provides students the quantitative skills necessary for employment in the insurance and risk industry, including a mathematical treatment of probability and statistics, interest-rate theory and financial mathematics, predictive analytics and other data science tools, and insurance operations.

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 Statistics and Probability 481. 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 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:

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	CREDITS
a. The following courses (19 to 23 credits):	
(1) One of the following courses (3 or 4 credits):	
LB 118 Calculus I	4
MTH 132 Calculus I	3
MTH 152H Honors Calculus I	3
(2) One of the following courses (4 credits):	
LB 119 Calculus II	4
MTH 133 Calculus II	4
MTH 153H Honors Calculus II	4
(3) One of the following course (4 credits):	
LB 220 Calculus III	4
MTH 234 Multivariable Calculus	4
MTH 254H Honors Multivariable Calculus	4
(4) One of the following groups of courses (4 to 7 credits):	
(a) MTH 299 Transitions	4
MTH 309 Linear Algebra I	3
(b) MTH 299 Transitions	4
MTH 314 Matrix Algebra with Applications	3
(c) MTH 317H Honors Linear Algebra	4
(5) One of the following courses (3 credits):	
CMSE 201 Computational Modeling and Data Analysis I	4
CSE 231 Introduction to Programming I	4
b. The following courses (10 credits):	
(1) The following course (4 credits):	
STT 180 Introduction to Data Science	4
(2) One of the following courses (3 credits):	
STT 441 Probability and Statistics I: Probability	3
STT 861 Theory of Probability and Statistics I	3
(3) One of the following courses (3 credits):	
STT 442 Probability and Statistics II: Statistics	3
STT 862 Theory of Probability and Statistics II	3
c. The following capstone course (3 credits):	
STT 481 Capstone in Statistics (W)	3
d. Three of the following courses (9 or 10 credits):	
EC 821A Cross Section and Panel Data Econometrics I	3
EC 821B Cross Section and Panel Data Econometrics II	3
EC 822A Time Series Econometrics I	3
EC 822B Time Series Econometrics II	3
STT 422 Statistics II 3	
STT 455 Actuarial Models I	3
STT 456 Actuarial Models II	3
STT 459 Construction and Evaluation of Actuarial Models	3
STT 461 Computations in Probability and Statistics	3
STT 464 Statistics for Biologists	3
STT 465 Bayesian Statistical Methods	3
STT 801 Design of Experiments	3
STT 802 Statistical Computation	3
STT 814 Advanced Statistics for Biologists	4
STT 825 Sample Surveys	3
STT 843 Multivariate Analysis	3
STT 844 Time Series Analysis	3
STT 847 Analysis of Survival Data	3
STT 855 Statistical Genetics	3
STT 863 Statistical Methods I	3
STT 864 Statistical Methods II	3
STT 886 Stochastic Processes and Applications	3
STT 888 Stochastic Models in Finance	3
Not more than two courses may be chosen from STT 455, 456, or 459.	
e. Electives chosen from any combination of the following, approved by the student's academic advisor (6 credits):	
(1) Courses from item d. not used to fulfill that requirement with the exception of STT 455, 456, or 459;	
(2) MTH 235 or any 300-level or higher MTH course;	
(3) CSE 232 or 260 or any 300-level or higher CSE course; or CMSE 381 or any 400-level or higher CMSE course;	
(4) 300-400 level courses in an area of application of statistics and probability.	

QUANTITATIVE RISK ANALYTICS

The Bachelor of Science degree in Quantitative Risk Analytics provides students the quantitative skills necessary for employment in the insurance and risk industry, including a mathematical treatment of probability and statistics, interest-

rate theory and financial mathematics, predictive analytics and other data science tools, and insurance operations.

Admission

To be considered for admission to the major, the student must have:

1. a cumulative grade-point average of at least 3.0 in all courses taken at MSU.
2. a minimum grade-point average of 3.0 in MTH 132, MTH 133, and MTH 234 or equivalent courses.
3. a minimum average of 3.0 in the grades in MTH 360 and STT 441.

