College of Science

The University of Notre Dame awarded its first bachelor of science degree in 1865. Before that time, courses had been taught in mathematics (from 1842), in biology (from 1844), and in chemistry (from 1850). In 1867, a program in general science was formulated. Subsequently, specialized programs were added, leading to the degree of bachelor of science in botany and in zoology (both now covered by one degree in biological sciences), in environmental sciences, in biochemistry, in chemistry, in physics, in mathematics, and in preprofessional studies.

Departments of the College of Science

The Department of Biological Sciences, located in the Galvin Life Science Center, has laboratories well equipped for courses of undergraduate and graduate instruction and research. The collections of museum specimens, including the Nieuwland-Greene Herbarium, are available for use in teaching and research. X-ray equipment and several radioactive sources also are available. The facilities include darkrooms, a green house, controlled environmental rooms, scanning and transmission electron microscopes, confocal optical microscopes, and extensive data storage and retrieval equipment.

The Freimann Life Science Center provides additional laboratories, vertebrate animal care, and associated specialized modern research facilities to serve the expanding needs of the life sciences at Notre Dame.

The recently completed Hank Center for Environmental Science adds more than 20,000 square feet of state-of-the-art research space for aquatic and environmental biology that includes greenhouses, wet laboratories, a field sample processing room, and a fully equipped workshop.

The Department of Chemistry and Biochemistry, located in Nieuwland Science Hall and Stepan Hall of Chemistry and Biochemistry, has laboratories devoted to research and instruction in several areas of chemistry: physical, inorganic, organic, and biochemistry. The laboratories are equipped with all necessary facilities for undergraduate students, graduate students, postdoctoral investigators, and faculty. The facilities for experimental research include many pieces of equipment, such as infrared, ultraviolet, Raman, mass, photoelectron, nuclear magnetic resonance, and electron paramagnetic resonance spectrometers; apparatus for dielectric measurements; electrochemical apparatus; gas liquid chromatographic adsorption equipment, both analytical and preparative; special apparatus for studying mechanisms and rates of reactions; special apparatus for synthesis and structural studies on biomolecules, including cell culture facilities for generating recombinant biomacromolecules, etc. For theoretical work, the computational facilities are available, including access to a Graphics Workstation Cluster. The facilities of the Radiation Research Laboratory are used by some faculty of the chemistry department for research in physical chemistry.

The Department of Mathematics is housed in Hayes-Healy Center/Hurley Hall, conveniently located in the central campus. The facilities for undergraduate and graduate instruction and research in mathematics include a first-rate research library; a faculty room; offices for the faculty, postdoctoral investigators, and other visitors, graduate students, and staff; several research seminar and conference rooms; and several large classrooms with state-of-the-art media capability.

The Department of Physics, located in Nieuwland Science Hall, has classrooms and laboratories for both undergraduate and graduate instruction and for research. There are facilities for experimental work in astrophysics, biophysics, condensed-matter physics, elementary particle physics, and nuclear physics. There are three atomic spectroscopy laboratories, and some additional use is made of facilities at Argonne National Laboratory. Elementary particle experiments are done at the Stanford and Fermi national laboratories, and at CERN in Geneva, Switzerland. Detector development for the major accelerators is also being done in the department. The Nuclear Structure Laboratory has a tandem accelerator with a heavy ion capacity and all necessary detection equipment. A variety of solid state facilities are available for the study of metals, high T_c superconductors, and semiconductors. Off-site facilities at Argonne, the National High Magnetic Field Laboratory, and the National Institutes of Standards and Technology are also heavily used. Notre Dame is a partner in the Large Binocular Telescope project, now in construction. This will be one of the most capable facilities in the world for cutting-edge cosmology and astrophysics research. Research is conducted in many major areas of theoretical physics, including all of the above areas as well as statistical mechanics, field theory, general relativity, and astrophysics. The department has a substantial machine shop and research library and a variety of staff technicians. Many faculty members and research groups have computing facilities, and all have access to the Office of Information Technologies' very large computers.

The Department of Preprofessional Studies is located in Nieuwland Science Hall. All courses for students enrolled in the preprofessional program and collegiate sequence programs are provided by the other departments of the College of Science and the other colleges of the University.

Undergraduate Education

The aim of the program of undergraduate education in the College of Science is to produce intellectually able graduates who are grounded in the broad fundamental principles of the basic sciences, versed in the advanced concepts of their chosen scientific discipline and educated in the humanistic and social studies, including theology. Each graduate should be a good scientist in his or her own field, a fully developed person, aware of his or her responsibilities to society and prepared to participate fruitfully in the affairs of society.

Education in science at Notre Dame is a coordinated program involving the basic sciences, the chosen advanced science, and the humanistic and social studies, including theology and philosophy. In this education, the student should acquire a thorough, integrated, and broad understanding of the fundamental knowledge in his or her field, a competence in orderly analytical thinking, and the capacity to communicate ideas to others, orally and in writing. This system of education is so arranged to develop in each student the desire and habit of continuing to learn after graduation, advancing over the years to higher levels of professional and personal stature and keeping abreast of the changing knowledge and problems of his or her profession.

Emphasis is placed on fundamental principles so that the students can develop abilities to apply these principles to the solution of new problems never before encountered by society, to the discovery of new things and to the invention of devices not learned about in books. Notre Dame stresses basic concepts useful in later learning rather than masses of particular facts and data that can better be found in books at the time of need.

Curricula and Degrees

The College of Science offers curricula leading to the degree of bachelor of science in each of five undergraduate departments:

Biological Sciences
Chemistry and Biochemistry
Mathematics
Physics
Preprofessional Studies

The following are degree programs offered by these departments:

Biochemistry
Biological Sciences
Chemistry
Chemistry combined with Business
Chemistry combined with Computing
Environmental Sciences
Mathematics
Mathematics (combined witih other programs)
Physics
Physics (combined with other programs)
Preprofessional Studies
Science-Business
Science-Computing
Science-Education

These degree programs are described in detail in later sections of this *Bulletin.*

See also the bachelor of science degree programs offered by the College of Engineering:

Computer Science
Environmental Geosciences

Each College of Science student must enroll in the department of his or her major beginning with the sophomore year. However, students may change freely from one program to another within their departmental major and may also change departments at any time up through the seventh class day of their senior year.

The College of Science maintains a website at www.science.nd.edu. Further information related to programs offered by the college may be found at that location.

Listed below are the allowed options for students interested in double science majors, double majors between colleges, second majors in the College of Science, and supplementary majors and minors in the College of Arts and Letters.

Students pursuing one of these combination programs must have superior scholastic ability and be formally accepted by the dean of both colleges involved. Approval will not be granted if there is substantial overlap between the two programs.

Note: Courses taken toward the completion of another major or supplementary major or minor or concentration requirement may not also be counted toward the student's other majors or minors or concentrations or University requirements.

Double Science Majors. In certain instances, students will have the option of pursuing majors in two departments of the College of Science. Details on the double science major option and lists of combinations that are normally approved are found under "Special Programs," later in this section of the *Bulletin.*

Dual Degree. Notre Dame students pursuing majors in two of the undergraduate colleges may qualify for a five-year dual-degree program.

The requirements for a dual degree generally are as follows: The student completes all of the university requirements, all of the requirements for both colleges, all of the requirements for both majors, and the total number of degree credits specified for a dual degree in the two colleges. While the total number of hours required does depend on the two major programs, the minimum required total number of degree credits is set to be 30 degree credits beyond the college total for the college with the greatest required number of degree credits. For students completing a dual degree in the College of Science and the College of Arts and Letters, the minimum number is thus 154 hours.

Double Majors in Two Colleges. Qualified Notre Dame students pursuing majors in one of the other undergraduate colleges or schools may add another major in the College of Science. Additionally, qualified Notre Dame students pursuing a major in the College of Science may also add another major in one of the other undergraduate colleges or schools.

The requirements for a double major between colleges generally are as follows: The student completes all the University requirements, the requirements of his or her college or school, and the requirements of both majors. In general, a single course may not satisfy requirements for both majors.

Supplementary Majors and Minors. Qualified Notre Dame students pursuing majors in the College of Science may add a supplementary major or minor. Options include programs offered through the College of Arts and Letters and the Environmental Geosciences minor offered through the College of Engineering.

Not all supplementary major programs are open to science students; e.g., science students may not add the Arts and Letters Preprofessional Studies supplementary major nor the Computer Applications supplementary major.

Supplementary Majors, Minors, and Concentrations in the College of Science. In the College of Science, the term "second major" is used for a supplementary major. Three departments offer a second major program specifically for students in the other colleges: Mathematics as a second major, physics as a second major, and environmental sciences as a second major. For details, see the departmental sections of this *Bulletin.*

There are no minor programs in the College of Science.

The only concentration programs offered in the College of Science are those for mathematics majors. For details, see the departmental sections of this *Bulletin.*

Combination Five-Year Program with the Mendoza College of Business. The College of Science and the Mendoza College of Business have established a competitive cooperative program in which a student may simultaneously earn a bachelor of science and a master of business administration degree. The program is structured so that the student who has completed the three years of a science bachelor's degree program, if accepted, completes the master of business administration and the bachelor of science in a major in the College of Science in a summer session and two subsequent academic years.

Students who wish to pursue this program should have a superior scholastic record in their major program and must make application to, and be accepted by, the MBA program.

The general sequence of courses in the five-year Science-MBA program may be found under "Dual Degree Program with the Mendoza College of Business," later in this section of the *Bulletin.*

University and College Requirements

A minimum of 124 credit hours is required for graduation from the College of Science. A minimum of 60 credit hours must be in science; however, each department may specify more than 60 credit hours for any of its programs.

All College of Science majors must fulfill University requirements, which include:

FYC 13100	3 hours
*Theology	6 hours
*Philosophy	6 hours
*History	3 hours
*Social Science	3 hours
*Fine Arts or Literature	3 hours

** One of these courses must be a University seminar.*

In addition, all College of Science majors must take courses in:

Chemistry (10113, 10114 or 10117, 10118 or 10181, 10182)
Mathematics (10350, 10360 or 10550, 10560 or 10850, 10860)
Physics (10310, 10320 or 10411, 10422 or 30210, 30220).

The appropriate sequence for a student depends on the student's major.

The College of Science requires language proficiency through intermediate level in one of the following languages: Arabic, Chinese, French, German, Greek, Irish, Italian, Japanese, Latin, Portuguese, Russian, and Spanish. Students may complete the language requirement by either completing a course taught at intermediate level or by demonstrating proficiency through placement examination. The college office maintains a list of language courses at intermediate level. (See the college website, www.science.nd.edu.)

