College of NATURAL SCIENCE

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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; Cell and Molecular Biology; Mathematics Education, Molecular Plant Science; Neuroscience; and Ecology, Evolutionary Biology 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–interdepartmental, human biology, and physical science-interdepartmental. 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. Clinical Laboratory Sciences majors are admitted at the junior level each fall semester. For specific details see the program statement in the *Biomedical Laboratory Diagnostics Program* section.

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 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 Programs

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

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

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

PREDENTAL PROGRAM:

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

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

Requirements for the Predental Program

CREDITS

1. A total of 60 credits in courses in the natural sciences, mathematics, social sciences, humanities, and writing, including courses that are used to satisfy the University requirements and the courses that are listed below: 60
   a. All of the following courses (31 credits):

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
CEM	141	General Chemistry	4
CEM	161	Chemistry Laboratory I	1
CEM	251	Organic Chemistry I	3
CEM	252	Organic Chemistry II	3
CEM	255	Organic Chemistry Laboratory	2
PHY	231	Introductory Physics I	3
PHY	232	Introductory Physics II	3
PHY	251	Introductory Physics Laboratory I	1
PHY	252	Introductory Physics Laboratory II	1

   Some dental colleges do not require Chemistry 252.
   b. 3 additional credits in general chemistry selected from the following courses: Chemistry 142, 152, and 162.
   c. 3 credits in a biological science course in addition to Biological Science 161, 171, 162, and 172.
   d. A minimum 3 credits in statistics.
2. Students who are enrolled in the predental program should complete the University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog.

   Students who are enrolled in the Predental Program in the College of Natural Science may complete an alternative track to Integrative Studies in Biological and Physical Sciences that consists of the following courses: Biological Science 161, 171, 162, and 172 and Chemistry 141. The completion of Biological Science 171 satisfies the laboratory requirement. Biological Science 161, 171, 162, and 172 and Chemistry 141 may be counted toward both the alternative track and the requirements for the predental program referenced in item 1. a. above.

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

PREMEDICAL PROGRAM (including Pre–Osteopathy, Pre–Podiatry, Pre-Pharmacy, and Pre-Physician's Assistant):

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

University regulations require that a student who has arrived at junior standing must select a major leading to a baccalaureate de-

gree. The College of Natural Science does **not** offer a bachelor's degree program for premedical students. Therefore, upon reaching junior standing, students who have been enrolled in the premedical program must be admitted to a major in either the College of Natural Science or in another college in order to complete the requirements for a bachelor's degree, regardless of whether they have completed the requirements for the premedical program.

Requirements for the Premedical Program (including Pre–Osteopathy, Pre–Podiatry, Pre-Pharmacy, and Pre-Physician's Assistant)

CREDITS

1. A total of 90 credits in courses in the natural sciences, mathematics, social sciences, humanities, and writing, including courses that are used to satisfy the University requirements and the courses that are listed below: 90
   a. All of the following courses (31 credits):

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
CEM	141	General Chemistry	4
CEM	161	Chemistry Laboratory I	1
CEM	251	Organic Chemistry I	3
CEM	252	Organic Chemistry II	3
CEM	255	Organic Chemistry Laboratory	2
PHY	231	Introductory Physics I	3
PHY	232	Introductory Physics II	3
PHY	251	Introductory Physics Laboratory I	1
PHY	252	Introductory Physics Laboratory II	1

   b. 3 additional credits in general chemistry selected from the following courses: Chemistry 142, 152, and 162.
   c. One 300–400 level course in biology with laboratory (3 credits) and another course in biology (3 credits).
   d. One additional course in biology, chemistry, or physics (3 credits).
      NOTE: Higher level equivalent biological science, chemistry, and physics course sequences may be substituted for the sequences listed above. Courses in biochemistry and genetics are highly recommended.
   e. A minimum of 3 credits in statistics.
2. Students who are enrolled in the premedical program should complete the University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog.

   Students who are enrolled in the Premedical Program (including Pre–Osteopathy, Pre–Podiatry, Pre-Pharmacy, and Pre-Physician's Assistant) in the College of Natural Science may complete an alternative track to Integrative Studies in Biological and Physical Sciences that consists of the following courses: Biological Science 161, 171, 162, and 172 and Chemistry 141. The completion of Biological Science 171 satisfies the laboratory requirement. Biological Science 161, 171, 162, and 172 and Chemistry 141 may be counted toward both the alternative track and the requirements for the premedical program referenced in item 1. a. above.

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

PREOPTOMETRY PROGRAM:

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

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

Requirements for the Preoptometry Program

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

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

TEACHER CERTIFICATION OPTIONS

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

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

Students interested in elementary teacher certification 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.

Students who elect the biological science–interdepartmental or the physical science–interdepartmental disciplinary major, or the biology disciplinary minor, must contact the Center for Integrative Studies in General Science in the College of Natural Science.

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

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

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

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

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

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

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

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

enrolled in the dual degree program and apply for admission to those programs.

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

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

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

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

Within the first semester of enrollment in the dual degree program, the student's master's 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, 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 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, microbiology and molecular genetics and genome sciences, pharmacology and toxicology, or physiology should apply through the BioMolecular Science Gateway 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 which aligns most closely with their educational goals. For additional information about the individual Ph.D. programs, refer to the statements on the *Departments of Biochemistry and Molecular Biology*, *Microbiology and Molecular Genetics*, and *Physiology* in the *College of Natural Science* section of this catalog, statements on the programs in *Cell and Molecular Biology* and *Genetics* 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, geological sciences, or mathematics.

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

Admission

An applicant for admission to the Master of Arts for Teachers program must be a senior in or a graduate of an institution having substantially the same requirements for the bachelor's degree as

Michigan State University, and possess, or be a candidate for, a teacher's certificate. Admission is recommended by the director of the program in which admission is sought, with approval of the Dean of the College of Natural Science.

Requirements for the Master of Arts for Teachers Degree

An appropriate course of study is planned with the candidate by an 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.

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
	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, evolutionary biology and behavior; general science; genetics; genetics–environmental toxicology; human biology; neuroscience; and physical science–interdepartmental. These programs are designed to serve students who wish to develop a broad background in the natural sciences. Students who desire academic preparation in the natural sciences with emphasis in a single discipline should enroll in a departmental major. The interdepartmental programs are not intended for this purpose.

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.

BIOLOGICAL SCIENCE—INTERDEPARTMENTAL

UNDERGRADUATE PROGRAM

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

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

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

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

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

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

					CREDITS
a.	All of the following courses:				30
	CEM	251	Organic Chemistry I	3	
	CEM	252	Organic Chemistry II	3	
	CEM	255	Organic Chemistry Laboratory	2	
	CEM	262	Quantitative Analysis	3	
	IBIO	341	Fundamental Genetics	4	
	IBIO	355	Ecology	3	
	IBIO	355L	Ecology Laboratory (W)	1	
	IBIO	445	Evolution (W)	3	
	ISE	401	Science Laboratories for Secondary Schools (W)	4	
	PSL	250	Introductory Physiology	4	
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)	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	
c.	One of the following *groups* of courses:				9 or 10
(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	
d.	One course from group (1) and one course from group (2):				6 to 8
(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	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	
e.	One of the following **groups** of courses:				8 or 10
(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	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	
(4)	LB	273	Physics I	4	
	LB	274	Physics II	4	
f.	One of the following, either (1) or (2):				8
(1)	BMB	401	Comprehensive Biochemistry	4	
	IBIO	408	Histology	4	
	IBIO	425	Cells and Development (W)	4	

(2) Both of the following courses:
MMG 301 Introductory Microbiology 3
MMG 302 Introductory Laboratory for General and Allied Health Microbiology 1
One of the following courses:
BMB 401 Comprehensive Biochemistry 4
IBIO 408 Histology 4
IBIO 425 Cells and Development (W) 4

g. One of the following courses: . . . . . 3 or 4
PLB 301 Introductory Plant Physiology 3
PLB 418 Plant Systematics 3
PLB 434 Plant Structure and Function 4
PLP 405 Plant Pathology 3

TEACHER CERTIFICATION OPTIONS

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

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

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

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

CELL AND MOLECULAR BIOLOGY

GRADUATE STUDY

Master of Science

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

Admission

Most students enter the Master of Science degree program in cell and molecular biology with the goal of eventually obtaining a Ph.D. degree. However, students with limited research experience or specific deficiencies in their undergraduate training may be admitted to this program to obtain additional experience. 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
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 are encouraged to apply for admission to the Ph.D. program through the BioMolecular Science Gateway – First Year, where students choose a doctoral major from any of six Ph.D. programs: biochemistry and molecular biology, cell and molecular biology, genetics and genome sciences, microbiology and molecular genetics, pharmacology and toxicology, or physiology. For additional information refer to the *College of Natural Science* section of this catalog.

CELL and MOLECULAR BIOLOGY —ENVIRONMENTAL TOXICOLOGY

Doctor of Philosophy

For information about the Doctor of Philosophy degree program in cell and molecular biology—environmental toxicology, refer to the statement on *Doctoral Program in Environmental and Integrative Toxicological Sciences* in the *Graduate Education* 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.

ECOLOGY, EVOLUTIONARY BIOLOGY AND BEHAVIOR

GRADUATE STUDY

Dual Major

The interdepartmental dual major in ecology, evolutionary biology 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, evolutionary biology 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, evolutionary biology and behavior alone.

The educational objectives of the interdepartmental program are to:

1. provide an opportunity for doctoral students to obtain a comprehensive and contemporary academic experience in the field of ecology, evolutionary biology and behavior.
2. stimulate doctoral students with an interest in ecology, evolutionary biology and behavior to become sensitive to their professional obligations and responsibilities.
3. develop an intellectual environment which will foster the growth of research and teaching in the area of ecology, evolutionary biology and behavior.

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

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

Admission

In order to enroll in the dual major in ecology, evolutionary biology 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, evolutionary biology 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, evolutionary biology and behavior faculty who will serve as the student's major professor will constitute a guidance committee that will assist in planning the student's program of study. At least two members of the ecology, evolutionary biology and behavior faculty shall be members of the committee. The student's program of study will involve ecology, evolutionary biology and behavior and a major in 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, evolutionary biology and behavior are expected to attend weekly seminars and to participate in the graduate student-organized research colloquium.

Requirements for the Dual Major in Ecology, Evolutionary Biology 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, evolutionary biology 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, evolutionary biology 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, evolutionary biology and behavior and the student's departmental major.

GENETICS AND GENOME SCIENCES

GRADUATE STUDY

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.

BIOMOLECULAR SCIENCE GATEWAY - FIRST YEAR

Students are encouraged to apply for admission to the Ph.D. program through the BioMolecular Science Gateway – First Year, where students choose a doctoral major from any of six Ph.D. programs: biochemistry and molecular biology, cell and molecular biology, genetics and genome sciences, microbiology and molecular genetics, pharmacology and toxicology, or physiology. For additional information refer to the *College of Natural Science* section of this catalog.

GENETICS AND GENOME SCIENCES —ENVIRONMENTAL TOXICOLOGY

Doctor of Philosophy

For information about the Doctor of Philosophy degree program in genetics and genome sciences—environmental toxicology, refer to the statement on *Doctoral Program in Environmental and Integrative Toxicological Sciences* in the *Graduate Education* section of this catalog.

HUMAN BIOLOGY

UNDERGRADUATE PROGRAM

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

Requirements for the Bachelor of Science Degree in Human Biology

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

   The University's Tier II writing requirement for the Human Biology major is met by completing NSC 495. That course is referenced in item 3. a. below.

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

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

					CREDITS
a.	One of the following groups of courses:				9 or 10
	(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
	(4)	LB	181H	Honors Cell and Molecular Biology	3
		LB	182H	Honors Organismal and Population Biology	3
		LB	191H	Honors Cell and Molecular Biology Laboratory	2
		LB	192H	Honors Organismal and Population Biology Laboratory	2
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
	IBIO		341	Fundamental Genetics	4
	NSC		495	Capstone in Human Biology (W)	3
c.	One of the following, either (1) or (2):				4 or 8
	(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
	(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
	(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 ChemistryII	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
	(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
	(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	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
	(4)	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
	(5)	LB	273	Physics I	4
		LB	274	Physics II	4
h.	One of the following courses:				3
	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:				12
	ANP		441	Osteology and Forensic Anthropology	4
	BLD		204	Mechanisms of Disease	3
	BLD		324	Hematology and Hemostatis	3
	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
	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
	IBIO		483	Environmental Physiology (W)	4
	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
	NSC		496	Directed Study in Human Biology	1 to 3
	NSC		497	Internship in Human Biology	1 to 3
	NSC		498	Research in Human Biology	1 to 3
	PHM		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, credits in research or independent study 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
	ANTR		350	Human Gross Anatomy for Pre-Health Professionals	3
	IBIO		320	Developmental Biology	4
	IBIO		328	Comparative Anatomy and Biology of Vertebrates	4

MOLECULAR PLANT SCIENCES

GRADUATE STUDY

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.