Students who declare the major in quantitative risk analytics are automatically reviewed at the end of every semester and are either admitted or informed of their progress. Students must be admitted to a degree-granting college at the time they have completed 56 credits. Those who do not meet the criteria may consider a major in either Mathematics or in Statistics and Probability.

Requirements for the Bachelor of Science Degree in Quantitative Risk Analytics

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 Quantitative Risk Analytics.

The University's Tier II writing requirement for the Quantitative Risk Analytics major is met by completing Statistics and Probability 467. That course is referenced in item 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. One course of at least 3 credits in biological science, entomology, microbiology, physiology, plant biology, or integrative biology as approved by the student's academic advisor.	
b. One of the following groups of courses (8 to 10 credits):	
(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
(3) CEM 181H Honors Chemistry I	4
CEM 182H Honors Chemistry II	4
CEM 185H Honors Chemistry Laboratory I	2
(4) LB 171 Principles of Chemistry I	4
LB 171L Introductory Chemistry Laboratory I	1
LB 172 Principles of Chemistry II	3
c. One of the following groups of courses (8 credits):	
(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	4
PHY 294H Honors Physics II – Electromagnetism	4
(3) LB 273 Physics I	4
LB 274 Physics II	4
d. One of the following groups of courses (11 or 12 credits):	
(1) MTH 132 Calculus I	3
MTH 133 Calculus II	4
MTH 234 Multivariable Calculus	4
(2) LB 118 Calculus I	4
LB 119 Calculus II	4
LB 220 Calculus III	4
(3) MTH 152H Honors Calculus I	3

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MTH 153H Honors Calculus II	4
MTH 254H Honors Multivariable Calculus	4
e. One of the following courses (3 credits):	
MTH 235 Differential Equations	3
MTH 340 Ordinary Differential Equations I	3
MTH 347H Honors Ordinary Differential Equations	3
f. One of the following groups of courses (4 to 7 credits):	
(1) MTH 299 Transitions	4
MTH 309 Linear Algebra I	3
(2) MTH 317H Honors Linear Algebra	4
g. All of the following courses (15 credits):	
MTH 360 Theory of Mathematical Interest	3
MTH 361 Financial Mathematics for Actuaries I	3
MTH 457 Introduction to Financial Mathematics	3
STT 441 Probability and Statistics I: Probability	3
STT 442 Probability and Statistics II: Statistics	3
h. Both of the following courses (6 credits):	
MTH 468 Predictive Analytics	3
STT 467 Insurance Operations	3
i. All of the following courses (19 credits):	
ACC 230 Survey of Accounting Concepts	3
CSE 231 Introduction to Programming I	4
EC 201 Introduction to Microeconomics	3
EC 202 Introduction to Macroeconomics	3
FI 311 Financial Management	3
FI 321 Theory of Investments	3

GRADUATE STUDY

The Department of Statistics and Probability offers three majors that lead to master's degrees: applied statistics, data science, 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 please visit the department website, www.stt.msu.edu.

APPLIED STATISTICS

Master of Science

The goal of the master's degree program in applied statistics is 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 a background in calculus equivalent to MTH 132, 133, and 234 at Michigan State University, a background in linear algebra equivalent to MTH 309 at Michigan State University, and at least one post-calculus –level course in statistics or probability. The overall grade-point average in these courses should be at least 3.0.

Requirements for the Master of Science Degree in Applied Statistics

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

	CREDITS
1. Complete either a. or b.	
a. All of the following courses (15 credits):	
STT 441 Probability and Statistics I: Probability	3
STT 442 Probability and Statistics II: Statistics	3
STT 801 Design of Experiments	3
STT 802 Statistical Computation	3
STT 863 Statistical Methods I	3
b. All of the following courses (15 credits):	
STT 801 Design of Experiments	3
STT 802 Statistical Computation	3
STT 861 Theory of Probability and Statistics I	3
STT 862 Theory of Probability and Statistics II	3
STT 863 Statistical Methods I	3
2. Complete at least 9 additional credits in courses in the Department of Statistics and Probability at the 800-level or higher.	
3. Complete an additional 9 credits in courses in the Department of Statistics and Probability, the Department of Mathematics, or in a field of application of statistics and probability.	
4. Complete a final examination or evaluation.	