Students with no previous background in a language should start with a beginning-level course. They take typically either nine credits over a three-semester period or two semesters of an intensive language sequence (8–10 credits total). Placement for students with some background in French, Spanish, Latin or German will be made only by examination (1) through the Advanced Placement test, (2) through the SAT II Subject test (French and Spanish), (3) through the International Baccalaureate Program or (4) through the Notre Dame departmental placement examinations. A maximum of six credits of placement can be granted for previous study in a given language. Thus, typically, College of Science students who have completed the language requirement will count from six to 10 credits in language toward the 124 credits required for graduation.

The College of Science will count a maximum of three credit hours from the following types of activity courses:

Band (Marching and Concert)
Orchestra
Chorale
Glee Club
Liturgical Choir
Folk Choir
Music Lessons and Ensembles
Dance
Debate
Social Concerns Seminar (including THEO 33936)
Science in the Classroom
No more than one credit hour total from any of these courses may be counted toward the degree per semester. Additionally, a maximum of six credit hours of upper-level (30000- or 40000-level) ROTC courses can be counted toward the 124-credit-hour requirement. These courses will be counted as free electives.

Not all science courses will count toward degree credit or science elective credit for science majors. The survey science courses offered as options for non-science majors for their University science requirement will not count as a science elective or toward the minimum science credit hour requirement. Because of overlap in content with required courses for science majors, many of these courses will also not count toward the degree credit requirement (see "Science Degree Credit," later in this section of the *Bulletin*).

Some major programs have a science elective requirement. Recommended science electives for particular science majors are found on the college's website, www.science.nd.edu. For a course to be a science elective, it must meet the following rules: (1) It is offered through one of the departments of the College of Science or through the college itself. (2) It is major's level; that is, other science majors are required to take this course to meet a major requirement or it has a prerequisite course that is offered for science majors, or the *Bulletin* description for the course states that it is a science elective in the College of Science. Finally, note the departments may place additional restrictions on allowed science electives, e.g., in the Department of Biological Sciences, a science elective must be a non-biology course.

All College of Science courses offered by a major program must be taken at the University of Notre Dame. If a student wants to take a course outside Notre Dame for credit toward the Notre Dame degree, prior approval of the dean's office must be obtained. This does not apply to the courses taken by a transfer student prior to attending Notre Dame.

Advising. All Notre Dame science majors have been assigned an advisor in the department of their major. All advisors are members of the faculty of the College of Science. In some departments, the director of undergraduate studies for the department advises all students. In others, the director of undergraduate studies or the department office may be contacted to find out the name of the student's advisor. A complete list of names of advisors is kept on the science website.

Notre Dame students who have questions concerning the choice of a major or considering a change of major are urged to make appointments with the advisors of the departments involved. Students needing help choosing from similar majors may request an advising appointment with the associate dean of the College of Science, 174 Hurley Hall.

Student Organizations and Activities

In addition to participation in University-wide student activities, the undergraduate students of the College of Science may participate in activities directly related to science, including the undergraduate departmental science organizations: the Biology Club, the Notre Dame Chapter of Student Affiliates of the American Chemical Society, the Mathematics Club, the Society of Physics Students, the Premed Club (preprofessional), the Prevet Club, the Science-Business Club, and the Notre Dame Chapter of Alpha Epsilon Delta (premedical honorary fraternity).

Student Council. The Student Council of the College of Science is composed of representatives of the majors of the College of Science. The student council serves as the official body representing the undergraduate students before the administration of the College of Science.

Student Awards and Prizes

The Dean's Award. Presented to the outstanding graduating senior in the College of Science in recognition of exemplary personal character, leadership, service, and outstanding achievement. Selected by the dean and associate dean.

Outstanding Senior Biological Scientist(s). To the senior(s) who has/have demonstrated the most promise in the biological sciences as evidenced by both academic performance and research participation.

American Institute of Chemists Award. For scholastic achievements, ability, and potential advancement in the chemical profession.

Merck Index Award. For outstanding achievements in chemistry or biochemistry.

Norbert L. Wiech PhD Award. Given to a chemistry or biochemistry major in the junior year for outstanding achievement in academics and research.

Outstanding Biochemist Award. For leadership, academic achievements, research and scholarship in biochemistry.

Outstanding Chemist Award. For academic and research achievements in chemistry as an undergraduate.

William R. Wischerath Outstanding Chemistry Major Award. For academic achievements of a graduating senior chemistry major.

Chemistry-Education Award. For academic achievements in preparation for teaching of chemistry in a secondary education system.

The General Electric Prizes for Honors Majors in Mathematics. Awarded to senior honors majors in the Department of Mathematics who, in the opinion of the members of the faculty, excelled in mathematics during their undergraduate career.

The General Electric Prizes for Majors in Mathematics. A similar award to senior majors.

The George Kolettis Award in Mathematics. An award established by friends of the late Prof. George Kolettis, for a graduating senior who excelled in mathematics and contributed notably to the esprit de corps of the mathematics student body.

*The Aumann Prize for First Year Students in Mathematics.*A prize given by Ms. Monika Caradonna in honor of her father, Prof. Georg Aumann, awarded on the basis of a competition among First Year honors mathematics students.

The Norman and Beatrice Haaser Mathematics Scholarships. These scholarships, made possible by the generosity of Professor and Mrs. Haaser, are awarded to worthy, needy students majoring in mathematics.

R. Catesby Taliaferro Competition for Sophomore Mathematics Honors Students. Friends and students of the late Professor Taliaferro established this prize, which is awarded to a sophomore mathematics major on the basis of an essay submitted by the student.

J & C Sophomore Award in Mathematics. Exemplary performance in mathematics classes by a non-honors math major sophomore female or minority (African-American, Asian, Hispanic, Native American) student.

Outstanding Senior Physics Major. This award is given to the outstanding senior physics major who, in the judgment of the departmental faculty, shows the most promise for a distinguished career in physics. Course grades, the opinion of those who have taught the candidates, and any research performance are considered in making the award.

Physics Outstanding Undergraduate Research Award. A monetary award given for excellence in research to an undergraduate physics major.

DiNardo Award. To the outstanding junior preprofessional student.

Emil T. Hofman Scholarhips. To six outstanding students pursuing premedical studies.

J.C. Lungren, M.D., Scholarships. Awarded to three outstanding science preprofessional students.

The Lawrence H. Baldinger Award. To seniors in the preprofessional program who excelled in scholarship, leadership, and character.

The Patrick J. Niland, M.D., Award. A monetary award given to a preprofessional studies senior to purchase books for the first year of medical school.

The Samuel Chmell, M.D., Award. To an outstanding senior in preprofessional studies who exemplifies high academic achievement and uncompromising integrity within the program.

The Chairman's Award. To a senior with a keen social awareness who shows great promise as a concerned physician.

Special Opportunities

Arts and Letters/Science Honors Program. In the fall of 1983, the University inaugurated an honors program for a small number of outstanding students in the College of Arts and Letters and the College of Science. A limited number of students with academic intents for each college are identified at the tim eof admission. Although selection criteria include the promise of outstanding academic performance as demonstrated by standardized test scores and high school performance, the program is looking for more than mere academic ability. It hopes to identify students a deep intellectual curiosity.

The program offers honors sections to fulfill most of the University and college requirements in the students' freshman and sophomore years. At present, there is the yearlong Honors Seminar (satisfying the writing and literature requirements). Honors Calculus, Honors Philosopphy, Honors Theology, Honors Biology, Honors Physics, and an array of Honors Social Science courses. Since these course are restricted to honors students, they are smaller than non-honors sections and are usually taught in a seminar format. The teachers for honors sections are chosen from the most outstanding teachers in each college. After the first year, each student's academic work will be mainly centered in his or her major field (or fields) of study, but two or more honors electives are also taken during these years. In the fall of the senior year, there is an "Honors Thesis/Research Seminar," which is followed by the "Senior Seminar" in the spring. The fall seminar is intended to be a spur to the students' capstone project, whereas the spring seminar brings the honors students from diverse majors back together for some concluding topical discussions. All honors students will also be expected to complete a special six-hour senior research honors projnect in their major field of study. In science, this is the culmination of a research project that is begun earlier, and in arts and letters, it is a two-semester project culminating in a thesis. Those writing senior theses work individually under the direction of a faculty advisor of their choosing in their major field. Funds are available for research projects during summers either at Notre Dame or other universities.

In addition to the more narrowly academic features of the honors program, students will be offered various opportunities for broadening personal, cultural, and spiritual growth. Regular colloquia, informal discussions, and cultural excursions are available.

Further information on the structure and content of the Honors Program may be obtained by contacting Prof. Alex Hahn or Prof. Cornelius Delaney, 323 O'Shaughnessy Hall, Notre Dame, IN 46556, (574)631-5398.

The Environmental Research Center (UNDERC), a University facility, is composed of approximately 7,500 acres located primarily in the Upper Peninsula of Michigan. Research is conducted at UNDERC by undergraduate as well as graduate students on a variety of environmental problems, including the manipulation of ecosystems. Internships are available to support student participation in BIOS 30569 at UNDERC each semester.

International Studies Program. Students from any of the majors in the College of Science may participate in one of the University of Notre Dame's international study programs. Science students who go abroad generally do so in one of the two semesters of their junior year. Science students interested in international studies should discuss their plans with their advisor and with the associate dean, 248 Nieuwland Science Hall. Further information can be obtained through the International Study Programs office, 109 Hurley Hall.