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.

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. In addition to core requirements, students can concentrate in cellular and developmental neuroscience; behavioral and systems neuroscience; or cognitive neuroscience.

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 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 pairs 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 I	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

b. One of the following pairs of courses (6 credits):
(1) CEM 251 Organic Chemistry I. 3
CEM 252 Organic Chemistry II 3
(2) CEM 351 Organic Chemistry I. 3
CEM 352 Organic Chemistry II 3

c. One of the following pairs of courses (6 or 8 credits):
(1) PHY 231 Introductory Physics I 3
PHY 232 Introductory Physics II. 3
(2) PHY 183 Physics for Scientists and Engineers I 4
PHY 184 Physics for Scientists and Engineers II 4
(3) PHY 193H Honors Physics I-Mechanics. 4
PHY 294H Honors Physics II-Electromagnetism 4
(4) LB 273 Physics I 4
LB 274 Physics II. 4

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 or 4 credits):
STT 201 Statistical Methods 4
STT 231 Statistics for Scientists 3
STT 421 Statistics I 3

f. Both of the following courses (8 credits):
BMB 401 Comprehensive Biochemistry 4
PSY 101 Introductory Psychology 4

g. 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

h. 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

i. All of the following courses (8 credits):
NEU 301 Introduction to Neuroscience I 3
NEU 302 Introduction to Neuroscience II 3
NEU 311L Neuroscience Laboratory (W). 2

j. One course from each of the following groups of courses (6 or 7 credits):
(1) PHM 350 Introductory Human Pharmacology. 3
PHM 431 Pharmacology of Drug Addiction. 3
PHM 480 Special Problems 3
(2) IBIO 341 Fundamental Genetics 4
MMG 409 Eukaryotic Cell Biology 3

k. Complete 15 credits in courses from one of the following concentrations:

Cellular and Developmental Neuroscience
IBIO 341 Fundamental Genetics 4
IBIO 343 Genetics Laboratory 3
IBIO 425 Cells and Development (W) 4
MMG 404 Human Genetics 3
MMG 409 Eukaryotic Cell Biology 3
NEU 416 Development of the Nervous System Through the Lifespan 3
NEU 420 Neurobiology of Disease. 3
NEU 425 Computational Modeling in Neuroscience. 3
NEU 435 Ion Channels of Excitable Membranes 3
NEU 440 Synaptic Transmission 3
NEU 490 Special Problems in Neuroscience . . . . . 1 to 3
NEU 492 Special Topics in Neuroscience . . . . . 1 to 3
PHM 422 Fundamentals of Neuropharmacology 3
PHM 431 Pharmacology of Drug Addiction. 3
PHM 480 Special Problems . . . . . 1 to 3
PLB 400 Introduction to Bioinformatics 3

Microbiology and Molecular Genetics 409, Integrative Biology 341, or Pharmacology and Toxicology 431 may not be used for requirement 3. j. (2) and this concentration. No more than 3 credits each of NEU 490 and NEU 492 may count toward this requirement. Students must have approval from the Neuroscience academic advisor to earn credit in NEU 490, NEU 492, PHM 480 for this concentration.

Behavioral and Systems Neuroscience
IBIO 313 Animal Behavior 3
IBIO 403 Integrative Neurobiology. 3
NEU 416 Development of the Nervous System Through the Lifespan 3
NEU 420 Neurobiology of Disease. 3
NEU 425 Computational Modeling in Neuroscience. 3
NEU 490 Special Problems in Neuroscience . . . . . 1 to 3
NEU 492 Special Topics in Neuroscience . . . . . 1 to 3
PHM 431 Pharmacology of Drug Addiction. 3
PHM 480 Special Problems . . . . . 1 to 3
PSY 209 Brain and Behavior 3
PSY 310 Psychology and Biology of Human Sexuality 3
PSY 402 Sensation and Perception (W) 3
PSY 409 Psychobiology of Behavioral Development (W) . . . 3
PSY 410 Neuroscience of Learning and Memory (W) 3
PSY 411 Hormones and Behavior (W). 3
PSY 413 Laboratory in Behavioral Neuroscience (W) 4
PSY 493 Issues in Psychology (W) 3

Pharmacology and Toxicology 431 may not be used for requirement 3. j. (1) and this concentration. No more than 3 credits each of NEU 490 and NEU 492 may count toward this requirement. Students must have approval from the Neuroscience academic advisor to earn credit in NEU 490, NEU 492, PHM 480, or PSY 493 for this concentration.

Cognitive and Computational Neuroscience
LIN 455 Neurolinguistics. 3
LIN 463 Introduction to Cognitive Science 3
NEU 425 Computational Modeling in Neuroscience. 3
NEU 490 Special Problems in Neuroscience . . . . . 1 to 3
NEU 492 Special Topics in Neuroscience . . . . . 1 to 3
PHL 101 Introduction to Philosophy. 3
PHL 462 Philosophy of Mind 3
PSL 429 Biomedical Imaging Methods 3
PSY 200 Cognitive Psychology 3
PSY 209 Brain and Behavior 3
PSY 301 Cognitive Neuroscience 3
PSY 401 Expertise and Skill (W) 3
PSY 402 Sensation and Perception (W) 3
PSY 410 Neuroscience of Learning and Memory (W) 3
PSY 493 Issues in Psychology (W) 3

No more than 3 credits each of NEU 490 and NEU 492 may count toward this requirement. Students must have approval from the Neuroscience academic advisor to earn credit in NEU 490, NEU 492, or PSY 493 for this concentration.

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 (5 credits):			
NEU	840	Social, Cognitive, and Affective Neuroscience	3
NEU	892	Special Topics in Neuroscience and the Law	2
2. The following course (2 credits):			
NEU	848	Foundations of Law and Legal Research	2
Students who have completed at least one year of law school are not required to complete this requirement for the certificate.			
3. At least 5 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	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.

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
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):			
	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
	PHM	830	Experimental Design and Data Analysis	3

2. Complete two elective courses relevant to neuroscience (4 to 6 credits).
3. Complete in the first year of enrollment in the program a one-semester laboratory rotation (NEU 890) with *each* of *two* 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.
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*.

NEUROSCIENCE—ENVIRONMENTAL TOXICOLOGY

Doctor of Philosophy

For information about the Doctor of Philosophy degree program in neuroscience—environmental toxicology, refer to the statement on *Doctoral Program in Environmental and Integrative Toxicological Sciences* in the *Graduate Education* section of this catalog.

PHYSICAL SCIENCE—INTERDEPARTMENTAL

UNDERGRADUATE PROGRAM

The physical science–interdepartmental major, which leads to the Bachelor of Science degree, is designed for persons who want a broad background in both physics and chemistry and to understand the interrelationships between these disciplines. This major is designed primarily for persons who plan to teach physics, chemistry and/or physical science in secondary schools.

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

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

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

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

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

				CREDITS
a.	One of the following courses (4 credits):			
	CEM	141	General Chemistry	4
	CEM	151	General and Descriptive Chemistry	4
b.	One of the following courses (3 credits):			
	CEM	142	General and Inorganic Chemistry	3
	CEM	152	Principles of Chemistry	3
c.	All of the following courses (57 credits):			
	CEM	161	Chemistry Laboratory I	1
	CEM	162	Chemistry Laboratory II	1
	CEM	251	Organic Chemistry I	3
	CEM	252	Organic Chemistry II	3
	CEM	255	Organic Chemistry Laboratory	2
	CEM	262	Quantitative Analysis	3
	CEM	383	Introductory Physical Chemistry I	3
	ISE	401	Science Laboratories for Secondary Schools (W)	4
	MTH	132	Calculus I	3
	MTH	133	Calculus II	4
	MTH	234	Multivariable Calculus	4
	MTH	235	Differential Equations	3
	PHY	183	Physics for Scientists and Engineers I	4
	PHY	184	Physics for Scientists and Engineers II	4
	PHY	191	Physics Laboratory for Scientists, I	1
	PHY	192	Physics Laboratory for Scientists, II	1
	PHY	215	Thermodynamics and Modern Physics	3
	PHY	431	Optics I	3
	PHY	440	Electronics	4
	An approved elective in chemistry or physics			3
d.	One of the following courses (3 or 4 credits):			
	BS	161	Cell and Molecular Biology	3
	ENT	205	Pests, Society and Environment	3
	PLB	105	Plant Biology	3
	PSL	250	Introductory Physiology	4
	ZOL	141	Introductory Human Genetics	3

TEACHER CERTIFICATION OPTION

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

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

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

QUANTITATIVE BIOLOGY

Dual Major

The interdepartmental dual major in quantitative biology 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 a research project and course work in quantitative biology and a major in one of the following departments that are affiliated with the interdepartmental program: Biochemistry and Molecular Biology, Cell and Molecular Biology, Chemical Engineering and Materials Science, Chemistry, Civil and Environmental Engineering, Computer Science and Engineering, Electrical and Computer Engineering, Epidemiology, Genetics, Mathematics, Mechanical Engineering, Microbiology and Molecular Genetics, Pharmacology and Toxicology, Physics and Astronomy, Physiology, Plant Biology, Statistics and Probability, and Zoology. The student does *not* have the option of completing a major in quantitative biology alone.

The educational objectives of the interdepartmental program are to:

1. provide an opportunity for doctoral students to obtain an interdisciplinary and contemporary academic experience in the field of quantitative biology.
2. stimulate doctoral students with an interest in biological sciences to develop skills in chemical/physical or mathematical/computational approaches while encouraging doctoral students in the chemical, physical, mathematical, and computational sciences to apply their skills to solve biological problems.
3. develop an intellectual environment that will foster the growth of research and teaching in the area of quantitative biology.

In addition to meeting the requirements of the university and of the department and college in which the student is enrolled, the student must meet the requirements specified below.

Admission

In order to enroll in the dual major in quantitative biology a student must also have been admitted to a major in one of the affiliated departments. A minimum undergraduate grade-point average of 3.0 and undergraduate mathematics through calculus are required for admission to the dual major. Students may apply to the quantitative biology program at any time prior to their preliminary exam.

Admission to the quantitative biology dual major is by approval of the quantitative biology recruiting committee and the graduate program director. In special cases, an applicant who has deficiencies in background courses may be admitted to the dual major on a provisional basis.

Guidance Committee

The student must select two mentors, typically one from a biological discipline and one from a chemical, physical, mathematical, computational, or engineering discipline. Both of these mentors will serve on the guidance committee. At least two members of the student's guidance committee must be members of the quantitative biology faculty. 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. The student's program of study will be planned in accordance with the statement on *Dual Major Doctoral Degrees* in the *Graduate Education* section of this catalog.

Requirements for the Dual Major in Quantitative Biology

CREDITS

1. At least two courses totaling a combined minimum of 5 credits that provide graduate training in biology to students in chemical/physical or mathematical/computational disciplines or that provide graduate training in chemical, physical, mathematical, or computational methods to those in the biological disciplines. The courses should be complementary to the student's research, relevant to the goals of the quantitative biology program, and must be approved by the program director. Approved concentration areas include: molecular biophysics, systems biology, ecological and evolutionary modeling, or genomics, bioinformatics, and computational biology.
2. Twenty-four credits in Doctoral Dissertation Research (course number 999) from one of the departments referenced above.
3. Pass a comprehensive examination that will be defined by the requirements of the participating primary department and that will demonstrate appropriate knowledge of quantitative biology as determined by the guidance committee.
4. Submit a dissertation that, in the judgment of the student's guidance committee, represents the area of quantitative biology.
5. Regularly attend and participate in quantitative biology sponsored seminars.