DATA SCIENCE

The Master of Science degree in Data Science is designed to provide students with an interdisciplinary blend of statistics, computer science, and computational science and mathematics which provides the necessary training to assimilate, process, analyze, and interpret data from diverse sources.

Admission

To be considered for admission to the master's degree, a student must:

1. Have a four-year bachelor's degree in a relevant quantitative discipline.
2. Demonstrate sufficient quantitative preparation through work or other relevant experiences.

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

Requirements for the Master of Science Degree in Data Science

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

	CREDITS
1. All of the following courses (18 credits):	
CMSE830 Foundations of Data Science	3
CMSE831 Computational Optimization	3
CSE 482 Big Data Analysis	3
CSE 881 Data Mining	3
STT 810 Mathematical Statistics for Data Scientists	3
STT 811 Applied Statistical Modeling for Data Scientists	3
2. Complete 9 credits of elective courses from the following:	
CMSE402 Data Visualization Principles and Techniques	3
CMSE822 Parallel Computing	3
CMSE890 Selected Topics in Computational Mathematics, Science, and Engineering	1 to 4
CSE 802 Pattern Recognition and Analysis	3
CSE 830 Design and Theory of Algorithms	3
CSE 847 Machine Learning	3
STT 802 Statistical Computation	3

COLLEGE OF NATURAL SCIENCE

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| STT 812 | Statistical Learning and Data Analysis | 3 |
| STT 873 | Statistical Learning and Data Mining | 3 |
| STT 874 | Introduction to Bayesian Analysis | 3 |
| STT 875 | R Programming for Data Sciences | 3 |
- CMSE 890 must be approved by the student's guidance committee.
Other courses may be available to fulfill this requirement with advisor approval.
3. Completion of a 3-credit capstone course involving an applied, industrial, or governmental data science project. Students may complete this requirement by enrollment in Computer Science and Engineering 890, Computational Mathematics, Science, and Engineering 890, or Statistics and Probability 890. The student's topic area must be approved by the student's guidance committee.
 4. Completion of a final examination or evaluation.

STATISTICS

Master of Science

The goal of the master's degree program 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 the master's degree program in statistics, the applicant should have a background in calculus equivalent to Mathematics 132, 133, and 234, in linear algebra equivalent to Mathematics 309, and probability and statistics equivalent to Statistics and Probability 441 and 442 at MSU with an overall grade point average of 3.0 in this course work.

Requirements for the Master of Science Degree in Statistics

CREDITS

The program is available under either Plan A (with thesis) or Plan B (without thesis). An academic advisor 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, or in a related field including:
 - a. All of the following courses (12 credits):

STT 861	Theory of Probability and Statistics I	3
STT 862	Theory of Probability and Statistics II	3
STT 863	Applied Statistics Methods I	3
STT 864	Applied Statistics Methods II	3
 - b. Nine additional credits in STT courses at the 800-level or above as approved by the student's academic advisor. At least 4 credits must be in STT 899 Master's Thesis Research.
 - c. Nine additional credits in STT courses or courses in related fields as approved by the student's academic advisor.
 - d. Completion of an oral examination in defense of the thesis, final examination or evaluation.

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.

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 level understanding of statistics and probability and a sound understanding of undergraduate-level real analysis are necessary for success in the doctoral program. Strong applicants with deficiencies in one of these areas will be considered for admission, and if accepted will be given the opportunity to learn the required material during their first year in the program. The Graduate Record Examination (GRE) General Test is required of all applicants.