Programs of Study

Biological Sciences

Chair:
Charles F. Kulpa Jr.
Assistant Chairs:
Paul R. Grimstad; Ronald A. Hellenthal; Gary A. Lamberti
Director of Undergraduate Studies:
Paul R. Grimstad
George and Winifred Clark Professor of Biological Sciences:
Frank H. Collins
Coleman Professor of Life Sciences:
Martin P.R. Tenniswood
Galla Associate Professor:
Jennifer L. Tank
Professor and Gillen Director of UNDERC:
Gary Belovsky
Martin J. Gillen Professor of Biological Sciences:
John G. Duman
Walther Cancer Institute Associate Professor:
Crislyn D'Souza-Schorey
Professor and Rev. Howard J. Kenna, CSC Memorial Director of the Zebrafish Center:
David R. Hyde
Professors:
John H. Adams; Harvey A. Bender; Nora J. Besansky; Harald E. Esch (emeritus); Malcolm J. Fraser; Morton S. Fuchs (emeritus); William C. Hamlett (adjunct); Ronald A. Hellenthal; Alan L. Johnson; Gary A. Lamberti; David M. Lodge; Kenneth Olson (adjunct); Joseph O'Tousa; Morris Pollard (emeritus); David W. Severson; Kristin Shrader-Frechette (concurrent); Kenyon S. Tweedell (emeritus); Paul P. Weinstein (emeritus); JoEllen Welsh
Associate Professors:
Sunny K. Boyd; Peter Diffley (concurrent); Jeffrey L. Feder; Paul R. Grimstad; Hope Hollocher; Lei Li; Robert E. Kingsley (adjunct); Rev. James J. McGrath, CSC (emeritus); Edward E. McKee (adjunct); John F. O'Malley (adjunct); Jeanne Romero-Severson; Jeffrey S. Schorey; Neil Shay; Kevin T. Vaughan
Assistant Professors:
Michael T. Ferdig; Kristin M. Hager; Jessica Hellmann; Edward H. Hinchcliffe; Mary Ann McDowell

Program of Studies. The Department of Biological Sciences offers programs of study leading to the degrees of bachelor of science with a major in biological sciences or bachelor of science with a major in environmental sciences, master of science in biological sciences and doctor of philosophy. Also offered is a second major in environmental sciences for students in the College of Arts and Letters or in the College of Business Administration.

Program in Biological Sciences. The biological sciences encompass all aspects of microbial, plant and animal life. They include the biochemistry, genetics, development, physiology, evolution and ecology of all living things. Every educated person must have sound knowledge of the fundamental principles and facts of the biological sciences to understand himself or herself and the world in which he or she lives. In addition biologists, through their research, contribute to the development of theories and methods required for the solution of humanity's problems in the fields of health, agriculture, industry and the preservation of the environment.

SUMMARY OF REQUIREMENTS FOR GRADUATION FOR ANY BIOLOGICAL SCIENCES MAJOR

	Credits	*Year Usually Taken*
Biological Sciences*	41	all
Chemistry (10113–10114 or 10117–10118 or 10125–10126;	8	First year
and 20247–20248 with labs)	10	Sophomore
Physics (30210–30220, or 10310–10320 or 10411–10421)	8	Junior
Mathematics (10350–10360 or or 10550–10560)	8	First year
Total Science:	75	
History**	3	First year
Social Science**	3	First year
Philosophy**	6	Sophomore/Junior
Theology**	6	Sophomore/Junior
FYC 13100	3	First year
Language	Intermediate Level Competency	Sophomore/Junior
Literature/Fine Arts**	3	Junior/Senior
Free Electives	16+	Sophomore/Senior
Physical Education or ROTC (2 semesters)	0	First year
	124 credits	

**** It is essential for prospective biology majors to begin their general biology courses in the first year to schedule all required core curriculum courses within a four-year period.***

*** One of these courses must be a University Seminar.*

+ Minimum number of free electives based on the assumption that intermediate-level competency in language was achieved by taking three-credit courses.

Majors with AP course credits and/or language Credit by Exam (CE) often have time to incorporate 20 or more free elective credits (i.e., a second major or minor) into their four-year course selection.

An undergraduate major in biological sciences prepares a student for graduate study (MS, PhD, MD/PhD) leading to a research career, and also for admission to medical, veterinary and other professional schools. Graduates with a bachelor's degree may enter careers in industry, government or health-related research laboratories. Those who wish to teach at the elementary or secondary level should be sure to include required education courses such as those offered through Saint Mary's College. College and university teaching requires the PhD degree.

The goal of the Department of Biological Sciences is to educate its majors first as scientists prepared for the challenges of modern biology and second for any specialty area(s) in which they develop an interest, especially if that interest is directed toward graduate school and research. Also, for the approximately 70 percent of biology majors who initially express an interest in going to medical school or other health-related graduate programs, the key topic areas of modern biology emphasized in the core curriculum are also very relevant to their training as "medical biologists."

Students majoring in biological sciences are required to follow a core curriculum. This core not only provides exposure to most areas of modern biology but also includes courses representative of all the levels of biological organization, i.e., from atoms and molecules through ecosystems. Students unsure of which area of biology most appeals to their interests will more easily arrive at that decision through the completion of the core.

Policy Statement on the Use of Organisms in Biological Sciences Teaching Laboratories. Some laboratory courses offered by the Department of Biological Sciences may involve the use of *living or preserved organisms.* Instructors use these *animal specimens* in cases where this is deemed necessary for teaching important biological concepts and principles.*Students who have concerns about the use of organisms in classes must, prior to registering, submit a request for alternate materials to the course instructor.* It is up to the discretion of the instructor(s) as to whether and how non-organism alternatives may be substituted for biological materials in classes. *Students permitted to use alternate materials are responsible for the same knowledge and application as their classmates and may be required to complete examinations that involve the inspection or handling of biological specimens.*

Bachelor of Science with a Major in Biological Sciences

The biological sciences majors take the following basic sequence of courses in the College of Science:

General Chemistry (CHEM 10113–10114 or 10117–10118 or 10125–10126)
Organic Chemistry (CHEM 20247-20248 and 21247–21248)[1]
Physics (PHYS 30210–30220)[2]
Calculus (MATH 10350–10360 or 10550–10560)

The requirements in biological sciences include courses from a basic core sequence and sufficient numbers of BIOS electives to complete the 41-credit-hour requirement. There are seven components to the biology core requirement, consisting of courses in the following areas:

Core I: Introductory Biology

a. Metabolism and Genetics
b. Ecology, Diversity, and Physiology

Students choose from either:
- Biological Sciences I and II (BIOS 10161–10162) (includes two labs)[3] or
- General Biology A and B (BIOS 20201-20202) (includes two labs)[3]

Core II: Genetics

Students choose from either:
a. Classical and Molecular Genetics (BIOS 20250 and 21250; lab #3)[4] or
b. Fundamentals of Genetics (BIOS 20303 and 21303; alternate lab #3)

Core III: Cellular Biology

Students choose from either:
a. Molecular Cell Biology (BIOS 20241)[4] or
b. Cellular Biology (BIOS 30341)
Optional labs available are BIOS 21241, a research-orientated 2 credit laboratory, or BIOS 31341, a basic 1 credit cell biology laboratory primarily for pre-professional students. Students *may not* take both cell labs.

Core IV: Physiology

Students choose from either:
a. Vertebrate (Human) Physiology (BIOS 30344) or
b. Integrative Comparative Physiology (BIOS 30421).
Optional labs available are BIOS 41344 and BIOS 31421. Students may take both labs if they choose.

Core V: Evolutionary Biology

Students choose from either:
a. Evolution (BIOS 30305) or The History of Life (BIOS 30310)
b. Other courses as designated in the future, prior to the Class of 2009 graduation.

Core VI: Ecology

Students choose from either:
a. General Ecology (BIOS 30312; optional lab BIOS 31312 is offered fall semesters only)
b. Aquatic Ecology (BIOS 30420 and required lab BIOS 31420).

Students are required to take a total of six laboratories; three of the six labs will be part of the Core (Core I(a,b), II, and the remaining three of the six laboratories are chosen among the core III through Core VI and/or BIOS electives, including 50000- and 60000-level courses. Thus, there are three *required* "named" BIOS labs and three additional elective BIOS labs. The minimum required credits in the core including labs is 27. An additional 14 credits of electives in biological sciences are chosen to complete the required total of 41 credits.[6,9] All biological sciences majors are encouraged to include non-science among their "free electives."

Notes:

1. All first-year majors completing BIOS 10161–10162, or those enrolling in BIOS 20201, are required to select the sequence CHEM 20247–20248 and its labs. This is especially important for career-oriented majors in biological sciences. Only those students changing their majors to biological sciences while enrolled in CHEM 20223 or 20224 would complete this alternative sequence. Students may not switch from CHEM 20223 to CHEM 20248 to complete the organic chemistry sequence.

2. Alternatively, students may select the physics sequences PHYS 10310–10320 or PHYS 10411–10421.

3. All majors are strongly encouraged to complete the sequence Biological Sciences I and II (BIOS 10161–10162) in their first year to ensure the completion of all requirements in four years. Students may begin the core with General Biology A and B (BIOS 20201–20202); however, they will be at a considerable *disadvantage* in scheduling requirements in the two remaining years; they also will have one year less to explore their interests in biology.

4. Career-oriented majors in biological sciences, as well as those considering a professional school (medicine, veterinary science, others), are urged to select the courses Molecular Cell Biology (BIOS 20241) and Classical and Molecular Genetics (BIOS 20250). These should be taken in the sophomore year but no later than the junior year.

5. Physiology should be completed by the end of the junior year for students planning to take the MCAT exam or the seventh semester for students planning to take the GRE biology subjects exam.

6. Most graduate (50000- and 60000-level) courses (through 60579) are open to eligible juniors and seniors; often the majority of students in these advanced courses are undergraduates.

7. Students may choose additional courses in the Core areas III through VI or among courses not assigned to the core (e.g., BIOS 40411, Biostatistics, or BIOS 48498, Undergraduate Research), or 50000- and 60000-level courses, to meet the required total of 41 credit hours in biological science courses.

8. Select non-BIOS major-level College of Science courses (i.e., those taken to meet science-major requirements and not those designated as "Recommended University electives") that are not being used to fulfill other specific graduation requirements can be chosen with the consent of the director of Undergraduate Studies for the Department of Biological Sciences and counted toward the BIOS elective credits. Only one non-BIOS science course (3 or 4 credits) may be thus used.

9. Undergraduate Research (BIOS 48498) and Directed Readings (BIOS 46497) count toward the 41-credit biological sciences requirement; however, only a maximum of two credits per semester per course and a combined total of six credits from these two courses may be counted in fulfilling the 41-credit requirement. A maximum of only nine credits in these courses may be used toward graduation; however, additional credits do remain on a student's permanent transcript record.

RECOMMENDED COURSE GROUPINGS

After consultation with the director of undergraduate studies or other faculty advisors including research mentors, each student is encouraged to select the curriculum which best fits his or her career goals. A great deal of flexibility is permitted in designing each individual's projected course schedule, within the context of the core curriculum. For students wishing to emphasize specific areas of biology in their curricula, the following four course groupings are *provided as guides* that have proved to be appropriate for most of our previous graduates.

General Biosciences: This grouping gives the student a broad foundation in biological sciences by requiring electives from each of its major areas. This grouping is designed as preparation for the Graduate Record Examination (GRE) in biology, or the Medical College Admission Test (MCAT). Students considering graduate school or secondary science education, or those without a clear career goal, should consider these courses.