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:

				CREDITS
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	404	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):			
	ANS	418	Animal Agriculture and the Environment	3
	ANS	427	Environmental Toxicology and Society	3
	COM	399	Special Topics in Communication	3
	CSUS	200	Introduction to Sustainability	3
	CSUS	300	Theoretical Foundations of Sustainability	3
	CSUS	310	History of Environmental Thought and Sustainability	3
	CSUS	320	Environmental Planning and Management	3

EEM	320	Environmental Economics	3
EEM	405	Corporate Environmental 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	Environmental Journalism Seminar	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
WRA	341	Nature and Environmental Writing	3

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

4. Freshmen students who elect the RISE Option are required to complete Natural Science 192.

ECOLOGY, EVOLUTIONARY BIOLOGY AND BEHAVIOR

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

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

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

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

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

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

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

Required Core Courses

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, evolutionary biology 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, evolutionary biology 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

Eric Grotewold, 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 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 Biochemistry:				61 to 69
	(1)	All of the following courses (11 credits):			
		CEM	262	Quantitative Analysis	3
		CEM	355	Organic Laboratory I	2
		CEM	356	Organic Laboratory II	2
		CMSE	201	Introduction to Computational Modeling and Data Analysis	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	3
		CEM	152	Principles of Chemistry	3
		CEM	182H	Honors Chemistry II	4
		LB	172	Principles of Chemistry II	3
	(4)	One course from each of the following groups of courses (2 to 4 credits):			
	(a)	CEM	161	Chemistry Laboratory I	1
		CEM	185H	Honors Chemistry Laboratory I	2
		LB	171L	Introductory Chemistry Laboratory I	1
	(b)	CEM	162	Chemistry Laboratory II	1
		CEM	185H	Honors Chemistry Laboratory I	2
		LB	172L	Principles of Chemistry II - Reactivity Laboratory	1
		Students who select CEM 185H may use that course alone to fulfill this requirement.			
	(5)	One course from each of the following groups of courses (6 credits):			
	(a)	CEM	251	Organic Chemistry I	3
		CEM	351	Organic Chemistry I	3
	(b)	CEM	252	Organic Chemistry II	3
		CEM	352	Organic Chemistry II	3
	(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	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
	(c)	PHY	241	Physics for Cellular and Molecular Biologists I	4
		PHY	242	Physics for Cellular and Molecular Biologists II	4
	(d)	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:				13
	All of the following courses:				
	BMB	101	Frontiers in Biochemistry		1
	BMB	461	Advanced Biochemistry I		3
	BMB	462	Advanced Biochemistry II		3
	BMB	470	Advanced Molecular Biology Laboratory		3
	BMB	471	Advanced Biochemistry Laboratory		3
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

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/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.

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 Biochemistry and Molecular Biology . . . . . 66 to 73
      (1) All of the following courses (11 credits):
      CEM 262 Quantitative Analysis 3
      CEM 355 Organic Laboratory I 2
      CEM 356 Organic Laboratory II 2
      CMSE 201 Introduction to Computational Modeling 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 3
      CEM 152 Principles of Chemistry 3
      CEM 182H Honors Chemistry II. 4
      LB 172 Principles of Chemistry II. 3
      (4) One course from each of the following groups of courses (2 credits):
      (a) CEM 161 Chemistry Laboratory I 1
      CEM 185H Honors Chemistry Laboratory I 2
      LB 171L Introductory Chemistry Laboratory I 1
      (b) CEM 162 Chemistry Laboratory II 1
      CEM 185H Honors Chemistry Laboratory I 2
      LB 172L Principles of Chemistry II-Reactivity Laboratory 1
      Students who select CEM 185H may use that course alone to fulfill this requirement.
      (5) One course from each of the following groups of courses (6 credits):
      (a) CEM 251 Organic Chemistry I. 3
      CEM 351 Organic Chemistry I. 3
      (b) CEM 252 Organic Chemistry II 3
      CEM 352 Organic Chemistry II 3
      (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 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
      (c) PHY 241 Physics for Cellular and Molecular Biologists I. 4
      PHY 242 Physics for Cellular and Molecular Biologists II 4
      (d) LB 273 Physics I 4
      LB 274 Physics II. 4
      (9) One of the following courses (3 credits):
      BMB 470 Advanced Molecular Biology Laboratory. 3
      CSS 451 Biotechnology Applications for Plant Breeding and Genetics 3
      MMG 408 Advanced Microbiology Laboratory (W) 3
      (10) One of the following courses (3 or 4 credits):
      CSS 350 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: 10
      BMB 101 Frontiers in Biochemistry. 1
      BMB 461 Advanced Biochemistry I. 3
      BMB 462 Advanced Biochemistry II 3
      BMB 471 Advanced Biochemistry Laboratory. 3
   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. Study for the Doctor of Philosophy degree with a major in biochemistry and molecular biology—environmental toxicology is administered by the College of Natural Science. 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, metalloenzymology, 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

1. 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.
2. Complete two additional 800-level courses as approved by the student's guidance committee.
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

Person's 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 are encouraged to apply for admission to the Ph.D. program through the BioMolecular Science Gateway – First Year, where students choose a doctoral major from any of six Ph.D. programs: biochemistry and molecular biology, cell and molecular biology, genetics and genome sciences, microbiology and molecular genetics, pharmacology and toxicology, or physiology.

For additional information refer to the *College of Natural Science* section of this catalog.

BIOCHEMISTRY and MOLECULAR BIOLOGY —ENVIRONMENTAL TOXICOLOGY

Doctor of Philosophy

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

BIOMEDICAL LABORATORY DIAGNOSTICS PROGRAM

John Gerlach, Director

UNDERGRADUATE PROGRAMS

Laboratory testing to diagnose, monitor, and treat human disease is a critical component of health care. The Biomedical Laboratory Diagnostics Program offers three undergraduate degree programs to assist students in entering the exciting, world of the clinical laboratory. Medical laboratory science, historically called medical technology, is the health profession focused on providing medical laboratory assays on human samples. Data generated from these assays form the basis of most diagnostic and treatment decisions. Based in the sciences of chemistry, biology, mathematics, and physics, the profession provides challenging careers for individuals interested in the medical applications of these sciences. Medical laboratory scientists manage the testing process from the selection of high quality tests to the reporting of results to the health care provider. This includes method selection and development, assay performance, quality assurance and results analysis in a highly automated and computerized environment. Medical laboratory scientists also manage laboratory operations including marketing, personnel management, regulatory compliance, and finances. 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.

The curricula in the Biomedical Laboratory Diagnostics Program build on a foundation of basic science. Courses such as hematology, immunology, immunohematology, hemostasis, clinical microbiology, molecular laboratory diagnostics, and clinical chemistry have a diagnostic medical emphasis. As a result, many students preparing for graduate professional education in medicine, dentistry, veterinary sciences, forensics, and other health professions select a Biomedical Laboratory Diagnostics Program major.

Employment in medical diagnostic laboratories is just one of the many opportunities available to graduates. The skills applicable to a medical laboratory translate readily into research and industrial settings. Graduates also find employment in pharmaceutical and medical supply sales. Alumni successfully compete for admission to graduate and graduate professional schools.

Three undergraduate programs that lead to the Bachelor of Science degree are available: biomedical laboratory science, clinical laboratory sciences, and medical laboratory science.

These programs are designed to meet the professional needs of graduates entering a highly regulated and rapidly changing technological environment and to prepare students for continuing professional education and advanced study beyond the bachelor's degree.

BIOMEDICAL LABORATORY SCIENCE

The biomedical laboratory science major is designed to prepare students for careers as laboratorians in a variety of settings or to pursue graduate or advanced professional education. The clinical laboratory experience required for national certification as a medical laboratory scientist is not included in this program. Students desiring certification are responsible for securing accredited clinical experiences subsequent to completion of the degree and are recommended to complete the medical laboratory science concentration. The Biomedical Laboratory Diagnostics Program will advise students in seeking and gaining clinical practicum experiences.

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
	(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
	MMG 365 Medical Microbiology	3
	MMG 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):	
	MMG 201 Fundamentals of Microbiology	3
	MMG 301 Introductory Microbiology	3
b.	All of the following Biomedical Laboratory Diagnostics courses:	24
	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 or minor:	
	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 421 Clinical Toxicology	3
	PHM 430 Human Pharmacology	3
	PHM 450 Introduction to Chemical Toxicology	3
	Immunology (10 or 11 credits)	
	(1) Both of the following courses (2 credits):	
	BLD 435L Immunohematology Laboratory	1
	BLD 452L Immunodiagnostics 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 (3 credits):	
	MMG 409 Eukaryotic Cell Biology	3
	MMG 461 Molecular Pathogenesis	3
	(4) One of the following courses (3 or 4 credits):	
	EPI 390 Disease in Society: Introduction to Epidemiology and Public Health	4
	IBIO 341 Fundamental Genetics	4
	MMG 465 Advanced Medical Microbiology	3
	MMG 431 Microbial Genetics	3
	Medical Microbiology (10 to 12 credits)	
	(1) All of the following courses (8 credits):	
	MMG 465 Advanced Medical Microbiology	3
	MMG 465L Advanced Medical Microbiology Laboratory	2
	MMG 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
	BLD 861 Emerging Infections, Emerging Technology	2
	EPI 290 History of Scientific Reasoning and Critical Thinking in Global Public Health and Epidemiology	3
	EPI 390 Disease in Society: Introduction to Epidemiology and Public Health	4
	HM 801 Introduction to Public Health	3
	IBIO 316 General Parasitology	3
	MMG 413 Virology	3
	MMG 421 Prokaryotic Cell Physiology	3
	MMG 431 Microbial Genetics	3
	Hematology and Hemostasis (9 to 11 credits)	
	(1) All of the following courses (5 credits):	
	BLD 424 Advanced Hematology and Hemostasis	2
	BLD 424L Advanced Hematology, Hemostasis and Urinalysis Laboratory	1
	BLD 435L Immunohematology Laboratory	1
	BLD 452L Immunodiagnostics 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
	BLD 835 Hemostasis, Thrombosis and Effective Resource Management	3
	IBIO 408 Histology	4
	IBIO 425 Cells and Development (W)	4
	IBIO 450 Cancer Biology (W)	3
	MMG 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
	MMG 465 Advanced Medical Microbiology	3
	MMG 465L Advanced Medical Microbiology Laboratory	2
	Molecular Diagnostics (10 credits)	
	(1) All of the following courses (7 credits):	
	BLD 430L Molecular Diagnostics Laboratory	1
	BLD 460 Advanced Molecular Diagnostics	2
	CMSE 201 Introduction to Computational Modeling	4
	(2) One of the following courses (3 credits):	
	MMG 409 Eukaryotic Cell Biology	3
	MMG 431 Microbial Genetics	3
	MMG 433 Microbial Genomics	3
	Minor in Information Technology (19 credits)	

Students must apply to the Minor in Information Technology through the Eli Broad College of Business. Students interested in

pursuing the minor must consult with the Biomedical Laboratory Diagnostics advisor prior to completion of the application.

CLINICAL LABORATORY SCIENCES

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

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

Admission as a Junior

Enrollment in the clinical laboratory sciences major is limited. A new class is admitted at the junior level each fall semester. Students beyond junior standing may be considered for admission contingent upon the projected schedule for completion of the degree requirements and availability of clinical placement sites. Applications for admission are accepted at any time.

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

1. Have an overall grade-point average of 2.5 or better including courses taken at other institutions.
2. Have completed Biological Science 161 and 171; Chemistry 251 and 252; and Biomedical Laboratory Diagnostics 213.

Students may apply before attainment of the above criteria in order to demonstrate their intentions to major in clinical laboratory sciences, however their applications will not be processed until all requirements are fulfilled. Students who present other exceptional credentials but do not meet the grade-point criterion noted above may be considered for admission on a probationary basis.

Applications for admission to the clinical laboratory sciences 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.

Academic Standards

To progress to the clinical phase of the curriculum, students must earn a grade-point average of 2.0 or higher in Microbiology and Molecular Genetics 463 and Biomedical Laboratory Diagnostics 324, 417, and 435.

A specific statement of the policies for the clinical phase is provided in the *Student Policies for Clinical 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, 322 N. Kedzie Hall. Admitted students are responsible for knowing and adhering to these program policies.