Requirements for the Doctor of Philosophy Degree in Statistics

The program of study is developed by the guidance committee in consultation with the student. Students must be able 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 Statistics and Probability 867, 868, 872, 881, and 882.
2. Complete at least five additional courses from lists (a) and (b), with at least one course from a. and one from b.:
 - a. Advanced Probability: Statistics and Probability 961, 962, 964, 996
 - b. Advanced Statistics: Statistics and Probability 873, 874, 951, 953, 997
3. Complete at least three additional elective courses offered at the 800-level or higher from any department. These courses must be approved by the student's guidance committee.
4. Pass two written preliminary examinations, the first covering Statistics and Probability 867, 868, and 872, and the second covering Statistics and Probability 881 and 882.

ABRAMS PLANETARIUM

Shannon Schmoll, Director

The Abrams Planetarium is an acknowledged leader in the popularization of astronomy. It is named after Dr. Talbert "Ted" and Mrs. Leota Abrams, who generously gave the original gift of \$250,000 over 50 years ago. Today, the building features a 140-seat Sky Theater housing a digital full-dome projector, a black light gallery, an exhibit hall, and gift counter.

The major goals of the planetarium include offering engaging multimedia presentations that always contain a live presentation to the public, tailored program for the needs of K-12 students, and up-to-date undergraduate education across disciplines through collaboration with people across campus and the community.

Star shows and other events are offered to the public on weekends and special occasions. Visitors to the exhibit hall are welcome between 8:30 a.m. and noon and 1:00 p.m. and 4:30 p.m. on weekdays.

For more information and full listing of our offerings visit www.abramsplanetarium.org.

CENTER FOR ADVANCED MICROSCOPY

Andrew S. Elwood Madden, Associate Director

Microscopy, the science of microscope use, traces its origins to the work of Hooke and Leeuwenhoek in the late 1600's. There are now many types of microscopes and dozens of different imaging and analytical methods. Images may be created using visible and invisible light, electrons, magnetic forces, mechanical probes, current flow, and atomic level attractive and repulsive forces. Much of the technology in our modern world would not have been possible without the images and analytical data from microscopes. Microscopy is a vital resource in creating and applying knowledge to help address the critical problems of the 21st century.

The Center for Advanced Microscopy (CAM), a university Core Facility, is the Central microscopy laboratory for the Michigan State University campus. Teaching, research, and service work are provided in Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Confocal Laser Scanning Microscopy (CLSM), Laser Capture Microscopy (LCM), and Energy Dispersive X-ray Spectroscopy (EDS). CAM has a large user base from 49 departments in nine colleges. Outreach is provided on a local and national level. Our comprehensive teaching program includes NSC-810 Biological TEM Lab (FS, SS), NSC-815 Physical Science TEM Lab (FS, SS), NSC-816 Advanced Physical Science TEM lab (FS, SS), NSC-820 SEM Lab (FS, SS), and NSC-837 CLSM Lab (FS, SS).

In scanning electron microscopy we offer the following imaging/analytical capabilities: secondary and backscattered electron imaging, energy dispersive X-ray microanalysis, low vacuum, ultra-high resolution imaging, low voltage imaging of uncoated non-conducting samples. Specimen preparation methods include critical point and freeze drying, ultra-high resolution coating, cryo methods.

In transmission electron microscopy we offer the following imaging/analytical capabilities: bright/dark field imaging, Z contrast imaging, energy-filtered imaging, energy dispersive X-ray microanalysis, electron energy loss spectroscopy, cryo electron tomography, advanced diffraction methods. Specimen preparation methods include cryo and ambient temperature ultramicrotomy, sample thinning via polishing, dimple grinding, and ion beam milling.

In confocal laser scanning microscopy we offer the following imaging/analytical capabilities: super resolution, transmitted and reflectance imaging, fluorescence correlation spectroscopy, total internal reflectance fluorescence microscopy, fluorescence recovery after photo bleaching, Forster resonance energy transfer, live and fixed cell imaging, differential interference contrast, polarization, phase contrast. Numerous laser lines are available.

BIOLOGICAL SCIENCE PROGRAM

The Biological Science Program is responsible for the development and operation of a foundational core curriculum in general biology appropriate for science majors and others interested in a comprehensive introduction to the field. Courses include the two semester lecture/lab sequence Biological Science 161/171 and 162/172. Equivalent honors courses are offered as Biological Science 181H/191H and 182H/192H.