Here, students follow the core curriculum, making choices in Cores III through VI. In the area of Core V, the course Evolution (BIOS 30305) and the course The History of Life (BIOS 30310) are recommended. Also recommended for electives in biological sciences is a course in either vertebrate or invertebrate biology (e.g., BIOS 30404, Vertebrate Biology, or BIOS 30406, General Entomology). Dependent on the credits associated with the choice of courses made in the core, students will be required to pick three to five more electives in biological sciences to complete the requirement of 41 credits.

Cellular and Subcellular: This grouping was designed for students considering graduate study in any of the many areas of cellular biology and biochemistry. It is also appropriate for premedical students who do not choose the general biosciences grouping.

For this grouping, students follow the core curriculum, making choices in Cores III through VI. In the area of Core IV, Physiology, students should consider taking both courses listed. The courses Introduction to Microbiology (BIOS 30401) and Virology (BIOS 40416) are recommended. For electives in biological sciences, a course in Immunology (BIOS 40419), Genomics (BIOS 30423), or Advanced Cell Biology (BIOS 50539) is recommended. Molecular Genetics (BIOS 30418) is also recommended as an elective. Dependent on the credits associated with the choice of courses made in the core, students will generally be required to pick two more electives in biological sciences to complete the requirement of 41 credits.

Organismal and Community: This grouping is primarily intended for students planning careers in ecology, environmental biology and related areas and allows students to develop considerable expertise during their undergraduate years. It requires electives in biological sciences beyond the 41 credits required of the major. Individual interests may be accommodated by judicious choice of biological science courses and of the science elective.

Students interested in this area of biological sciences may wish to take advantage of the University of Notre Dame Environmental Research Center (UNDERC), a University facility which comprises about 7,000 acres, including more than 20 lakes, in the Upper Peninsula of Michigan. Biological research (including whole-ecosystem experiments), graduate studies and undergraduate course work take place at the center. Paid internships are available to support student participation in BIOS 30569 at UNDERC each summer.

In this grouping, students follow the core curriculum, making choices in Cores III through VI. In the area of Core VI, Ecology, students should consider taking both courses listed. Students are encouraged to take General Botany (BIOS 30304) or Plant Science (BIOS 30325). Also recommended are Vertebrate Biology (BIOS 30404) and/or General Entomology (BIOS 30406) and Animal Behavior (BIOS 30407).

Microbiology and Infectious Disease: This grouping is intended for students interested in microorganisms and molecular biology and who are considering graduate study in these areas. It is also appropriate for premedical students. It requires electives in biological sciences beyond the 41 credits required of the major.

Here, students follow the core curriculum, making choices in Cores III through VI. Students should take Principles of Microbiology (BIOS 30401 and the lab BIOS 31401); Virology (BIOS 40416); or Medical and Veterinary Parasitology (BIOS 40415); Immunology (BIOS 40419); Cellular and Molecular Basis of Human Disease (BIOS 40435); and/or AIDS (BIOS 40440).

Sample Curriculum: The sample curriculum for the four-year program listed below is only one of a number of ways a student can complete all the requirements for a biology major. Students should discuss their specific interests with their departmental advisor and plan their semesters accordingly. Alternative sample curricula can be developed with the assistance of the biology advisor.

Note that this sample curriculum asumes that no AP or language CE credits are included.

First Year

Fall Semester

BIOS 10161 (Core Ia: Principles) (Lab 1)	4
MATH 10350 or 10550	4
CHEM 10113, 11113 or 10117, 11117	4
History or Sociology[1]	3
FYC 13100	3
Physical Education or ROTC	0
	18

Spring Semester

BIOS 10162 (Core Ib: Principles) (Lab 2)	4
MATH 10360 or 10560	4
CHEM 10114, 11114 or 10118, 11118	4
History or Sociology[1]	3
Theology or Philosophy[1]	3
Physical Education or ROTC	0
	18

Sophomore Year

Fall Semester

BIOS 20250 (Core II: Genetics)	47
BIOS 21250 (required genetics 3)	1
CHEM 20247, 21247[2]	5
Theology/Philosophy	3
Language	3
	16

Spring Semester

BIOS 20241 (Core III: Cell Biology)	3
Elective Lab 4 (e.g., 21241 Cell Biology)	2
CHEM 20248, 21248[2]	5
Theology/Philosophy	3
Language	3
	16

Junior Year

Fall Semester (overseas study is an option)

BIOS Core VI (Ecology)[3]	3/4
Physics 30210, 31210	4
Free Elective	3
Theology/Philosophy	3
Language	3
	16/17

Spring Semester

BIOS Elective	3
BIOS Core IV (Comp. Physiology)	4/5
Physics 30220, 31220	4
Fine Art/Literature[4]	3
	16

Senior Year

Fall Semester

BIOS Core V (Evolutionary Biology)	3
BIOS Elective	3
Science Elective5	3
Free Elective	3
Elective Lab 5	-/1
	12/13

Spring Semester	
BIOS Elective	3
BIOS Elective5	3
Free Elective	3
Free Elective	3
Elective Lab 6	-/1
	12/13

TOTAL: 124 minimum

[1] One of these courses must be a University seminar.

[2] Students delcaring a biology major during the fall semester of their sophomore or junior year while taking organic chemistry (CHEM 20223/21223) must complete the sequence with CHEM 20224/21224. ***For all other biology majors, CHEM 20247/21247 and CHEM 20248/21248 are required courses.*** *In special circumstances, with the permission of the director of undergraduate studies in biological sciences, students may receive permission to satisfy the organic chemistry requirement by taking CHEM 20223/21223 and/or CHEM 20224/21224 during Notre Dame's summer session.*

[3] Offered spring semester also.

[4] For premedical students, it is strongly recommended that the student take a 30000-level English literature course. This ensures that the student will be able to meet the standard medical-school admission requirement of two English courses. Medical ethics and biochemistry are also generally required.

[5] A non-BIOS/Science elective can be any 30000-50000-level course other than those required, and approved by the director of undergraduate studies for the Department of Biological Sciences. Biochemistry (e.g., CHEM 40420) is especially recommended.

In addition to the undergraduate curriculum, the Department of Biological Sciences offers programs of graduate study leading to the degrees of master of science and doctor of philosophy, as described in the *Graduate School Bulletin of Information.*

BIOLOGICAL SCIENCES COURSE DESCRIPTIONS

Course descriptions. The following course descriptions give the number and title of each course. The courses listed below are those reasonably expected to be offered several times to every semester during the next four years. However, changes may occur as faculty add new courses or drop those with little demand. Courses without laboratories are indicated as lecture only. The first number in parentheses indicates lecture hours; the second indicates laboratory hours; the third indicates total credits for the course.

BIOS 10101. Human Genetics, Evolution, and Society

(3-0-3) Bender

Corequisite(s): BIOS 12101

This course will address fundamental biological principles using the two cornerstones of modern biology: genetics and evolution. Elementary chemistry, cell theory, reproduction, and development will also be covered. The emphasis, however, will be on human genetics and will include such topics as the cause and effects of genetic abnormalities, the genetic basis of intelligence and skin color, genes and cancer, and elementary population genetics. The state of "genetic engineering" research, the recombinant DNA controversy (including the implications of this kind of research on society and the individual) will be presented. Fall and spring.

BIOS 10102. Plants, Food, and Society

(3-0-3)

Overview topics will cover primary reproductive biology in plants and influences in bioengineering topics, chiefly involving DNA and gene-splicing. World food concerns and environmental consequences of agronomy occupy a good portion of class time. Video presentations each Friday are on topics covered in lecture. The role of fungi in fundamental situations of plant disease and the degradation of waste materials conclude the topics of environmental influences. Fall and spring.

BIOS 10106. Common Human Diseases

(3-0-3) Streit

The goal of this course is to introduce students to diseases that may afflict them, their parents, and/or their children, as well as other health problems common to the Tropics. It will provide the student with the information necessary to understand the biology of the disease process. Fall.

BIOS 10107. Environment and Evolution

(3-0-3) Filchak

Emphasis will be placed upon today's ecological and environmental problems and the possible effect they may have upon the future evolution of life on Earth. Topics will generally include an overview of the theory of evolution and a discussion of ecological principles as observed at the population, community, and ecosystem levels. The influence of cultural and political factors will also be discussed. Each academic year, one or more sections will be offered; some may be individually subtitled, allowing for one-time presentation of specific topics within the context of "environment and evolution" in addition to multiple-semester presentations of a specific topic (e.g., Evolutionary Ecology, Freshwater and Society, Environmental Issues and Solutions). Fall and spring.

BIOS 10108. Revolutions in Biology

(5-0-3)

The goal of this course is to teach six basic tenets of biology, the historical context for each discovery, the scientific and technical advances made, and their ethical implications. The topics will include genetics and evolution, cell biology and biochemistry, the germ theory, and ecology. A term paper is required. Summer.

BIOS 10109. Human Reproduction and Society

(3-0-3)

Basic aspects of human development and reproduction will be covered from conception through sexual senescence. In addition, the science behind many currently debated social issues will be addressed. Selected topics might include causes and treatment of infertility, in vitro fertilization, control of male and female fertility, pregnancy and paternity testing, gene therapy, the effects of legal and illegal drug use on reproductive function and embryonic/fetal development, and the impact of current health care policy and practice on infant and prenatal health. Fall.

BIOS 10110. Genetics, Technology, and Society

(5-0-3)

The objectives of this course are to give students an overview of human genetics and an appreciation for the relatively new field of molecular biology that is currently being used to study human genetic diseases. Genetic technologies such as cloning and manipulating genes, genetic biotechnology, gene therapy, DNA testing, and so forth will be emphasized. The ethical, social, and legal implications of these technologies will also be covered. In addition, this course will address the role of genetics in human cancer, behavior, obesity, intelligence, and sexual orientation. Generally offered in the summer where there are five lectures per week. When offered during the academic year, there are three lectures per week.

BIOS 10115. Microbes and Man

(3-0-3)

The course will provide a survey of relationships between man and microorganisms. General information about microbial physiology, biochemistry, and ecology will support more detailed discussions of interesting topics in food, medical, and applied microbial biology. Included will be subjects of general and historical interest, as well as current newsworthy topics. The student should get a better understanding of the role of microorganisms in disease, the production of common foods, relevant environmental issues, and biotechnology.