Requirements for the Bachelor of Science Degree in Clinical Laboratory Sciences

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

   The University's Tier II writing requirement for the Clinical Laboratory Sciences major is met by completing Biomedical Laboratory Diagnostics 455. 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: . . . . . 48 to 51

(1) All of the following courses (31 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
MMG	463	Medical Microbiology	3
MMG	464	Diagnostic 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), (b), or (c) (4 credits):

(a)	PSL	250	Introductory Physiology	4
(b)	PSL	310	Physiology for Pre-Health Professionals	4
(c)	PSL	431	Human Physiology I	4
	PSL	432	Human Physiology II	4

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

MMG	201	Fundamentals of Microbiology	3
MMG	301	Introductory Microbiology	3

b. All of the following Biomedical Laboratory Diagnostics courses: . 52

BLD	204	Mechanisms of Disease	3
BLD	213	Application of Clinical Laboratory Principles	2
BLD	220	Preparing for a Health Professions Career	1
BLD	324	Fundamentals of Hematology, Hemostasis and Urinalysis	3
BLD	324L	Introductory Laboratory in Hematology, Hemostasis and Urinalysis	1
BLD	416	Clinical Chemistry	4
BLD	417	Quality Processes in Diagnostic Laboratory Testing	2
BLD	424	Advanced Hematology, Hemostasis, and Urinalysis	2
BLD	424L	Advanced Laboratory in Hematology, Hemostasis, and Urinalysis	1
BLD	430	Molecular Laboratory Diagnostics	2
BLD	433	Clinical Immunology and Immunohematology Laboratory	1
BLD	434	Clinical Immunology	3
BLD	435	Transfusion Medicine	2
BLD	442	Education and Management in the Clinical Laboratory	2
BLD	450	Eukaryotic Pathogens	3
BLD	455	Integrating Clinical Laboratory Science Discipline (W)	2
BLD	471	Advanced Clinical Chemistry Laboratory	3
BLD	472	Advanced Clinical Chemistry	1
BLD	473	Advanced Clinical Hematology and Body Fluids Laboratory	3
BLD	474	Advanced Clinical Hematology and Body Fluids	1
BLD	475	Advanced Clinical Immunology and Immunohematology Laboratory	2
BLD	476	Advanced Clinical Immunology and Immunohematology	1
BLD	477	Advanced Clinical Microbiology Laboratory	3
BLD	478	Advanced Clinical Microbiology	1
BLD	498	Focused Problems in Clinical Laboratory Science	2
BLD	498L	Infectious Disease Diagnostic Laboratory	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.

MEDICAL LABORATORY SCIENCE

The medical laboratory science major is designed to prepare students for certification in medical laboratory science. The program includes courses in the 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. Students are admitted as Biomedical Laboratory Science major until the application process for Medical Laboratory Science is completed.

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, MMG 201 or MMG 301, 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
MMG	365	Medical Microbiology	3
MMG	365L	Medical Microbiology Laboratory	1
MMG	465	Advanced Medical Microbiology	3
MMG	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
	PSL	432	Human Physiology II	4

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

MMG	201	Fundamentals of Microbiology	3
MMG	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 MMG 465, MMG 465L, BLD 402, 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
	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 achieve-

ments 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
Additional Requirements for Plan B:			
BLD	890	Selected Problems in Clinical Laboratory Science	3

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.

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

Robert E. Maleczka Jr., 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 the chemical industries or in governmental laboratories and for those planning graduate study in chemistry. The Bachelor of Science degree program in chemistry has been accredited by the American Chemical Society.

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

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

Requirements for the Bachelor of Science Degree in Chemistry

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

   The University's Tier II writing requirement for the Chemistry major is met by completing Chemistry 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:			29 to 36
	(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
		LB 144	Biology I: Organismal Biology	4
		LB 145	Biology II: Cellular and Molecular Biology	5
		MMG 201	Fundamentals of Microbiology	3
		PLB 105	Plant Biology	3
		PSL 250	Introductory Physiology	4
		ZOL 141	Introductory Human Genetics	3
	(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 255H	Honors 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
	(7) 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
b.	The following courses in the Department of Chemistry:			45 or 46
	(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 (30 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 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

Bachelor of Arts

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

Requirements for the Bachelor of Arts Degree in Chemistry

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

   The University's Tier II writing requirement for the Chemistry major is met by completing Chemistry 333 and 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:			22 to 27
	(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
	LB	144	Biology I: Organismal Biology	4
	LB	145	Biology II: Cellular and Molecular Biology	5
	MMG	201	Fundamentals to Microbiology	3
	PLB	105	Plant Biology	3
	PSL	250	Introductory Physiology	4
	ZOL	141	Introductory Human Genetics	3
	(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 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
	(5) The following course (4 credits):			
	BMB	401	Comprehensive Biochemistry	4
b.	The following courses in the Department of Chemistry:			36 or 37
	(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:			47 to 56
	(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
	LB	144	Biology I: Organismal Biology	4
	LB	145	Biology II: Cellular and Molecular Biology	5
	MMG	201	Fundamentals of Microbiology	3
	PLB	105	Plant Biology	3
	PSL	250	Introductory Physiology	4
	ZOL	141	Introductory Human Genetics	3
	(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	255H	Honors Differential Equations	3
	MTH	340	Ordinary Differential Equations I	3
	MTH	347H	Honors Ordinary Differential Equations	3
	(6) 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 Applications	3
	(c) MTH	317H	Honors Linear Algebra	4
	(7) One of the following courses (3 credits):			
	MTH	310	Abstract Algebra I and Number Theory	3
	MTH	320	Analysis I	3
	MTH	415	Applied Linear Algebra	3
	MTH	418H	Honors Algebra I	3
	MTH	428H	Honors Complex Analysis	3
	MTH	441	Ordinary Differential Equations II	3
	MTH	442	Partial Differential Equations	3
	MTH	443	Boundary Value Problems for Engineers	3
	MTH	451	Numerical Analysis I	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
	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	3
	PHY	294H	Honors Physics II–Electromagnetism	3
	(c) LB	273	Physics I	4
	LB	274	Physics II	4
	(9) 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
	(10) 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 Atomic, Molecular and Condensed Matter Physics 3
PHY 492 Nuclear and Elementary Particle Physics 3

b. The following courses in the Department of Chemistry: . . . . . 28 to 30

(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) 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 2

(5) Both of the following courses (6 credits):
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 majors leading to the Bachelor of Arts and Bachelor of Science degrees are available for teacher certification.

A chemistry disciplinary minor is also available for teacher certification.

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

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

GRADUATE STUDY

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

Master of Science
Chemistry
Doctor of Philosophy
Chemical Physics
Chemistry
Chemistry—Environmental Toxicology

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

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, inorganic, organic, or physical chemistry, or chemical physics. Numerous cross–disciplinary research opportunities involving, for example, biochemistry or the cyclotron laboratory, are also available.

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

Admission

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

Requirements for the Doctor of Philosophy Degree in Chemistry

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

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

CHEMISTRY—ENVIRONMENTAL TOXICOLOGY

Doctor of Philosophy

For information about the Doctor of Philosophy degree program in chemistry—environmental toxicology, refer to the statement on *Doctoral Program in Environmental and Integrative Toxicological Sciences* in the *Graduate Education* section of this catalog.

DEPARTMENT of COMPUTATIONAL MATHEMATICS, SCIENCE and ENGINEERING

Andrew J. Christlieb, Chairperson

Computational Mathematics, Science and Engineering is the multidisciplinary field that is concerned with the use of advanced computing capabilities to solve complex problems pertaining to computational modeling and data science. Among the 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 is designed to provide 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.

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
		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 credits):			
	(1)	LB	273 Physics I	4
		PHY	183 Physics for Scientists and Engineers I	4
	(2)	LB	274 Physics II	4
		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	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 students' 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

Complete 17 credits from the following:

				CREDITS
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	Introducation 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, is designed to provide 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
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 Certificate
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

David W. Hyndman, Chairperson

Earth and Environmental Sciences (EES) target understanding the dynamic nature of the Earth - from its origin to today. We study the transformation of Earth over timescales ranging from milliseconds to billions of years. We collaborate to understand how physical, biological, and chemical systems formed and continue to shape the Earth.

Among the natural sciences, this is the quintessential interdisciplinary science. In addition to geological disciplines, including seismology, petrology, hydrology, geomicrobiology, paleobiology, geochemistry, mineral physics, tectonics, and cognition, EES students can expect to take courses in related sciences, including biology, chemistry, physics, math, and computational sciences. This multi-disciplinary curriculum provides a unique perspective on issues 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
      (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.
   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 - Equalibrium 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 426may be used to satisfy either the requirements for the major or therequirements 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

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Science degree in Geological Sciences.
   The University's Tier II writing requirement for the Geological Sciences major is met by completing 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.
3. The following requirements for the major:

CREDITS

   a. The following courses outside the Department of Earth and Environmental Sciences:. . . . . 26 or 27
      (1) All of the following courses (8 credits):
      CEM 161 Chemistry Laboratory I 1
      MTH 132 Calculus I 3
      MTH 133 Calculus II 4
      (2) One of the following pairs of courses (7 credits):
      (a) CEM 141 General Chemistry 4
      CEM 142 General and Inorganic Chemistry 3
      (b) CEM 151 General and Descriptive Chemistry 4
      CEM 152 Principles of Chemistry 3
      (3) One of the following options (3 or 4 credits):
      (a) MTH 234 Multivariable Calculus 4
      (b) One course of at least 3 credits in statistics and probability.
      (4) One of the following groups of courses (8 credits):
      (a) PHY 231 Introductory Physics I 3
      PHY 232 Introductory Physics II. 3
      PHY 251 Introductory Physics Laboratory I 1
      PHY 252 Introductory Physics Laboratory II. 1
      (b) PHY 183 Physics for Scientists and Engineers I 4

PHY 184 Physics for Scientists and Engineers II 4

b. The following courses in the Department of Earth and Environmental Sciences:. 40

GLG 201 The Dynamic Earth 4
GLG 304 Physical and Biological History of the Earth 4
GLG 321 Mineralogy and Geochemistry. 4
GLG 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 491fulfills 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

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 minerology, 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.

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:

Requirements for Both Plan A and Plan B

			CREDITS
1. Tier I requirements (10 to 12 credits):			
a. General Component. The following course (1 credit):			
GLG	423	Environmental Geosciences	1
b. Soil Component. One of the following courses (3 or 4 credits):			
CSS	455	Pollutants in the Soil Environment	3
CSS	825	Clay Mineralogy and Soils Genesis.	4
CSS	855	Interfacial Environmental Chemistry	4
c. Chemical Component. One of the following courses (3 credits):			
GLG	421	Environmental Geochemistry	3
GLG	821	Aqueous Geochemistry	3
GLG	823	Isotope Geochemistry	3

d. Hydrogeology Component. One of the following courses (3 or 4 credits):

CE	421	Engineering Hydrology	3
CE	821	Groundwater Hydraulics	3
GLG	411	Hydrogeology	4

2. Tier II requirement. One of the following courses (3 or 4 credits):

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

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

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

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

Additional Requirements for Plan A

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

Additional Requirements for Plan B

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

ENVIRONMENTAL GEOSCIENCES—ENVIRONMENTAL TOXICOLOGY

Doctor of Philosophy

For information about the Doctor of Philosophy degree program in environmental geosciences–environmental toxicology, refer to the statement on *Doctoral Program in Environmental and Integrative Toxicological Sciences* in the *Graduate Education* section of this catalog.

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

Thomas Getty, 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.

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/zoology is to help students to understand the concepts of environmental biology and to apply those concepts to improve both the natural environment and the environment perturbed by human activities. The focus of the program is on animal biology. The 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 328, 353, 355L, 384, 415, 425, 445, 450, 483; 485. 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 an d 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 to 10 credits):				

(1) PHY 231 Introductory Physics I 3
PHY 232 Introductory Physics II 3
PHY 251 Introductory Physics Laboratory I 1
PHY 252 Introductory Physics Laboratory II 1
(2) PHY 183 Physics for Scientists and Engineers I 4
PHY 184 Physics for Scientists and Engineers II 4
(3) LB 273 Physics I 4
LB 274 Physics II 4

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 (25 credits):
CSS 210 Fundamentals of Soil Science 3
IBIO 306 Invertebrate Biology 4
IBIO 341 Fundamental Genetics 4
IBIO 355 Ecology 3
IBIO 355L Ecology Laboratory (W) 1
IBIO 445 Evolution (W) 3
IBIO 483 Environmental Physiology (W) 4
PLB 441 Plant Ecology 3
Entomology 404 may be substituted for Integrative Biology 306.
Forestry 404 may be substituted for Plant Biology 441.

h. One course or pair of courses from each of the following four groups of courses (13 to 15 credits):
(1) 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
(2) PLB 218 Plants of Michigan 3
PLB 418 Plant Systematics 3
(3) FW 420 Stream Ecology 3
GEO 221 Introduction to Geographic Information 3
and
GEO 221L Introduction to Geographic Information Laboratory 1
GEO 324 Remote Sensing of the Environment 4
IBIO 353 Marine Biology (W) 4
IBIO 485 Tropical Biology (W) 3
PLB 424 Algal Biology 4
Both Geography 221 and 221L must be completed to satisfy this requirement.
(4) FW 416 Marine Ecosystem Management 3
FW 472 Limnology 3
GLG 421 Environmental Geochemistry 4
IBIO 357 Global Change Biology (W). 3
IBIO 446 Environmental Issues and Public Policy 3