MSU/DOE PLANT RESEARCH LABORATORY

Christoph Benning, Director

A center for research in modern plant biology, the MSU/DOE Plant Research Laboratory was established in 1964. The Laboratory is administered by the College of Natural Science under a core research grant from the U.S. Department of Energy.

The Laboratory conducts a broad range of energy-related research at the molecular, subcellular, cellular, tissue, organ and organismal levels and draws on plant physiology, biochemistry, structural biology, cell and molecular biology, genetics, synthetic biology and other disciplines. Areas of research under investigation emphasize topics related to energy capture, conversion, and deposition in energy-rich molecules. These topics include dynamic regulation of photosynthesis and growth, identification of energy-sensing and response pathways, mechanisms and regulation of carbon fixation, compartmentalization of photosynthetic metabolism in organelles and bacterial microcompartments, transduction of environmental information by the plant, and effects of stress conditions upon growth and productivity.

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, Plant Biology, Microbiology and Molecular Genetics, and Plant, Soil and Microbial Sciences. The interdepartmental doctoral programs in Molecular Plant Sciences, Genetics, and Cellular and Molecular Biology are also available. The student's admission and program of study are subject to the regulations and approval of the appropriate department or program as well as the College of Natural Science.

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 stay 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.

Graduate students are given freedom of choice in selecting, within the Laboratory, the areas of their research and their major advisors, who are members of the above-mentioned departments and programs. These selections must be compatible with the Laboratory's objectives. Students are expected to spend the first two semesters familiarizing themselves with the research programs of the Laboratory's staff and related research in other departments, including participation in several research projects, and to make their selection on this basis.

Because of the intensity of the program, the student is expected to work on a year-round basis.

PLANT RESILIENCE INSTITUTE (PRI)

Seung Yon (Sue) Rhee, Director

The Plant Resilience Institute (PRI) is an interdisciplinary plant research center established in 2016 under Michigan State University (MSU)'s Global Impact Initiative. An internationally recognized Center of Excellence, PRI performs groundbreaking research addressing the challenges that climate change poses to food production and crop resilience. PRI brings together faculty and trainees from diverse career stages and disciplines across departments and colleges at MSU.

PRI excels in several synergistic areas of research related to plant resilience, extending from basic science to agricultural improvements. The Institute's research integrates molecular, genetic, physiological, ecological, and computational approaches to understand the complex mechanisms of how plants respond to, resist, and tolerate environmental stresses. Emphasis is placed on mechanistic studies of stress tolerance, plant-microbe interactions, regulatory metabolites, and genotype × environment interactions. This research combines insights from both natural biological systems and crop species to inform agricultural improvement, environmental sustainability, and conservation goals.

PRI focuses on convergent science, uniting cutting-edge plant researchers from colleges, departments, and programs throughout MSU. It maintains a vibrant and collaborative research community of interdisciplinary laboratories comprising faculty, postdoctoral researchers, graduate students, undergraduate students, and technical staff. PRI faculty hold joint appointments in departments such as Plant Biology, Biochemistry and Molecular Biology, Plant, Soil and Microbial Sciences, Entomology, and Microbiology, Genetics, and Immunology. PRI members benefit from mentorship programs, outreach and training opportunities, research and funding resources, and integrations with national and global research networks.

Degree programs are administered through affiliated academic units, with which the Institute faculty hold joint appointments. The student's admission and program of study are subject to the regulations and approval of the appropriate department, program, and college. As students cannot apply to PRI directly, prospective graduate students interested in joining PRI labs are encouraged to apply through the BioMolecular Science Gateway, Department of Plant Biology, or Molecular Plant Sciences program, specifying their interest in being considered by PRI and indicating any faculty members whose research aligns with their interests. It is also recommended to reach out to faculty directly to inquire about joining their labs, as not all faculty members accept students every year. Applicants referred by affiliated degree-granting units are also considered.