BIOS 10116. Biology and Nutrition

(3-0-3)

This course provides a general overview of the field in nutrition. Topics to be presented include an introduction to the field of nutrition, nutrient composition of foods, recommended intakes and health claims, a review of the nutrients, food intake and energy balance, sports nutrition, eating disorders, current issues of food safety, fads, and other aspects encompassing nutrition during all stages of life.

BIOS 10117. Biodiversity: Its Challenge and Future

(3-0-3)

Today, species of plants and animals are going extinct at an unprecedented rate in the 3.5 billion-year history of life on Earth. Not only are species going extinct, but complete assemblages of species in particular habitats are threatened. The class will survey the reasons why this disappearance of species and habitats concerns biologists, the basic concepts that biologists hope to employ to help prevent the continuance of this trend, and the problems faced in formulating policies that address this problem. This human problem is important locally and globally, since legislation attempting to halt the loss of biological diversity will affect the actions of people

at the community, state, national, and international levels. To the majority of people in the US and other developed countries, concern for biodiversity is second only to their economic well-being. Spring.

BIOS 10161 and BIOS 10162. Biological Sciences I

(3-0-3) Shay

This is a *two-semester course* with three lectures and one three-hour laboratory a week for first-year students contemplating a career in biology, medicine, or related areas of life science.

The *first semester* presents a description of biologically important molecules and then proceeds to cell structure, energy metabolism, and classical and modern genetics. The topics presented in the *second semester* in the context of modern evolutionary theory include biological diversity, ecology, and organismal physiology.

BIOS 10161 and 10162 are not typical survey courses; they go into greater depth, especially in modern molecular biology. When followed by BIOS 20241 and BIOS 20250, they will provide biology and biochemistry majors, including premedical intents, with a thorough in-depth overview of basic concepts of modern biology.

BIOS 11161 and BIOS 11162. Biological Sciences I—Lab

(0-3-1)

Corequisite(s): BIOS 10161; BIOS 10162

The laboratory sessions are an integral part of the lecture courses, which will complement the lectures. The lab sessions will also offer the student direct experience in using the scientific method and simultaneously introduce numerous biological and analytical techniques. In addition, students learn to present their findings *during the course of the two semesters of laboratory* as they would for a journal article or a scientific meeting (seminar and poster presentations).

BIOS 10191. Molecular Genetic Technology

(3-0-3) Filchak

Open to non-science honors students only. Not available to students who have previously taken BIOS 10101 or BIOS 11110. The objectives of the course are to have students learn the basics of cell division and Mendelian genetics and then explore the relatively new field of DNA technologies such as gene cloning, genetic testing, biotechnology, and cancer genetic analysis. This course also has a service-learning component in which students will work at the Logan Center in South Bend. Fall.

BIOS 12101. Human Genetics, Evolution, and Society Tutorial

(1-0-0)

Corequisite(s): BIOS 10101

Tutorial for BIOS 10101.

BIOS 20201. General Biology A

(3-0-3) O'Tousa

Prerequisite(s): see online Course Catalog for details.

Corequisite(s): BIOS 21201

Introduction to living organisms with emphasis on biological processes and principles. BIOS 20201 and 20202, along with their concomitant laboratories (BIOS 21201 and 20202) constitute a traditional two-semester introduction to biology. This sequence covers more topics, but in less depth, than the former BIOS 155-156 or BIOS 10161-10162 and is designed to provide students with the necessary background for subsequent advanced biology courses and to help them prepare for MCATS. A prerequisite is a full year of college chemistry. In addition, organic chemistry is to be taken concurrently. The general sequence of topics is reversed compared to BIOS 10155 and 10156. BIOS 20201 introduces biology to the student at the cellular level, covering such topics as important biological molecules, energy metabolism, and classical and modern genetics.

BIOS 20202. General Biology B

(3-0-3) Hellenthal, Staff

Prerequisite(s): (BIOS 20201 or BIOS 201)

Corequisite(s): BIOS 21202

Introduction to living organisms with emphasis on biological processes and principles. BIOS 20201 and 20202, along with their concomitant laboratories (BIOS 21201 and 21202) constitute a traditional two-semester introduction to biology. This sequence covers more topics, but in less depth, than BIOS 10155 and 10156 or BIOS 10161 and 10162 and is designed to provide students with the necessary background for subsequent advanced biology courses and to help them prepare for MCATS. A prerequisite is a full year of college chemistry. In addition, organic chemistry is to be taken concurrently. The general sequence of topics is reversed compared to BIOS 10155 and 10156. BIOS 20201 introduces biology to the student at the cellular level, covering such topics as important biological molecules, energy metabolism, and classical and modern genetics. BIOS 10202 goes beyond the cellular level, with an emphasis on organismic physiology, evolution, diversity, and ecology. Note: CHEM 10114 or 10118 or 10126 must be completed before taking BIOS 20201. BIOS 20201, 21201 and 20202, 21202 may be substituted for 10155-10156 or 10161-10162; however, this sequence is quite different from 10155-10156 or 10161-10162 in content and does not provide the depth afforded by 10155-10156 or 10161-10162 nor does 20201-20202 provide the equivalent laboratory experience essential to biology majors intent on taking BIOS 21241 and 21250.

BIOS 20241. Molecular Cellular Biology

(3-0-3) Vaughan

This course is restricted to biological science and biochemistry majors only. This course explores the fundamental structural and functional basis of cell biology, with specific emphasis on molecular mechanisms that regulate cellular activities involved in ion and solute transport, organelle biogenesis, protein trafficking and vesicular transport, intracellular communication and signaling, cell cycle growth control regulation, and cytomechanics. The lecture portion of the course is dedicated to exposing students to the protein machinery driving cell functions, while the laboratory complements lecture by providing a combination of experiments and opportunities for independent project-based investigation focused on elucidating basic cell function. Spring.

BIOS 20250. Classical and Molecular Genetics

(4-0-4) Hyde

Prerequisite(s): see online Course Catalog for details.

Corequisite(s): BIOS 21250

This course is restricted to biological science and biochemistry majors only. The course exposes students to classical and molecular genetics and demonstrates how these two approaches can combine to examine complex problems. The lecture is strongly weighted toward teaching students to solve genetic and molecular biological problems. Classical genetic principles are introduced first. Students are then presented with the techniques to examine underlying genetic principles through problem solving. Basic principles and techniques of molecular biology are next presented, and students learn how to apply these techniques to explore genetic problems. The laboratory gives the students hands-on experience in a number of genetic and molecular techniques and demonstrates how these procedures are combined to produce a cohesive genetic picture. Experiments begin with classical genetic analysis of a mutation, progress to isolating the mutant gene by PCR and standard cloning techniques, followed by DNA sequencing the genomic fragments to determine the nature of the genetic defect. Immunolocalization of the protein in mutant and wild-type flies brings the molecular work back to the organism, providing a full-circle study of the genetic mutation under study. At the end of the lab, students are ready for the independent study projects conducted in the laboratory for BIOS 20241, Molecular Cell Biology. Fall.

BIOS 20303. Fundamentals of Genetics

(3-0-3)

An elementary course dealing with the principles of variation and inheritance in plants and animals, with special reference to humans. Designed primarily for junior preprofessional students. Spring.

BIOS 21201. General Biology Laboratory

(0-3-1) Lewis

Corequisite(s): BIOS 20201

Students registering for BIOS 20201 must concurrently register for 21201.

BIOS 21202. General Biology Laboratory

(1-0-1) Lewis

Corequisite(s): BIOS 20202

Materials covered in laboratory parallel the lecture material for the most part.

BIOS 21241. Molecular Cellular Biology Laboratory

(0-3-1) Whaley

Corequisite(s): BIOS 20241

This cell biology laboratory is a special section only for biochemistry (BCHM) majors. It focuses on techniques rather than the investigational experimental approach of BIOS 27241R. Note: Prior to Spring 2003, there was a single BIOS 20241 laboratory. See the current description of BIOS 27241 for details of that experimental laboratory.

BIOS 21250. Classical and Molecular Genetics Laboratory
(0-3-1) Whaley
Prerequisite(s): see online Course Catalog for details.
Corequisite(s): BIOS 20250
In this laboratory course, students will characterize mutations that cause retinal degeneration in the fruit fly, *drosophila melanogaster*, in a series of related experiments comprising a semester-long study. The labs will be broken into two major sections, starting with the genetic characterization of a mutation, followed by the molecular characterization of the altered gene causing that mutation. This directed research project will be presented in two drafts of a complex research paper. Some work outside the three-hour lab period will be required. Fall.

BIOS 21303. Genetics Laboratory
(0-3-1)
Prerequisite(s): (Pre/Co-Req BIOS 20303 or Pre/Co-Req BIOS 303)
Laboratory provides experience in genetic experimentation and analysis. Either BIOS 21250 or 31303 is required for biology majors, optional for others. Spring.

BIOS 27241. Molecular Cell Biology Laboratory
(0 V-2) Whaley
Corequisite(s): BIOS 20241
This cell biology laboratory, reserved exclusively for BIOS majors, is an investigative, project-based laboratory designed to expose students to a bona fide research experience involving the development and application of critical thinking skills to solve complex research problems. Working in groups of four to six, students will devote themselves to tackling self-chosen research projects reviewed and approved by course instructors. The culmination of the laboratory experience ends when students formally prepare and present their findings in a poster-style scientific meeting. Spring.

BIOS 30301. Embryology
(3-0-3) Kolberg
Prerequisite(s): see online Course Catalog for details.
Overview of the embryology and histology of the developing organism with an emphasis on the clinical aspects. Content very similar to BIOS 40342.

BIOS 30304. General Botany
(4-0-4)
Prerequisite(s): see online Course Catalog for details.
Corequisite(s): BIOS 31304
A broad survey of the plant kingdom, emphasizing morphology and anatomy, with attention given to major plant functions of growth and development in chiefly angiospermous (= "higher") plants. Laboratory instruction includes a semester project involving photomicrography or seed germination and cloning.

BIOS 30305. Evolution
(3-0-3) Hollocher
Prerequisite(s): see online Course Catalog for details.
The mechanisms and processes involved in the production of life as we know it today, as well as a discussion on the impact current events may have upon life in the future. Spring.

BIOS 30310. The History of Life
(3-0-3) Feder
Prerequisite(s): see online Course Catalog for details.
This course explores the origin, history, and systematics of life on Earth, starting from hypotheses examining life's origin(s) and including current thinking concerning the systematic relationships of organisms and the evolution of humans. The class will be taught primarily from a macroevolutionary perspective. BIOS 30310 therefore represents the complement to BIOS 30305 (Evolution), which concentrates on processes generating gene frequency changes within populations (i.e., microevolution). Fall.