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 328, 353, 355L, 425, 445, 483. 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. One course from each of the following groups of courses (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 to 10 credits):
(1) PHY 231 Introductory Physics I 3
PHY 232 Introductory Physics II. 3
PHY 251 Introductory Physics Laboratory I 1
PHY 252 Introductory Physics Laboratory II. 1
(2) PHY 183 Physics for Scientists and Engineers I 4
PHY 184 Physics for Scientists and Engineers II 4
(3) LB 273 Physics I 4
LB 274 Physics II. 4
(4) PHY 193H Honors Physics I – Mechanics 4
PHY 294H Honors Physics II – Electromagnetism 4

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
MMG 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
MMG 409 Eukaryotic Cell Biology 3

j. One of the following courses (3 or 4 credits):
IBIO 483 Environmental Physiology (W) 4
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 and Molecular Genetics 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 be-

yond 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 two of the following courses: Integrative Biology 328, 353, 355L, 384, 415, 425, 445, 450, 483, and 485. 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 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 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 Writing (W) . . . 3
   WRA 331 Writing in the Public Interest (W) . . . 3
   WRA 341 Nature, Environmental, and Travel Writing . . . 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
   CSUS 325 Study and Practice of Communication for Sustainability (W) . . . 3
   FW 435 Integrated Communications for the Fisheries and Wildlife Professional . . . 3
   (3) **Computer Systems** (3 or 4 credits):
   CSE 101 Computing Concepts and Competencies . . . 3
   CSE 201 Fundamentals of Information Technology . . . 3
   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 . . . 3
   and
   GEO 221L Introduction to Geographic Information Laboratory . . . 1
   GEO 324 Remote Sensing of the Environment . . . 4
   GEO 325 Geographic Information Systems . . . 3
   NSC 204 Introduction to Computational Modeling . . . 4
   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

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. 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 credits):
(1) PHY 231 Introductory Physics I . . . 3
PHY 232 Introductory Physics II. . . . 3
PHY 251 Introductory Physics Laboratory I . . . 1
PHY 252 Introductory Physics Laboratory II. . . . 1
(2) PHY 183 Physics for Scientists and Engineers I . . . 4
PHY 184 Physics for Scientists and Engineers II . . . 4
(3) LB 273 Physics I . . . 4
LB 274 Physics II. . . . 4
(4) PHY 193H Honors Physics I-Mechanics. . . . 4
PHY 294H Honors Physics II-Electromagnetism . . . 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. 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 402 Neurobiology . . . 3
IBIO 405 Neural Basis of Animal Behavior. . . . 3
(3) One of the following courses (4 credits):
IBIO 306 Invertebrate Biology . . . 4
IBIO 328 Comparative Anatomy and Biology of Vertebrates . . . 4
(4) One of the following courses (3 or 4 credits):
ANS 305 Applied Animal Behavior . . . 3
ANS 405 Endocrinology of Reproduction . . . 4
ANS 455 Avian Physiology . . . 4
FW 364 Ecological Problem Solving. . . . 3
FW 419 Applications of Geographic Information Systems to Natural Resource Management . . . 4
GEO 221 and GEO 221L Introduction to Geographic Information . . . 3 and Introduction to Geographic Information Laboratory . . . 1
GEO 324 Remote Sensing of the Environment. . . . 4
GEO 325 Geographic Information Systems . . . 3
IBIO 320 Developmental Biology . . . 4
IBIO 483 Environmental Physiology (W) . . . 4
LIN 463 Introduction to Cognitive Science . . . 3
PSY 301 Cognitive Neuroscience . . . 3
PSY 402 Sensation and Perception (W) . . . 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.

Cell and Developmental 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) One of the following courses (4 credits):
IBIO 320 Developmental Biology . . . 4
IBIO 425 Cells and Development (W) . . . 4
(3) Eighteen credits from the following courses:
BMB 401 Comprehensive Biochemistry . . . 4
IBIO 328 Comparative Anatomy and Biology of Vertebrates . . . 4
IBIO 343 Genetics Laboratory . . . 3
IBIO 402 Neurobiology . . . 3
IBIO 408 Histology . . . 4
IBIO 450 Cancer Biology (W). . . . 3
MMG 301 Introductory Microbiology . . . 3
MMG 302 Introductory Laboratory for General and Allied Health Microbiology. . . . 1
MMG 404 Human Genetics . . . 3
MMG 409 Eukaryotic Cell Biology . . . 3
Biochemistry and Molecular Biology 461 and 462 combined, may be substituted for Biochemistry and Molecular Biology 401. If Integrative Biology 320 and 425 are both completed in item (2), students only need to complete 14 credits in course work to fulfill this requirement.

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) One of the following courses (4 credits):
IBIO 306 Invertebrate Biology . . . 4
IBIO 328 Comparative Anatomy and Biology of Vertebrates . . . 4
(3) One of the following courses (3 or 4 credits):
IBIO 313 Animal Behavior . . . 3
IBIO 316 General Parasitology. . . . 3
IBIO 357 Global Change Biology (W). . . . 3
IBIO 483 Environmental Physiology (W) . . . 4
IBIO 485 Tropical Biology (W) . . . 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 and GEO 221L Introduction to Geographic Information . . . 3 and Introduction Geographic Information Laboratory . . . 1
GEO 324 Remote Sensing of the Environment. . . . 4
GEO 325 Geographic Information Systems . . . 3
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.

Genetics

(1) All of the following courses (23 credits):
BMB 461 Advanced Biochemistry I. . . . 3
BMB 462 Advanced Biochemistry II . . . 3
IBIO 341 Fundamental Genetics . . . 4
IBIO 343 Genetics Laboratory . . . 3
IBIO 355 Ecology . . . 3
IBIO 355L Ecology Laboratory (W) . . . 1

IBIO 445 Evolution (W). 3
MMG 431 Microbial Genetics. 3

(2) One of the following courses (3 or 4 credits):
BMB 472 Advanced Molecular Biology Laboratory. 3
IBIO 425 Cells and Development (W) 4

(3) A minimum of 4 credits completed in a genetics laboratory or field experience arranged in consultation with 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 items (2) and (3). Additional courses completed from items (2) and (3) may be counted as Integrative Biology electives toward the 33 credits. Courses beyond those taken to satisfy items (1), (2), and (3) may come from other departments with the approval of the student's academic advisor.

General Zoology

(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) One of the following courses (4 credits):
IBIO 306 Invertebrate Biology 4
IBIO 328 Comparative Anatomy and Biology of Vertebrates. 4

(3) One of the following courses (3 or 4 credits):
IBIO 313 Animal Behavior 3
IBIO 483 Environmental Physiology (W) 4

(4) One of the following courses (3 or 4 credits):
IBIO 320 Developmental Biology 4
IBIO 408 Histology 4
IBIO 425 Cells and Development (W) 4
MMG 409 Eukaryotic Cell Biology 3

(5) A minimum of 4 laboratory courses at the 300-400 level selected from the following:
ANS 313 Principles of Animal Feeding and Nutrition . . . 4
IBIO 306 Invertebrate Biology 4
IBIO 320 Developmental Biology 4
IBIO 328 Comparative Anatomy and Biology of Vertebrates 4
IBIO 343 Genetics Laboratory 3
IBIO 355L Ecology Laboratory (W) 1
IBIO 360 Biology of Birds 4
IBIO 365 Biology of Mammals 4
IBIO 384 Biology of Amphibians and Reptiles (W). 4
IBIO 408 Histology 4
IBIO 425 Cells and Development (W) 4
MMG 302 Introductory Laboratory for General and Allied Health Microbiology. 1
Laboratory courses taken to satisfy items (1), (2), and (4) may also be applied to this requirement.

(6) 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), and (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), (4) or (5) may come from other departments with the approval of the student's academic advisor.

Marine Biology

(1) All of the following courses (23 credits):
IBIO 303 Oceanography. 4
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 (W) 4

(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
(b) BMB 401 Comprehensive Biochemistry 4
CEM 383 Introductory Physical Chemistry I 3
FW 416 Marine Ecosystem Management. 3
FW 424 Population Analysis and Management . . 4
GEO 221 Introduction to Geographic Information. . 3
and
GEO 221L Introduction Geographic Information Laboratory 1
GEO 324 Remote Sensing of the Environment. . . . 4
IBIO 357 Global Change Biology (W). 3
MMG 425 Microbial Ecology 3
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):
ENT 469 Biomonitoring of Streams and Rivers 3
FW 474 Field and Laboratory Techniques for Aquatic Studies 3
IBIO 440 Field Ecology and Evolution 4
PLB 424 Algal Biology 4
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 (30 credits):
IBIO 313 Animal Behavior 3
IBIO 328 Comparative Anatomy and Biology of Vertebrates 4
IBIO 341 Fundamental Genetics 4
IBIO 355 Ecology 3
IBIO 355L Ecology Laboratory (W) 1
IBIO 368 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. 2
IBIO 498 Internship in Zoo and Aquarium Science 4

(2) One of the following courses (3 or 4 credits):
ENT 404 Fundamentals of Entomology 3
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

(3) One of the following courses (3 or 4 credits):
ANS 313 Principles of Animal Feeding and Nutrition 4
ANS 314 Genetic Improvement of Domestic Animals 4
ANS 315 Anatomy and Physiology of Farm Animals 4
FW 444 Conservation Biology 3
FW 472 Limnology 3
IBIO 353 Marine Biology (W) 4

(4) Two of the following courses (6 to 8 credits):
ANS 405 Endocrinology of Reproduction 4
ANS 455 Avian Physiology. 4
FW 424 Population Analysis and Management 4
GEO 221 Introduction to Geographic Information. 3
and
GEO 221L Introduction Geographic Information Laboratory 1
GEO 324 Remote Sensing of the Environment. 4
IBIO 303 Oceanography. 4
IBIO 306 Invertebrate Biology 4
IBIO 483 Environmental Physiology (W) 4
IBIO 485 Tropical Biology (W) 3
SOC 412 Animals, People and Nature 3
Both GEO 221 and 221L must be completed to satisfy this requirement.

(5) One additional course of at least 3 credits selected from a list of approved courses that is available from the Department of Integrative Biology.

(6) 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. The department also offers a Doctor of Philosophy degree program in Integrative Biology-Environmental Toxicology. 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.

Students may obtain specialized graduate training through interdepartmental graduate programs. Integrative Biology faculty are affiliated with interdepartmental graduate programs and research in genetics, cell and molecular biology, neuroscience, and ecology and evolutionary biology. Additional information about the doctoral programs in genetics and neuroscience, and about the Specialization in Ecology and Evolutionary Biology, may be found in other sections of this catalog. Students specializing in ecological research may take courses and carry out research at the W. K. Kellogg Biological Station located near Kalamazoo.

Faculty research interests are available from the department Web site. Interested students are also encouraged to contact the Chairperson or 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.

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 he/she did not enter with a master's and is working directly toward the doctoral degree.
5. Successfully defend the doctoral dissertation.

INTEGRATIVE BIOLOGY—ENVIRONMENTAL TOXICOLOGY

Doctor of Philosophy

For information about the Doctor of Philosophy degree program in integrative biology—environmental toxicology, refer to the statement on *Doctoral Program in Environmental and Integrative Toxicological Sciences* in the *Graduate Education* section of this catalog.

W. K. KELLOGG BIOLOGICAL STATION

Katherine L. Gross, Director

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

Keith Promislow, 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 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 Computational Mathematics prepares students for either for 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

Admission to the Major

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.

Additional criteria for admission includes the following:

1. Passing a Society of Actuaries exam in one of the following ways:
   a. Passing the Society of Actuaries Exam P (Probability), or the Casualty Actuary Society Exam 1 (Probability) before August of the year of admission into the degree program.
   b. Passing the Society of Actuaries Exam FM (Financial Mathematics), or the Casualty Actuary Society Exam 2 (Financial Mathematics) before August of the year of admission into the degree program.
2. Passing an MSU screening which involves satisfactory performance in an interview with the Director of the Actuarial Science Program or their delegate.

Students wishing to major in actuarial science need to make a request to the Actuarial Science program director or delegate when they are eligible and ready to be considered for the major. The Actuarial Science program director approves acceptance into the major. The Director of the Actuarial Science program, or their delegate, could admit students into the program who do not satisfy both of these criteria under exceptional circumstances. A student denied access to the actuarial science major could become an actuary by successfully taking Actuarial Science Exams.

Students who declare the major in actuarial science 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, Quantitative Risk Analytics, or in Statistics and Probability.

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 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 (6 to 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
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

COMPUTATIONAL MATHEMATICS

Requirements for the Bachelor of Science Degree in Computational Mathematics

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

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

   Students who are in the teacher certification program are required to complete Mathematics 330 or 432 and Statistics and Probability 430.