BIOS 30312. General Ecology
(3-0-3) Hellmann, Tank
The study of populations and communities of organisms and their interrelations with the environment. Fall and spring.

BIOS 30325. Plant Science
(3-0-3) Romero-Severson
Prerequisite(s): see online Course Catalog for details.
This course for biology majors provides a more detailed examination of plant development, biochemistry, genetics, and ecology than presented in the general and cell biology courses. Specific topics include energy capture and biosynthesis strategies, plant biochemistry, nitrogen fixation, defense mechanisms, plant diversity, plant reproductive strategies, plant genetics, grassland and forest ecology, plant domestication, the ecological impact of plant domestication, and forest management policy (Fall).

BIOS 30338. Neurobiology
(3-0-3) Li
Prerequisite(s): see online Course Catalog for details.
Neuroscience is a relatively new field. It consists of several quite separate disciplines, for example, neuroanatomy, which studies the structure of neural tissue; neurophysiology, which investigates individual nerve cell properties; neurochemistry, which is concerned with the substances found in brain tissue; and cognitive neuroscience, which deals with higher brain function. This course will discuss all of these issues. Topics will include nerve cell function (i.e., electric and chemical synapses, neurotransmitters, and neural control of locomotion), and cognition (i.e., perception, learning, and memory). By the end of the course, students will be expected to understand our current knowledge of how the brain controls our actions and behaviors.

BIOS 30341. Cellular Biology
(3-0-3) Vaughan
Prerequisite(s): see online Course Catalog for details.
Designed primarily for junior preprofessional students. Structural and functional aspects of the biology of cells are addressed. Fall and spring.

BIOS 30344. Vertebrate Physiology
(3-0-3) Boyd
Prerequisite(s): see online Course Catalog for details.
Physiological functions and processes at the level of organs and organ systems, oriented primarily toward humans. Designed primarily for junior preprofessional students. Fall.

BIOS 30401. Principles of Microbiology
(3-0-3) Kulpa
Prerequisite(s): see online Course Catalog for details.
An introduction to microbial life, including structure and function of bacteria. Characterization and classification of microorganisms are considered and include their ecology, growth and death, metabolism, physiology, genetics and antigenic analysis. The impact of microorganisms on human health is discussed through representative pathogenic bacteria. Fall.

BIOS 30404. Vertebrate Biology
(3-0-3) Johnson
Prerequisite(s): see online Course Catalog for details.
A study of systematic relationships, evolution, and life histories of living and extinct vertebrates, and the physiology and behavior of living vertebrates. Fall.

BIOS 30406. General Entomology
(3-0-3) Collins
A study of the morphology, life histories, and systematic relationships of insects, with emphasis on medical and agricultural aspects. Alternating fall semesters.

BIOS 30407. Animal Behavior
(3-0-3) Esch
Prerequisite(s): see online Course Catalog for details.
A consideration of individual and social behavior patterns, with emphasis on organization and adaptive significance. Neural, endocrine, genetic, and environmental factors modifying behavior will be examined. Spring.

BIOS 30408. Arthropods and Human Disease
(3-0-3) Collins
Emphasis on physiology, genetics, and relationships of arthropods as agents and vectors of disease. Alternating spring semesters.

BIOS 30418. Molecular Genetics
(3-0-3) Adams
Prerequisite(s): see online Course Catalog for details.
The course will introduce the tools of modern molecular biology and explore their applications at the frontiers of biological research. Advanced topics may include molecular medicine, biotechnology, development, evolution, and neurobiology. Fall.

BIOS 30420. Aquatic Ecology
(3-0-4) Hellenthal
Prerequisite(s): see online Course Catalog for details.
Corequisite(s): BIOS 31420
A study of the structure and function of aquatic systems with emphasis on the behavioral, physiological and morphological adaptations generated by the physical and chemical characteristics of various aquatic habitats. Fall.

BIOS 30421. Integrative Comparative Physiology
(4-0-4) Duman/Johnson
Prerequisite(s): (BIOS 20241 or BIOS 241)
Designed primarily for students in the biology or biochemistry majors sequences. This course is designed to be taken either as an introductory animal physiology course for students without formal training in physiology beyond general biology or as a second physiology course for students who have already taken BIOS 30344. General physiological principles are introduced, and the course is designed around the classical organ/system approach to physiology but with stress on comparative and evolutionary relationships. Emphasis is placed on the integrated nature of the various physiological systems and on the relationships of the physiology of the organism to its environment (physiological ecology) as well as to the lower levels of biological hierarchy (biochemistry, cell, and molecular biology). Special emphasis is placed on adaptations to environmental extremes. This course has four lectures per week. Spring.

BIOS 30423. Genomics: Sequence to Organism
(3-0-3) Ferdig
Prerequisite(s): see online Course Catalog for details.
This course will introduce the methods of genome science and explore their applications in biological research and their impact on biological thinking. Topics will include how genomes are studied, how they function, and how they evolve. The importance of comparative and functional genomics in identifying mechanisms of human diseases will be highlighted. Spring.

BIOS 30475. Laboratory Animal Science
(2-0-2) Stewart
An introduction to laboratory animal science, focusing on federally mandated regulations, animal rights/animal welfare controversies, general care and use of animals in a full-compliance program, and common methodologies used in animal-based research. Enrollment is by consent of instructor only and limited to junior or senior undergraduate pre-veterinary students, or biology majors whose graduate career program will require animal use, or graduate students whose research requires animal use at Notre Dame. Spring.

BIOS 30569. Practicum in Aquatic Biology
(V V-6) Belovsky
Practical training in aquatic and environmental biology through lecture and field experience at the University's environmental research facility located in northern Wisconsin and the upper peninsula of Michigan. Course includes an independent research project. (Summer)

BIOS 31304. Botany Laboratory
(0-3-0)
Prerequisite(s): see online Course Catalog for details.
Corequisite(s): BIOS 30304
General botany laboratory is to be taken concurrently with the general botany lecture. Students may not take lecture alone or laboratory alone.

BIOS 31312. General Ecology Laboratory
(0-1-1) Staff
General ecology laboratory is to be taken concurrently with the general ecology lecture. Students may not take lecture alone or laboratory alone.

BIOS 31341. Cell Biology Laboratory
(0-3-1) Welch
Prerequisite(s): see online Course Catalog for details.
This laboratory course exposes students to a variety of techniques in modern cell biology. Students will get hands-on experience in working with cultured cell lines, including sterile technique, media preparation, and passaging of cells. Individual experiments will include assessment of cell growth and apoptosis, examination of subcellular structure using fluorescent microscopy, separation and analysis of nucleic acids and proteins, enzyme assays, and measurement of cell cycle by flow cytometry. It provides an excellent introduction to the approaches routinely used in analysis of cells and their functions. Fall.

BIOS 31401. Principles of Microbiology Lab
(0-3-1) Kul
Prerequisite(s): see online Course Catalog for details.
Laboratory exercises consider basic techniques in microbiology, such as sterile procedures and microbial metabolism. Fall.

BIOS 31406. General Entomology Laboratory
(0-3-1) Collins
Prerequisite(s): (Pre/Co-Req BIOS 30406 or Pre/Co-Req BIOS 406)
The laboratory introduces students to insect morphology, systematics, and techniques used in the study of insects. Offered concurrently with lecture.

BIOS 31408. Medical and Veterinary Entomology Laboratory
(0-3-1) Collins
Prerequisite(s): (Pre/Co-Req BIOS 30408 or Pre/Co-Req BIOS 408)
The labaoratory introduces students to the variety of arthropods that vector disease agents or otherwise affect the lives of humans and other vertebrate animals. Offered concurrently with lecture.

BIOS 31420. Aquatic Ecology Laboratory
(0-3-0) Hellenthal
Prerequisite(s): see online Course Catalog for details.
Corequisite(s): BIOS 30420
Aquatic ecology laboratory is to be taken concurrently with the aquatic ecology lecture. Students may not take lecture alone or laboratory alone.

BIOS 31421. Integrative Comparative Physiology Laboratory
(0-3-1) Johnson
Prerequisite(s): (Pre/Co-Req BIOS 30421 or Pre/Co-Req BIOS 421)
Laboratory provides experience with experimentation and analysis of physiological concepts at the organismal, cellular, and molecular levels. Spring.

BIOS 37491. Teaching Practicum in the Life Sciences
(0-0-0) Staff
Same as BIOS 37495 except that students who are registered for this section are paid as undergraduate teaching assistants; this section is not graded and no academic credit is given.

BIOS 37492. Teaching Practicum in the Life Sciences
(V-0-V) Staff
Same as BIOS 37495 except that this is a S/U-graded variable credit section; 2.0 maximum credits allowed

BIOS 37493. Teaching Practicum in the Life Sciences
(V-0-V) Staff
Same as BIOS 37495 except that this is a letter-graded variable credit section; 2.0 maximum credits allowed

BIOS 37495. Teaching Practicum in Life Sciences
(2-0-2) Stafff
This course gives the advanced student an opportunity to gain direct experience in teaching. Students are assigned regular teaching duties in certain laboratory courses and must be prepared to accept responsibility. Note: Most states will not accept this in lieu of practice teaching in an education department. Students must clear lab assignments with each section's practicum coordinator. Fall and spring.

BIOS 40342. Developmental Biology
(3-0-3)
Development of plants, animals, and microorganisms studied at the molecular, cellular, and organismic levels. BIOS 40342 is taught at a higher level with genetics and cell biology as prerequisite compared to 30342. Spring.

BIOS 40411. Biostatistics
(4-0-4) Lamberti
Prerequisite(s): see online Course Catalog for details.
Corequisite(s): BIOS 42411
Basic principles of statistical analysis and their application to biological problems, including statistical inference, analysis of variance, regression, non-parametric approaches, and introduction to statistical computing. This course's "lab" is a tutorial; it does not fulfill the laboratory elective requirement (after 1993). Students may not take both BIOS 40411 and MATH 20340. Spring.

BIOS 40415. Medical and Veterinary Parasitology
(3-0-3) Adams
Prerequisite(s): see online Course Catalog for details.
The animal parasites of humans and related hosts are reviewed. The pathology caused by these parasites, epidemiology, life cycles, prophylactic and therapeutic control are considered. Spring.

BIOS 40416. Virology
(3-0-3) Fraser
Prerequisite(s): see online Course Catalog for details.
A study of viruses as primitive biological entities and as disease-inducing agents in humans and other animals: characteristics of viruses and virus infections; molecular aspects of virus replication; methods for diagnosis and prevention of infections; artificial use of viruses. Spring.