   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:. . 28 or 29
(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, entomology, microbiology, physiology, plant biology, or integrative biology. Any course noted in item (2) (c) below may count towards the 2 credit laboratory requirement.
(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
(3) Both of the following courses (8 credits):
CSE 231 Introduction to Programming I. 4
CSE 232 Introduction to Programming II 4
(4) One course from each of the following groups (8 credits):
(a) PHY 183 Physics for Scientists and Engineers I . . 4
LB 273 Physics I 4
(b) PHY 184 Physics for Scientists and Engineers II . . 4
LB 274 Physics II. 4

b. First–year competency in a foreign language
or
For students, who have been admitted to the teacher certification program, completion of the Professional Education Courses in the Department of Teacher Education.

c. A total of 33 to 40 credits in courses in the Department of Mathematics including:
(1) One course from each of the following two groups (6 to 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. 3
LB 119 Calculus II 4
(2) One of the following courses (3 or 4 credits):
MTH 234 Multivariable Calculus 4
MTH 254H Honors Multivariable Calculus. 3
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) One course from each of the following groups (6 credits):
(a) MTH 310 Abstract Algebra I and Number Theory. . 3
MTH 418H Honors Algebra I 3
(b) MTH 320 Analysis I. 3
MTH 327H Honors Introduction to Analysis. 3
(5) All of the following courses (9 credits):
MTH 451 Numerical Analysis I 3
MTH 481 Discrete Mathematics I 3
MTH 496 Capstone in Mathematics (W). 3
The completion of Mathematics 496 satisfies the capstone course requirement of the computational mathematics major.
(6) One of the following courses (3 credits):
MTH 452 Numerical Analysis II. 3
MTH 482 Discrete Mathematics II. 3
(7) 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

d. At least one of the following courses: 3
Students who select Mathematics 452 or 482 may count the credits toward either requirement 3.c.(6) or 3.d. but not toward both of those requirements.

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

CSE 331 Algorithms and Data Structures 3
CSE 440 Introduction to Artificial Intelligence. 3
MTH 360 Theory of Mathematical Interest 3
MTH 415 Applied Linear Algebra 3
MTH 416 Introduction to Algebraic Coding. 3
MTH 441 Ordinary Differential Equations II 3
MTH 452 Numerical Analysis II. 3
MTH 457 Introduction to Financial Mathematics. 3
MTH 482 Discrete Mathematics II. 3
STT 351 Probability and Statistics for Engineering 3
STT 430 Introduction to Probability and Statistics 3
STT 441 Probability and Statistics I: Probability 3
STT 455 Actuarial Models I 3
STT 461 Computations in Probability and Statistics 3

Requirements for the Bachelor of Arts Degree in Computational Mathematics

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

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

   Students who are in the teacher certification program are required to complete Mathematics 330 or 432 and Statistics and Probability 430.

   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:	21
	(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):	
	LB 273 Physics I	4
	PHY 183 Physics for Scientists and Engineers I	4
	(3) 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
	(4) Both of the following courses (8 credits):	
	CSE 231 Introduction to Programming I	4
	CSE 232 Introduction to Programming II	4
b.	Second–year competency in a foreign language. *or* For students, who have been admitted to the teacher certification program, first-year competency in a foreign language and completion of the Professional Education Courses in the Department of Teacher Education.	
c.	A total of 33 to 40 credits in courses in the Department of Mathematics including:	
	(1) One course from each of the following two groups (6 to 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	3
	LB 119 Calculus II	4
	(2) One of the following courses (3 or 4 credits):	
	MTH 234 Multivariable Calculus	4
	MTH 254H Honors Multivariable Calculus	3
	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) One course from each of the following groups (6 credits):	
	(a) MTH 310 Abstract Algebra I and Number Theory	3
	MTH 418H Honors Algebra I	3
	(b) MTH 320 Analysis I	3
	MTH 327H Honors Introduction to Analysis	3
	(5) All of the following courses (9 credits):	
	MTH 451 Numerical Analysis I	3
	MTH 481 Discrete Mathematics I	3
	MTH 496 Capstone in Mathematics (W)	3
	(6) One of the following courses (3 credits):	
	MTH 452 Numerical Analysis II	3
	MTH 482 Discrete Mathematics II	3
	(7) 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
d.	At least one of the following courses:	3

Students who select Mathematics 452 or 482 may count the credits toward either requirement 3.c.(6) or 3.d. but not toward both of those requirements.

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

CSE 331 Algorithms and Data Structures 3
CSE 440 Introduction to Artificial Intelligence 3
MTH 360 Theory of Mathematical Interest 3
MTH 415 Applied Linear Algebra 3
MTH 416 Introduction to Algebraic Coding 3
MTH 441 Ordinary Differential Equations II 3
MTH 452 Numerical Analysis II 3
MTH 457 Introduction to Financial Mathematics 3
MTH 482 Discrete Mathematics II 3
STT 351 Probability and Statistics for Engineering 3
STT 430 Introduction to Probability and Statistics 3
STT 441 Probability and Statistics I: Probability 3
STT 455 Actuarial Models I 3
STT 461 Computations in Probability and Statistics 3

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 396 or 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:	20 or 21
	(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, entomology, microbiology, physics, 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 I	2
	LB 171L Introductory Chemistry Laboratory I	2
	(3) One course from each of the following groups (8 credits):	
	(a) PHY 183 Physics for Scientists and Engineers I	4
	LB 273 Physics I	4
	(b) PHY 184 Physics for Scientists and Engineers II	4
	LB 274 Physics II	4
b.	First–year competency in a foreign language *or* For students who have been admitted to the teacher certification program, completion of the Professional Education Courses in the Department of Teacher Education.	
c.	A total of 36 to 43 credits in courses in the Department of Mathematics including:	36 to 43
	(1) One course from each of the following two groups (6 to 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	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. Students in the teacher certification program may substitute Mathematics 396 Capstone in Mathematics for Secondary Education for Mathematics 496.

(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. Mathematics 415 may not be used to fulfill the requirements of the major. Students may use no more than one of Mathematics 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 430 is required for students in the teacher

certification program. Either Statistics and Probability 430 or 441 may be substituted for one 300-level mathematics course. The 300-400 level courses as referenced in item 3. c. partially satisfy this requirement.

(6) Two of the following courses (6 credits):
MTH 310 Abstract Algebra I and Number Theory. 3
MTH 411 Abstract Algebra II. 3
MTH 418H Honors Algebra I 3
MTH 419H Honors Algebra II 3
Students may not satisfy this requirement with the combination of MTH 411 and MTH 418H.

(7) One course from each of the following groups of courses (6 credits):
(a) MTH 320 Analysis I 3
MTH 327H Honors Introduction to Analysis. 3
(b) MTH 421 Analysis II 3
MTH 429H Honors Real 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
Students in the teacher certification program must take either Mathematics 330 or 432. Students not in the teacher certification program must take Mathematics 340 or 347H. Students not in the teacher certification program with prior credit in Mathematics 235 may substitute an approved 400-level Mathematics course for Mathematics 340.

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 396 or 496 and Mathematics 309 or 310 or 418H. Those courses are referenced in items 3. c. (1) and 3. c. (3) below.
Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
2. The requirements of the College of Natural Science for the Bachelor of 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
(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, entomology, microbiology, physics, physiology, plant biology, or integrative biology.
(2) One of the following courses (4 credits):
LB 273 Physics I 4
PHY 183 Physics for Scientists and Engineers I 4
(3) 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

b. Second–year competency in a foreign language
or
For students who have been admitted to the teacher certification program, first–year competency in a foreign language and completion of the Professional Education Courses in the Department of Teacher Education.

c. A total of 36 to 43 credits in courses in the Department of Mathematics including:. . . . . 36 to 43
(1) One course from each of the following two groups (6 to 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. 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. Students in the teacher certification program may substitute Mathematics 396 Capstone in Mathematics for Secondary Education for Mathematics 496.
(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. Mathematics 415 may not be used to fulfill the requirements of the major. 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 430 is required for students in the teacher certification program. Either Statistics and Probability 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) Two of the following courses (6 credits):
MTH 310 Abstract Algebra I and Number Theory. 3
MTH 411 Abstract Algebra II. 3
MTH 418H Honors Algebra I 3
MTH 419H Honors Algebra II 3
Students may not satisfy this requirement with the combination of MTH 411 and MTH 418H.
(7) One course from each of the following groups of courses (6 credits):
(a) MTH 320 Analysis I 3
MTH 327H Honors Introduction to Analysis. 3
(b) MTH 421 Analysis II 3
MTH 429H Honors Real 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
Students in the teacher certification program must take either Mathematics 330 or 432. Students not in the teacher certification program must take Mathematics 340 or 347H. Students not in the teacher certification program with prior credit in Mathematics 235 may substitute an approved 400-level Mathematics course for Mathematics 340.

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 (12 or 13 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
CEM 181H Honors Chemistry I 4
LB 171 Principles of Chemistry I 4
(3) One of the following courses (4 credits):
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. Second-year competency in a foreign language
or
For students who have been admitted to the teacher certification program, completion of the Professional Education Courses in the Department of Teacher Education and first-year competency in a foreign language.

c. 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 (25 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 428H Honors Complex Analysis 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.

d. A minimum of 12 credits in electives. Two courses must be selected from group (1) and two courses from group (2). Any MTH course at the 800-level or above may also satisfy the requirement from group (1). Any MTH course at the 400-level or above may also satisfy the requirement from group (2). Students in the teacher certification program must take MTH 432 to fulfill part of this elective requirement and may not use STT 430 towards fulfillment of this requirement. Any other substitutions must be approved by an advisor for the Mathematics, Advanced program.

(1) Two of the following courses (6 credits):
MTH 416 Introduction to Algebraic Coding 3
MTH 417 Topics in Number Theory 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

(2) Two of the following courses (6 to 8 credits):
CMSE 820 Mathematical Foundations of Data Science . . 3
CMSE 821 Numerical Methods for Differential Equations. 3
CMSE 823 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 Formal Methods in Software Development . . . 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
EC 820A Econometrics IA 3
EC 820B Econometrics IB 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

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, 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 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 (17 to 21 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 groups of courses (8 or 10 credits):
(a) CEM 141 General Chemistry 4
CEM 142 General and Inorganic Chemistry 3
CEM 161 Chemistry Laboratory I 1
(b) CEM 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 172 Principles of Chemistry II. 3
LB 171L Introductory Chemistry Laboratory I 1

(3) One of the following groups of courses (6 or 8 credits):
(a) PHY 183 Physics for Scientists and Engineers I . . 4
PHY 184 Physics for Scientists and Engineers II . . 4
(b) PHY 193H Honors Physics I – Mechanics 4
PHY 294H Honors Physics II – Electromagnetism . . 4
(c) LB 273 Physics I 4
LB 274 Physics II. 4

(4) A minimum of 2 credits in laboratory courses in biological science, chemistry, entomology, microbiology, physics, physiology, plant biology, or integrative biology.

b. First-year competency in a foreign language
or
For students who have been admitted to the teacher certification program, completion of the Professional Education Courses in the Department of Teacher Education.

c. A total of 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 (25 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 428H Honors Complex Analysis 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.

d. A minimum of 12 credits in electives. Two courses must be selected from group (1) and two courses from group (2). Any MTH course at the 800-level or above may also satisfy the requirement from group (1). Any MTH course at the 400-level or above may also satisfy the requirement from group (2). Students in the teacher certification program must take MTH 432 to fulfill part of this elective requirement and may not use STT 430 towards fulfillment of this requirement. Any other substitutions must be approved by an advisor for the Mathematics, Advanced program.

(1) Two of the following courses (6 credits):
MTH 416 Introduction to Algebraic Coding 3
MTH 417 Topics in Number Theory 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

(2) Two of the following courses (6 to 8 credits):
CMSE 820 Mathematical Foundations of Data Science . . 3
CMSE 821 Numerical Methods for Differential Equations. 3
CMSE 823 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 Formal Methods in Software Development . . . 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
EC	820A	Econometrics IA	3
EC	820B	Econometrics IB	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

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

Complete the following (21 to 28 credits):

				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
	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 disciplinary majors leading to the Bachelor of Arts and Bachelor of Science degrees are available for teacher certification. The mathematics, advanced major leading to the Bachelor of Science degree is also available for secondary teacher certification.

A mathematics-elementary and mathematics-secondary disciplinary minor are also available for teacher certification.

Students who elect a mathematics or mathematics, advanced disciplinary major or the mathematics-elementary or 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, as well as a Master of Arts for Teachers degree. 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.