BIOS 40417. Human Musculoskeletal Anatomy
(3-0-3) O'Malley
Prerequisite(s): see online Course Catalog for details.
An introduction to basic anatomical principles relating to bones and muscles and to the normal anatomical and biochemical aspects of the human musculoskeletal system. Fall.

BIOS 40419. Immunology
(3-0-3) McDowell
Prerequisite(s): see online Course Catalog for details.
An introductory course emphasizing the cells and tissues of the immune system and the nature and function of antigens and antibodies. A survey is presented of immune capabilities of humans and animals, immune diseases, immunodeficiency states, transplantation of organs, and the influence of nutrition on the immune system. Fall.

BIOS 40424. Tumor Cell Biology
(3-0-3) Welsh
Prerequisite(s): see online Course Catalog for details.
Overview of the cancer development process at the cellular and molecular level, including regulatory networks involved in growth control and tissue organization and an introduction to animal, cell, and molecular techniques for studying progression, treatment, and prevention of cancer. Spring.

BIOS 40435. Cellular and Molecular Basis of Human Disease
(3-0-3) Schorey
Prerequisite(s): see online Course Catalog for details.
This course will explore the cellular and molecular mechanisms underlying various human diseases. Following an introduction to principles of disease, lectures will focus on recent advances in cellular and molecular aspects of immune responses and inflammation, pathogenic mechanisms and tumor cell biology (including abnormal growth regulation, invasion and metastasis). Specific examples of human diseases will be utilized to illustrate the concepts of disease-related gene products, the use of experimental animal models and the development of novel therapeutic strategies.

BIOS 40440. AIDS
(3-0-3) Fraser
Prerequisite(s): see online Course Catalog for details.
This course will explore the phenomenon of AIDS, including characteristics of the worldwide AIDS pandemic, the virus (HIV) itself, the immune system and HIV, methods of diagnosis, prevention, treatment, and basic epidemiology as it relates to AIDS. This is an advanced course in infectious diseases designed for preprofessional and other interested students. Fall.

BIOS 40460. Plant Ecology
(3-0-3)
Prerequisite(s): (BIOS 30312 or BIOS 312)
An overview of ecological principles as they relate to botanical ecosystems.

BIOS 41342. Developmental Biology Laboratory
(0-3-1)
Corequisite(s): BIOS 40342
Laboratory exercises will examines the basic developmental mechanisms of animals and plants. Students may not take both BIOS 30342 and 40342 and/or 40414 because the lecture materials are very similar in the three developmental biology courses. Offered on an irregular basis.

BIOS 41344. Vertebrate (Human) Physiology Laboratory
(0-3-1) Boyd
Prerequisite(s): see online Course Catalog for details.
Laboratory experience in physiology. Ideally, this laboratory is taken after students have completed the BIOS 30344 lecture. Fall.

BIOS 41415. Medical and Veterinary Parasitology Laboratory
(0-3-1) Adams
Corequisite(s): BIOS 40415
The laboratory introduces students to the microscopic world of parasites. Extensive microscope work is needed. Spring, on demand.

BIOS 41417. Anatomy Laboratory
(0-3-1) O'Malley
Prerequisite(s): see online Course Catalog for details.
This lab is available by special arrangement with the instructor and is designed primarily for physical therapy intents. The focus is on musculoskeletal anatomy and should NOT considered a substitute for a general anatomy laboratory.

BIOS 41475. Laboratory Animal Science Laboratory
(2-0-2) Stewart
Prerequisite(s): (BIOS 30475 or BIOS 475)
This course focuses on experimental techniques and methodologies in both laboratory and clinical settings. Students will divide their laboratory time between hands-on work in the animal facility and clinical experience in area veterinary clinics when possible. Enrollment is by consent of instructor only and limited to senior undergraduate pre-veterinary students, or senior biology majors whose graduate research program will require animal use at Notre Dame. Every student will be required to keep a complete notebook and develop a semester journal project or case study. Fall.

BIOS 42411. Biostatistics Tutorial
(0-1-0) Lamberti
Corequisite(s): BIOS 40411
The biostatistics tutorial is to be taken concurrently with the lecture. Students may not take lecture alone or the tutorial alone.

BIOS 46497. Directed Readings
(0-0-V) Staff
This course provides the opportunity for independent study through readings on specific topics in biological science. Readings are chosen with the advice of the supervising instructor. Students may not register for more than three credits per semester; only two credits per semester may be counted as BIOS elective credits by majors. Offered all semesters.

BIOS 48498. Undergraduate Research
(0-0-V) Staff
Research in collaboration with members of the faculty. Evaluation of performance will be accomplished through regular discussions with the faculty member in charge of the course. Enrollment must be completed before the end of the first week each semester. Students may not register for more than three credits per semester; only two credits per semester may be counted as BIOS elective credits by majors. Offered all semesters.

BIOS 50543. Ethics and Science
(3-0-3) Shrader-Frechette
Use of four ethical theories and five classical logical/analytical criteria to ethically evaluate case studies in contemporary science. Problems analyzed via contemporary science include practical issues of plagiarism, attribution, peer reviewing, data sharing, data ownership, collaborative science, scientific misconduct, paternalism, whistleblowing, conflicts of interest, secrecy in science, and advocacy in science. Methodological issues to be dealt with include scientists misrepresenting their opinions with confirmed science, cooking and trimming their data, failure to attend to the purposes for which their research may be used or misused, and scientists' use of evaluative presuppositions, questionable inferences and default rules, question-begging validation and benchmarking, and misleading statistics. On demand.

BIOS 50544. Environmental Justice
(3-0-3) Shrader-Frechette
Students will examine methodological and ethical problems in current environmental impact assessments (EIAs) and technology assessments (TAs). The goal of the course is doing project-based philosophical analysis of current EIAs and TAs that typically are used to discriminate against poor people and minorities. Most noxious and polluting facilities are sited in poor and minority neighborhoods. Cross-listed with GSC 474, PHIL 470 and STV 496.

BIOS 50573. Topics in Ecology: Current Trends in Environmental Policy and Politics
(3-0-3)
Evans

Subject matter changes depending on students' needs. Prospective subjects include systems analysis in ecology or biogeography.

The following undergraduate courses have been offered periodically as demand dictates:

10102. Plants, Food, and Society
10105. Parasitism, Disease, and Public Health
10111. Biological Basis of Human Behavior
10112. The Marine Environment
10113. Understanding Viruses
10114. Avian Biology
10115. Microbes and Man
40402. Microbial Physiology
30403. Invertebrate Biology
30409. Plant Taxonomy
40413. Cytology
30422. Marine Biology
40424. Tumor Cell Biology
40430. Advanced Animal Physiology
40455. Infection and Immunity
30460. Plant Ecology
40462. Applied Environmental Microbiology
40463. Aquatic Botany
40464. Antibiotics and Chemotherapeutics

UNDERC Field Biology Program.
A special seven-credit program primarily for undergraduate students involving three semesters that emphasizes field biology is offered at the University's Environmental Research Center. Undergraduate students must apply to the program; only a limited number may be selected each year because of limited availability of space on site. On selection in late fall, students enroll in BIOS 30568 for one credit and BIOS 30569 for six credits. The summer's project is completed in the subsequent fall semester.

Many of the former 500-level BIOS courses may be offered as either 50000- or 60000-level, or both, classes any given semester. This cross-listing provides for one lecture to be both a graduate-level class and still have a clear undergraduate component where requirements may vary.

SELECT GRADUATE-LEVEL COURSES

The 50000- and 60000-level courses in biological sciences are open to qualified undergraduates, subject to the approval of the course instructors and the director of undergraduate studies. Graduate-level courses that generally include a majority of upperclass students and that are recommended to undergraduate majors include:

60501. Advanced Molecular Genetics
60502. Genetics of Lower Eukaryotes
60503. Advanced Microbial Physiology
60504. Developmental Genetics
60506. Cytogenetics
60508. Population Genetics
60509. Plant Anatomy
60510. Experimental Parasitology
60511. Protozoology
60512. Helminthology
60514. Field Parasitology
60515. Vector Genetics
60516. Physiological Chemistry of Animal Parasites
60517. Biological Microtechnique
60518. Cell Variation and Growth
60520. Arbovirology
60523. Practicum in Environmental Biology
60524. Ichthyology
60525. Community Ecology
60526. Invertebrate Pathology
60527. Stream Ecology
60528. Environmental Microbiology
60529. Theoretical Population Ecology
60530. Immunobiology of Infectious Diseases
60531. Molecular Biology I
60532. Molecular Biology II
60533. Proteins and Nucleic Acids
60534. Plant Physiology
60535. Comparative Endocrinology
60536. Advanced Virology
60537. Microbial Genetics
60538. Neurobiology
60539. Advanced Cell Biology I
60540. Advanced Cell Biology II
60541. Physical Chemistry for Biologists
60543. Ethics and Science
60554. Biological Research Applications of Computers
60556. Histology
60558. Biological Electron Microscopy
60560. Environmental Physiology and Biochemistry
60561. Advanced Aquatic Ecology
60562. Aquatic Insects
60563. Wetland Ecology
60564. Behavioral Ecology
60565. Nutrition
60570–60579. Topics Courses

Additional undergraduate and graduate-level courses are expected to be added during the next four years.

The above 60000-level courses are described in the *Graduate School Bulletin of Information.*

Chemistry and Biochemistry

Chair:
A. Graham Lappin
George and Winifred Clark Professor of Chemistry:
Marvin J. Miller
Grace-Rupley Professor of Chemistry:
Thomas P. Fehlner
Charles L. Huisking Professor of Chemistry:
Xavier Creary
Kleiderer/Pezold Professor of Biochemistry
Francis J. Castellino
Navari Family Professor of Life Sciences:
Shahriar Mobashery
William K. Warren Professor of Chemistry:
W. Robert Scheidt
Clare Boothe Luce Assistant Professor of Biochemistry:
Patricia L. Clark
Professsors:
Subhash C. Basu; Gregory V. Hartland; Paul Helquist; Paul W. Huber; Dennis C. Jacobs; A. Graham Lappin; Joseph P. Marino; Dan Meisel; Thomas L. Nowak; Anthony Serianni; Slavi Sevov; Bradley D. Smith; Richard E. Taylor; Olaf G. Wiest
Associate Professors:
Seth Brown; J. Daniel Gezelter; Kenneth W. Henderson; Marya Lieberman
Assistant Professors:
Brian M. Baker; Steven A. Corcelli; Jennifer DuBois; Holly V. Goodson; S. Alexander Kandel; Masaru Kenneth Kuno; Jeffrey W. Peng
Emeriti:
Roger K. Bretthauer; Richard W. Fessenden; Jeremiah P. Freeman; Robert G. Hayes; Emil T. Hofman; John Magee; Robert H. Schuler; Maurice E. Schwartz; J. Kerry Thomas; Anthony M. Trozzolo; Rev. Joseph L. Walter, CSC

Program of Studies. Chemistry is the science of substances that comprise the world about us and is concerned with their structure, their properties and the reactions that change them into other substances. Chemists and biochemists practice their profession in many ways—in educational institutions, government laboratories, private research institutions and foundations and in many commercial areas, including the chemical, drug, health, biotechnology, pharmaceutical and food industries.