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
   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 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.

MATHEMATICS

Master of Arts for Teachers

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

Admission

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

Requirements for the Master of Arts for Teachers Degree in Mathematics

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

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

Master of Science

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

Admission

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

Requirements for the Master of Science Degree in Mathematics

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

DEPARTMENT of MICROBIOLOGY and MOLECULAR GENETICS

Victor DiRita, Chairperson

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

Microbiology involves the study of microscopic organisms: bacteria, viruses, algae, fungi, and protozoa, as well as 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 and Molecular Genetics 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 and Molecular Genetics also participates in the joint bachelor's degree/master's degree of the College of Natural Science. For additional information, refer to the *College of Natural Science Dual Degree Program: Bachelor of Science and Master of Science* section of this catalog.

UNDERGRADUATE PROGRAMS

ENVIRONMENTAL BIOLOGY/MICROBIOLOGY

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

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

The educational objectives of the program are to:

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

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

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

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

   The University's Tier II writing requirement for the Environmental Biology/Microbiology major is met by completing Microbiology 408. That course is referenced in item 3.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:	62 or 64
	(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 (57 credits):	
	BS 161 Cell and Molecular Biology	3
	BS 162 Organismal and Population Biology	3
	BS 171 Cell and Molecular Biology Laboratory	2
	or	
	BS 172 Organismal and Population Biology Laboratory	2
	CE 280 Principles of Environmental Engineering and Science	3
	CEM 141 General Chemistry	4
	CEM 142 General and Inorganic Chemistry	3
	CEM 161 Chemistry Laboratory I	1
	CEM 162 Chemistry Laboratory II	1
	CEM 251 Organic Chemistry I	3
	CEM 252 Organic Chemistry II	3
	CEM 255 Organic Chemistry Laboratory	2
	CSS 210 Fundamentals of Soil Science	3
	GLG 201 The Dynamic Earth	4
	GLG 421 Environmental Geochemistry	4
	MTH 132 Calculus I	3
	PHY 231 Introductory Physics I	3
	PHY 232 Introductory Physics II	3
	PHY 251 Introductory Physics Laboratory I	1
	PHY 252 Introductory Physics Laboratory II	1
	STT 231 Statistics for Scientists	3
	ZOL 355 Ecology	3
	ZOL 355L Ecology Laboratory (W)	1
b.	The following courses in the Department of Microbiology and Molecular Genetics:	19
	(1) All the following courses (16 credits):	
	MMG 301 Introductory Microbiology	3
	MMG 302 Introductory Laboratory for General and Allied Health Microbiology	1
	MMG 408 Advanced Microbiology Laboratory (W)	3
	MMG 421 Prokaryotic Cell Physiology	3
	MMG 425 Microbial Ecology	3
	MMG 431 Microbial Genetics	3
	(2) One of the following two options (3 credits):	
	(a) MMG 491 Current Topics in Microbiology and Molecular Genetics	3
	(b) MMG 492 Undergraduate Research Seminar	1
	One of the following courses:	

MMG 499 Undergraduate Research 2
MMG 499H Honors Research 2
The completion of either of these two options fulfills the department's capstone course requirement.

c. One course from two of the following areas: 6
(1) CSS 455 Pollutants in the Soil Environment. 3
(2) FOR 404 Forest Ecology 3
(3) FSC 440 Food Microbiology 3
(4) GEO 206 Physical Geography 3
GEO 221 Introduction to Geographic Information 3
(5) MMG 426 Biogeochemistry 3
(6) MMG 445 Microbial Biotechnology (W) 3
(7) FOR 466 Natural Resource Policy 3
ZOL 446 Environmental Issues and Public Policy 3
(8) FW 420 Stream Ecology 3
FW 472 Limnology 3

GENOMICS AND MOLECULAR GENETICS

The objective of the Bachelor of Science degree program with a major in genomics and molecular genetics is to provide a broad foundation in science, with emphasis in genomics and molecular genetics. 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. On completion of the program, graduates may apply for certification with the National Registry of Microbiologists of the American Society for Microbiology.

In addition to the general degree requirements of the College of Natural Science, the undergraduate program in genomics and molecular genetics encompasses fundamental training in chemistry, mathematics, physics, and biology. This foundation provides the prerequisites for undertaking the basic courses in genomics and molecular genetics. 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 by the student. This research may fulfill part of the department's capstone course requirement for the bachelor's degree with a major in genomics and molecular genetics.

Requirements for the Bachelor of Science Degree in Genomics and Molecular Genetics

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 Genomics and Molecular Genetics.
   The University's Tier II writing requirement for the Genomics and Molecular Genetics major is met by completing Microbiology 434. That course is 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 and Molecular Genetics: . . . . . 47 to 57
(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
(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
CEM 186H Honors Chemistry Laboratory II 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
(6) The following course (4 credits):
ZOL 341 Fundamental Genetics 4
(7) One of the following groups of courses (8 to 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) 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
(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 and Molecular Genetics: 19
(1) All of the following courses (13 credits):
MMG 301 Introductory Microbiology 3
MMG 302 Introductory Laboratory for General and Allied Health Microbiology 1
MMG 409 Eukaryotic Cell Biology 3
MMG 431 Microbial Genetics. 3
MMG 433 Microbial Genomics. 3
(2) One of the following courses (3 credits):
MMG 408 Advanced Microbiology Laboratory (W) 3
MMG 434 Laboratory in Genomics and Molecular Genetics (W) 3
(3) One of the following two options (3 credits):
(a) MMG 491 Current Topics in Microbiology and Molecular Genetics. 3
(b) MMG 492 Undergraduate Research Seminar 1
One of the following courses:
MMG 499 Undergraduate Research 2
MMG 499H Honors Research 2
The completion of Microbiology 491, or Microbiology 492 and 499 or 499H, fulfills the department's capstone course requirement.

c. Two of the following courses: . . . . . 6 to 8
ANS 314 Genetic Improvement of Domestic Animals 4
ANS 425 Animal Biotechnology 3
CSE 231 Introduction to Programming I. 4
CSE 232 Introduction to Programming II 4
CSS 350 Introduction to Plant Genetics. 3
CSS 441 Plant Breeding and Biotechnology 3

MMG 404 Human Genetics 3
MMG 413 Virology 3
PLB 400 Introduction to Bioinformatics 3
ZOL 445 Evolution (W). 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. On completion of the program, graduates may apply for certification with the National Registry of Microbiologists of the American Society for Microbiology.

In addition to the general degree requirements of the College of Natural Science, the undergraduate program in microbiology encompasses fundamental training in chemistry, mathematics, physics, and biology. This foundation provides the prerequisites for undertaking the basic courses in microbiology.

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

Requirements for the Bachelor of Science Degree in Microbiology

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

   The University's Tier II writing requirement for the Microbiology major is met by completing Microbiology 408. That course is referenced in item 3. b. (1) below.

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

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

CREDITS

a. The following courses outside the Department of Microbiology:. . . . . 43 to 53

(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
  CEM 186H Honors Chemistry Laboratory II 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

(6) One of the following groups of courses (8 to 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) 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

(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 and Molecular Genetics: 16

(1) All of the following courses (13 credits):
- MMG 301 Introductory Microbiology 3
- MMG 302 Introductory Laboratory for General and Allied Health Microbiology. 1
- MMG 408 Advanced Microbiology Laboratory (W) 3
- MMG 421 Prokaryotic Cell Physiology. 3
- MMG 431 Microbial Genetics. 3

(2) One of the following, either (a) or (b) (3 credits):
- (a) MMG 491 Current Topics in Microbiology and Molecular Genetics. 3
- (b) MMG 492 Undergraduate Research Seminar 1

  and

  One of the following courses:
  - MMG 499 Undergraduate Research 2
  - MMG 499H Honors Research 2

  The completion of Microbiology 491, or Microbiology 492 and 499 or 499H, fulfills the department's capstone course requirement.

c. 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
- MMG 413 Virology 3
- MMG 425 Microbial Ecology 3
- MMG 433 Microbial Genomics 3
- MMG 445 Microbial Biotechnology (W) 3
- MMG 451 Immunology 3
- MMG 461 Molecular Pathogenesis 3
- MMG 463 Medical Microbiology 3

GRADUATE STUDY

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

MICROBIOLOGY and MOLECULAR GENETICS

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

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

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

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

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

Master of Science

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

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

Admission

In general, applicants should have had the equivalent of 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, and grades of 3.0 or above in science and mathematics courses. 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 and Molecular Genetics

The student must complete 30 credits under Plan A (with thesis). At least 5 credits of MMG 899 Master's Thesis Research is required. The final oral examination, which covers both course work and thesis research, is administered by the student's guidance committee and a representative of the department Graduate Committee. The examining committee recommends a grade for the thesis research and the advisability of further graduate study. All master's students are required to participate in laboratory teaching, and are expected to attend departmental seminars.

Students may select from the following courses:

			CREDITS
BMB	801	Molecular Biology	3
BMB	802	Metabolic Regulation and Signal Transduction	3
BMB	803	Protein Structure and Function	2
BMB	805	Protein Structure, Design, and Mechanism	3
MMG	801	Integrative Microbial Biology	4
MMG	803	Topics in Integrative Microbial Biology	2
MMG	813	Molecular Virology	3
MMG	825	Cell Structure and Function	3
MMG	833	Microbial Genetics	3
MMG	835	Eukaryotic Molecular Genetics	3
MMG	851	Immunology	3
MMG	861	Advanced Microbial Pathogenesis	3
MMG	991	Topics in Microbiology	1 to 3

Other courses may be used if approved by the Director of Graduate Studies.

Doctor of Philosophy

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

Admission

A student may apply for admission to the doctoral program in Microbiology and Molecular Genetics when the individual is about to earn or has earned a Bachelor of Science, Bachelor of Arts, Master of Science, or a professional medical degree. In general, applicants should have had the equivalent of 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, and grades of 3.0 or above in science and mathematics courses. Scores on the Graduate Record Examination General Test and a personal letter of professional intent and objectives are required. Although preparation in the fundamentals of microbiology is desirable, interested students with degrees in any of the physical or biological sciences or mathematics are invited to apply for admission to the program. Applicants not possessing all of the requirements may be admitted to the program provisionally and permitted to make up deficiencies on a collateral basis.

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

The student must:

1. Complete a minimum of 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 and Molecular Genetics.
2. Complete five graduate seminar courses, each of which involves an oral presentation by the student.
3. Complete at least two, and preferably three, rotations in the laboratories of different faculty members in the Department of Microbiology and Molecular Genetics. This requirement must be completed by the end of the first calendar year of enrollment in the program.
4. Pass the preliminary examination, which involves an oral defense of the research proposal. This examination is normally given at the end of the second year of enrollment in the program.
5. Submit a dissertation and a publishable manuscript, based on original research and representing a new and significant contribution to knowledge.

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

Academic Standards

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

BIOMOLECULAR SCIENCE GATEWAY - FIRST YEAR

Students are encouraged to apply for admission to the Ph.D. program through the BioMolecular Science Gateway – First Year, where students choose a doctoral major from any of six Ph.D. programs: biochemistry and molecular biology, cell and molecular biology, genetics and genome sciences, microbiology and molecular genetics, pharmacology and toxicology, or physiology. For additional information refer to the *College of Natural Science* section of this catalog.

MICROBIOLOGY—ENVIRONMENTAL TOXICOLOGY

Doctor of Philosophy

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

DEPARTMENT of PHYSICS and ASTRONOMY

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.

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. Cer-

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

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

CREDITS

a. The following courses outside the Department of Physics and Astronomy: . . . . . 33 to 39

(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

(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 (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	Introduction to Computational Modeling	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 Astro–nomy: . . . . . 33 to 38

(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 fo Scientists, I	1
PHY	192	Physics Laboratory for Scientistis, II	1

(b)

PHY	191	Physics Laboratory fo Scientists, I	1
PHY	192	Physics Laboratory for Scientistis, 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

(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.

(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

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

(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

(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 Astro–nomy: . . . . . 39 to 41

(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. (2) below.
   Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
2. The requirements of the College of Natural Science for the Bachelor of Arts degree.
   The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
3. The following requirements for the major:

CREDITS

a. The following courses outside the Department of Physics and Astronomy: . . . . . 25 or 26
(1) One of the following courses (3 or 4 credits):
BS 110 Organisms and Populations 4
BS 111 Cells and Molecules 3
ENT 205 Pests, Society and Environment 3
MMG 205 Allied Health Microbiology 3
PLB 105 Plant Biology 3
PSL 250 Introductory Physiology 4
ZOL 141 Introductory Human Genetics 3
(2) One of the following courses (4 credits):
CEM 141 General Chemistry 4
CEM 151 General and Descriptive Chemistry. 4
(3) All of the following courses (18 credits):
CEM 161 Chemistry Laboratory I 1
MTH 132 Calculus I 3
MTH 133 Calculus II 4
MTH 234 Multivariable Calculus 4
MTH 235 Differential Equations 3
One Mathematics course at the 300 level or above of at least 3 credits.

b. The following courses in the Department of Physics and Astro–nomy: . . . . . 27 to 32
(1) All of the following courses (8 credits):
PHY 191 Physics Laboratory for Scientists, I 1
PHY 192 Physics Laboratory for Scientists, II 1
PHY 321 Classical Mechanics I 3
PHY 410 Thermal and Statistical Physics 3
(2) One of the following clusters of courses (4 to 6 credits):
(a) Thesis cluster:
PHY 390 Physics Journal Seminar. 1
PHY 490 Senior Thesis 3
(b) Lecture course cluster:
PHY 491 Atomic, Molecular, and Condensed Matter Physics. 3
PHY 492 Nuclear and Elementary Particle Physics 3
(3) One of the following courses (3 or 4 credits):
PHY 183 Physics for Scientists and Engineers I 4
PHY 183B Physics for Scientists and Engineers I 4
PHY 193H Honors Physics I—Mechanics. 3
(4) One of the following courses (3 or 4 credits):
PHY 184 Physics for Scientists and Engineers II 4
PHY 184B Physics for Scientists and Engineers II 4
PHY 294H Honors Physics II—Electromagnetism 3
(5) One of the following courses (3 credits):
PHY 215 Thermodynamics and Modern Physics 3
PHY 215B Thermodynamics and Modern Physics 3
(6) One of the following courses (3 or 4 credits):
PHY 431 Optics I 3
PHY 440 Electronics. 4
(7) One of the following courses (3 credits):
PHY 471 Quantum Physics I 3
PHY 481 Electricity and Magnetism I 3
The completion of Physics 390 and 490 or Physics 491 and 492, fulfills the department's capstone course requirement.

TEACHER CERTIFICATION OPTIONS

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

A physics disciplinary minor is also available for teacher certification.

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

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

GRADUATE STUDY

The Department of Physics and Astronomy offers graduate programs leading to the Masters of Science and Doctor of Philosophy degrees in both physics and astrophysics. A Graduate Certificate in Accelerator Science and Engineering is 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.

ASTROPHYSICS AND ASTRONOMY

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

Master of Science

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

Admission

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

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

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

Requirements for the Master of Science Degree in Astrophysics and Astronomy

The student must:

1. Complete a total of 30 credits for the degree under either Plan A (with thesis) or Plan B (without thesis).
2. Pass 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

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 on the *Department of Chemistry*.

PHYSICS

Master of Science

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

Admission

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

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

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

Requirements for the Master of Science Degree in Physics

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

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

Concentration in Beam Physics. Students interested in pursuing a concentration in beam physics may do so through a partially or entirely online option. The regular requirements for the master's degree in physics apply. Credits for the concentration may be earned through courses and research including PHY 861, PHY 961, PHY 962, PHY 963, and PHY 964. The student's program of study must be approved by the student's guidance committee. Students may transfer up to 9 credits in relevant course topics approved on a case-by-case basis. Up to 10 credits of master's thesis research (PHY 899) may be earned under supervision of MSU faculty or through a suitable external mentor at a university or national laboratory near the student's location as determined on a case-by-case basis.

Doctor of Philosophy

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

Admission

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

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

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

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

Requirements for the Doctor of Philosophy Degree in Physics

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

Concentration in Beam Physics. Students interested in pursuing a concentration in beam physics may do so through a partially or entirely online option. The regular requirements for the doctoral degree in physics apply which includes successful completion of four subject examinations in core areas of physics which can be administered by a mutually approved local proctor, where such practice is permissible, and successful completion of a minimum of 24 credits of doctoral dissertation research. A minimum of 54 credits is required for completion of the program when combined with the requirements for the master's degree with a concentration in beam physics.

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

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

			CREDITS
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	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 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

Charles Leroy Cox, 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 PROGRAM

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
(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
(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 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

(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
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.

LINKED BACHELOR'S-MASTER'S DEGREE IN PHYSIOLOGY

Bachelor of Science Degree in Physiology
Master of Science Degree in Physiology

The department welcomes applications from Michigan State University Physiology undergraduate students in their junior and senior year. Admission applications must be made during the prior spring semester for an anticipated spring graduation or the prior fall semester for an anticipated fall graduation to allow admission before the final semester as a Physiology undergraduate. Admission to the program requires a minimum undergraduate grade-point average of 3.5 and an approved program of study for the Master of Science degree in Physiology at the time of admission. Admission to the Linked Bachelor's-Master's program allows the application of up to 9 credits toward the master's program for qualifying 400-level and above course work taken at the undergraduate level at Michigan State University or an external accredited institution. The number of approved credits, not to exceed 9, are applied toward the credit requirement of the master's degree. Credits applied to the Linked Bachelor's-Master's program are not eligible to be applied to any other graduate degree program.

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 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. Study for the Doctor of Philosophy degree with a major in physiology—environmental toxicology is administered by the College of Natural Science.

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

PHYSIOLOGY

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

A manual available at the department graduate office contains information on admission policies, financial support, and requirements for the Master of Science 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.

Requirements for the Master of Science Degree in Physiology

The student must complete 30 credits under Plan A (with thesis). The program of study is planned by the student in consultation with a major 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:

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

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

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

PHYSIOLOGY—ENVIRONMENTAL TOXICOLOGY

Doctor of Philosophy

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

BIOMOLECULAR SCIENCE GATEWAY - FIRST YEAR

Students are encouraged to apply for admission to the Ph.D. program through the BioMolecular Science Gateway – First Year, where students choose a doctoral major from any of six Ph.D. programs: biochemistry and molecular biology, cell and molecular biology, genetics and genome sciences, microbiology and molecular genetics, pharmacology and toxicology, or physiology. For additional information refer to the *College of Natural Science* section of this catalog.

DEPARTMENT of PLANT BIOLOGY

Danny J. Schnell, 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.

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 biotechnology industries, nurseries, botanical gardens, museums, herbaria, agricultural extension, or research laboratories, or who plan to pursue graduate study in the field of plant biology or related disciplines.

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

   The University's Tier II writing requirement for the Plant Biology major is met by completing Plant Biology 498 and 499 and Zoology 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. Cer-

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

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

					CREDITS
a.	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
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)	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
c.	Both of the following courses (6 credits):				
		CEM	251	Organic Chemistry I	3
		CEM	252	Organic Chemistry II	3
d.	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	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
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):				
		PLB	203	Biology of Plants	4
		PLB	415	Plant Physiology	3
		PLB	416L	Plant Physiology Laboratory	2
		PLB	418	Plant Systematics	3
		PLB	498	Undergraduate Research	3
		PLB	499	Senior Seminar	1
		ZOL	355	Ecology	3
		ZOL	355L	Ecology Laboratory (W)	1
		ZOL	341	Fundamental Genetics	4
		ZOL	445	Evolution (W)	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 courses (3 or 4 credits):				
		PLB	434	Plant Structure and Function	4
		PLB	441	Plant Ecology	3
j.	One of the following courses (3 credits):				
		MMG	409	Eukaryotic Cell Biology	3
		MMG	431	Microbial Genetics	3
k.	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. Graduates may be employed in nature organizations, environmental impact firms, or government.

Requirements for the Bachelor of Science Degree in Environmental Biology/ Plant 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 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 Zoology 355L. Those courses are referenced in item 3. a. below.
   Students who are enrolled in the College of Natural Science may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading *Graduation Requirements* in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
2. The requirements of the College of Natural Science for the Bachelor of Science degree.
   The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
3. The following requirements for the major:

					CREDITS
a.	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)	LB	171	Principles of Chemistry I	4
		LB	171L	Introduction to Chemistry Laboratory I	1
		LB	172	Principles of Chemistry II	3
	(3)	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
	(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 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
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, 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
f.	All of the following courses:				30
		CSS	210	Fundamentals of Soil Science	3
		FW	417	Wetland Ecology and Management	3
		GEO	221	Introduction to Geographic Information	3
		PLB	203	Biology of Plants	4
		PLB	415	Plant Physiology	3
		PLB	418	Plant Systematics	3
		PLB	498	Undergraduate Research	3
		PLB	499	Senior Seminar (W)	1
		STT	231	Statistics for Scientists	3
		ZOL	355	Ecology	3
		ZOL	355L	Ecology Laboratory (W)	1
g.	One of the following courses:				3 or 4
		CSS	350	Introduction to Plant Genetics	3
		ZOL	341	Fundamental Genetics	4
h.	One of the following courses:				3 or 4
		ENT	404	Fundamentals of Entomology	3
		PLP	405	Plant Pathology	3
		PLP	407	Diseases and Insects of Forest and Shade Trees	4
i.	One of the following courses:				3
		FW	410	Upland Ecosystem Management	3
		FW	444	Conservation Biology	3
j.	Two 300–400 level courses relating to environmental biology approved by the Department of Plant Biology				6 to 8

GRADUATE STUDY

The Department of Plant Biology is administered jointly by the College of Natural Science and the College of Agriculture and Natural Resources. The department offers Master of Science and Doctor of Philosophy degree programs with majors in plant biology. Those programs are referenced below. The department also offers Master of Science and Doctor of Philosophy degree programs with majors in plant breeding, 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

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. Both of the following courses:

PLB	801	Foundations of Plant Biology	3
PLB	804	Frontiers in Plant Biology	2

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

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

1. Complete the following courses:
   a. Both of the following courses:

PLB	801	Foundations of Plant Biology	3
PLB	804	Frontiers in Plant Biology	2

   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
PLP	894	Seminar in Plant Pathology	1
ZOL	891	Current Topics in Ecology and Evolution	1
ZOL	895	Seminar	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.

DEPARTMENT of STATISTICS and PROBABILITY

Frederi Viens, Chairperson

Statistics, as a discipline, drives data science, and provides systematic ways for scholars from all fields to collect, summarize, model, and interpreting the data, basing their decisions on these analyses and their associated computational methods. Probability theory is a branch of mathematics used to develop and analyze various aspects of statistical models guided by practical aspects of computation and scientific interpretability. In the past 20 years, statistics and probability enabled great strides to be made in the physical, biological, social, and agricultural sciences, and in engineering and business. Statistics and probability are also areas of theoretical and basic methodological research, as self-standing intellectual endeavors which are part of the mathematical and computational sciences.

UNDERGRADUATE PROGRAMS

The first two years of an undergraduate program in statistics stress development of a solid background in two areas, basic mathematics and computers. The rest of the student's program involves a mixture of work selected from statistics, mathematics, and computer programming, and possibly one or more fields of application. Statistics majors who plan to do graduate work should include advanced calculus in their undergraduate programs. The department also offers courses for actuarial science majors housed in the Department of Mathematics.

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:

CREDITS

a. The following courses (19 to 23 credits):
   (1) One of the following courses (3 or 4 credits):
   LB 118 Caluclus 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) The following course (4 credits):
   CSE 231 Introduction to Programming I. 4

b. The following courses (9 credits):
   (1) The following course (3 credit):
   STT 301 Computational Methods for Data Science. . . . 3
   (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;
   (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 croups 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
   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 two majors that lead to master's degrees: applied statistics, and statistics. The department also offers a major in statistics that leads to the Doctor of Philosophy degree.

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

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

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 Grad-

uate 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. an 4:30 p.m. on weekdays.

For more information and full listing of our offerings visit *www.abramsplanetarium.org*.

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.

CENTER FOR ADVANCED MICROSCOPY

Stanley L. Flegler, Director

Microscopy, the science of microscope use, traces its origins to the work of Hooke and Leeuwenhoek in the late 1600's. There are now many types of microscopes and dozens of different imaging and analytical methods. Images may be created using visible and invisible light, electrons, magnetic forces, mechanical probes, current flow, and atomic level attractive and repulsive forces. Much of the technology in our modern world would not have been possible without the images and analytical data from microscopes.

Microscopy is a vital resource in creating and applying knowledge to help address the critical problems of the 21st century.

The Center for Advanced Microscopy (CAM), a university Core Facility, is the Central microscopy laboratory for the 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, advanced sample thinning equipment including 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 beaching, Forster resonance energy transfer, live and fixed cell imaging, differential interference contrast, polarization, phase contrast. Numerous laser lines are available.