The Department of Chemistry and Biochemistry has a strong undergraduate program together with a strong graduate education and research program. The graduate program greatly benefits undergraduate education by attracting highly qualified faculty and results in the availability of excellent research facilities and modern instrumentation necessary to train the scientists of tomorrow. This department is able to provide an excellent program of undergraduate research to complement regular course work. Student participation in research is highly encouraged as a key part of the education of chemistry and biochemistry majors.

The programs in chemistry and biochemistry described in the following pages prepare students for graduate studies and professional work in the chemical and biochemical sciences, as well as in interdisciplinary areas that rely heavily on chemistry. Bachelor of science degrees are offered with a major in chemistry or a major in biochemistry. At the graduate level, the Department of Chemistry and Biochemistry offers programs leading to the degrees of master of science and doctor of philosophy, as described in the *Graduate School Bulletin of Information.*

Bachelor of Science with a Major in Chemistry

The chemistry curriculum at Notre Dame includes two programs: the Chemistry Career Program, designed for students interested in a professional career in chemistry, and the Chemistry Combination Program, designed for those students who are interested in combining chemistry with business or with computing.

All chemistry majors take the following basic sequence of courses:

General Chemistry (CHEM 10181–11181 recommended; or optionally, CHEM 10113–10114 or 10117–10118)
Organic Chemistry (CHEM 10182, 11182, 20283, 21283)
Inorganic Chemistry (CHEM 20284, 21284, 40443, 41443)
Physical Chemistry (CHEM 30321, 31321, 30322, 31322)
Analytical Chemistry (CHEM 30333, 31333)
Physical Methods of Chemistry (CHEM 40434)
Principles of Biochemistry (CHEM 40420)
Chemistry Seminars (CHEM 23201, 23202), three semesters
Physics (PHYS 10310, 10320, 20330)[1]
Calculus (MATH 10550, 10560, and 20550)
In addition to this basic sequence, the following courses are required for each program.

Chemistry Career Program
Science Electives (six credit hours)[2,3]

Combination Program
Program Electives (15 credit hours)
Science Electives (three credit hours)[2,3]

The program electives for the Chemistry Combination Program are from either the area of business or from the area of computing and are the same as those in the corresponding Collegiate Sequence programs:

Chemistry with Business
Accounting and Accountancy I (ACCT 20100)
Accounting and Accountancy II (ACCT 20200)
Business Finance (FIN 20100)
Introduction to Management (MGT 20200)
Introduction to Marketing (MARK 20100)
Introduction to Economics (ECON 10010 or 12101) is suggested, as a non-program elective, as a prerequisite to MARK 20100 and meets the University social science requirement.

Chemistry with Computing
Advanced Programming (CSE 20232)
Discrete Mathematics (CSE 20110)
Data Structures (CSE 30331)
and
Functional Programming (CSE 20033) and Database Concepts (CSE 30246)
or Automata (CSE 40411) and Algorithms (CSE 40113)
or Automata (CSE 40411) and Compilers (CSE 40243)

Sample Curriculum (Career Program):
First Year

First Semester	
CHEM 10181	3
CHEM 11181	1
MATH 10550	4
PHYS 10310	4
FYC 13100	3
History[4]	3
Physical Education/ROTC	0
	18

Second Semester	
CHEM 10182	3
CHEM 11182	1
MATH 10560	4
PHYS 10320	4
Philosophy[4,5]	3
Social Science[4]	3
Physical Education/ROTC	0
	18

Sophomore Year

First Semester	
CHEM 20283	3
CHEM 21283	1
MATH 20550	3.5
PHYS 20330	3.5
Language	3
	14

Second Semester	
CHEM 20284	3
CHEM 21284	2
CHEM 23202[6]	1
Language	3
Theology[5]	3
	15

Junior Year

First Semester	
CHEM 30321	3
CHEM 31321	2
CHEM 30333	2
CHEM 31333	2
CHEM 23201[6]	1
Elective (or Language)	3
Theology	3
	16

Second Semester	
CHEM 30322	3
CHEM 31322	2
CHEM 40434	3
Philosophy	3
Elective	3
	14

Senior Year

First Semester	
CHEM 40420	3
CHEM 40443	3
Electives	6
Fine Arts or Literature	3
	15

Second Semester	
CHEM 23202[5]	1
CHEM 41443	2
Science Electives[2,3]	6
Electives	6
	15

Sample Curriculum (Combination Program):
First Year

First Semester	
CHEM 10181	3
CHEM 11181	1
MATH 10550	4
PHYS 10310	4
FYC 13100	3
History[4]	3
Physical Education/ROTC	0
	18

Second Semester	
CHEM 10182	3
CHEM 11182	1
MATH 10560	4
PHYS 10320	4
Philosophy[4,5]	3
Social Science[4]	3
Physical Education/ROTC0	
	18

Sophomore Year

First Semester	
CHEM 20283	3
CHEM 21283	1
MATH 20550	3.5
PHYS 20330	3.5
Language	3
	14

Second Semester	
CHEM 20284	3
CHEM 21284	2
CHEM 23202[6]	1
Language	3
Theology[5]	3
	12

Junior Year

First Semester

CHEM 30321	3
CHEM 31321	2
CHEM 30333	2
CHEM 31333	2
Elective (or Language)	3
Program elective[7]	3
	15

Second Semester

CHEM 23202[6]	1
CHEM 30322	3
CHEM 31322	2
CHEM 40434	3
Theology	3
Program Elective[7]	3
	15

Senior Year

First Semester

CHEM 40420	3
CHEM 40433	3
Program Electives[7]	6
Elective	3
	15

Second Semester

CHEM 23202[5]	1
CHEM 41443	2
Science Elective[2,3]	3
Program Elective[7]	3
Fine Arts or Literature	3
Philosophy	3
	15

Notes:

1. Substitution with permission only.
2. Linear Algebra/Differential Equations (MATH 20580) is a recommended science elective.
3. Undergraduate research, CHEM 48498, is a recommended science elective in all programs beginning in the sophomore year with typically one or two credits per semester.
4. The student should take three general requirement courses during the first year, including one course that is designated a University Seminar. Economics is required for the Chemistry with Business program.
5. One course in theology and philosophy should be completed by the end of the sophomore year. These courses may be taken in either semester of the first or second year.
6. In all the programs, one chemistry seminar is generally taken in each of the sophomore, junior and senior years.
7. Note: Program electives in computing require careful scheduling, and some sequences may require more than two years to complete.
8. For alternative physics, take PHYS 10310, 132.
9. BIOS 20201, 21201, 20202, and 21202 are alternative choices for the sophomore year.

BACHELOR OF SCIENCE WITH A MAJOR IN BIOCHEMISTRY

The biochemistry curriculum emphasizes the chemical basis of biological processes. All biochemistry majors are required to take the following courses:
General Chemistry (CHEM 10181 AND 11181 recommended; or optionally CHEM 10113–10114 or 10117–10118)
Organic Chemistry (CHEM 10182, 11182, 20283, 21283)[1]
Physical Chemistry (CHEM 30321–30322)
Analytical Chemistry (CHEM 30333, 31333)
Chemistry Seminars (CHEM 23201, 23202), three semesters
Biochemistry Seminar (CHEM 23212)
Biochemistry (CHEM 30341, 31341, 30342)
Calculus (MATH 10550, 10560, 225)
Physics (PHYS 30210-30220)[8]
General Biology (BIOS 10161–10162 or 20201, 21201, 20202, 21202)
Genetics (BIOS 30303, 31303)
Cell Biology (BIOS 30341, 31341)
Molecular Biology (BIOS/CHEM 50531)

Sample Curriculum (Biochemistry Program):

First Year

First Semester

CHEM 10181	3
CHEM 11181	1
MATH 10550	4
BIOS 10161	3
BIOS 11161	1
FYC 13100	3
History[4]	3
Physical Education/ROTC	0
	18

Second Semester

CHEM 10182	3
CHEM 11182	1
MATH 10560	4
BIOS 10162	3
BIOS 11162	1
Philosophy4,5	3
Social Science4	3
Physical Education/ROTC	0
	18

Sophomore Year

First Semester

CHEM 20283	3
CHEM 21283	1
CHEM 23212	0
PHYS 30210	4
MATH 20550	3.5
Language	3
	15.5

Second Semester

CHEM 20284	3
CHEM 21284	2
CHEM 23202	1
PHYS 30220	4
Language	3
Theology[5]	3
	16

Junior Year

First Semester

CHEM 30321	3
CHEM 30341	3
CHEM 31341	2
CHEM 23201	1
BIOS 30341, BIOS 31341	4
Elective (or Language)	3
	16

Second Semester

CHEM 30322	3
CHEM 30342	3
BIOS 30303, BIOS 31303	4
Philosophy	3
Elective	3
	16

Senior Year

First Semester

CHEM 30333	2
CHEM 31333	2
BIOS/CHEM 50531	3
Theology	3
Elective	3
	13

Second Semester

CHEM 23202	1
Fine Arts or Literature	3
Electives	8
	12

Chemistry and Biochemistry Course Descriptions. The following course descriptions give the number and title of each course. Lecture hours per week, laboratory and/or tutorial hours per week and credits each semester are in parentheses.

CHEM 10101. Foundations of Chemistry

(3-0-3)

This course covers forms, properties, and separation of matter; atomic structure and periodicity; nuclear chemistry; chemical bonding and structure; reactivity with applications to acid-base and oxidation-reduction reactions; and chemistry of carbon and living systems. This course is not open to students who have taken CHEM 10103, 10115, 10113, or 10117.

CHEM 10102. Chemistry, Environment, and Energy

(3-0-3)

Chemistry of the atmosphere, hydrosphere, and lithosphere; agricultural chemistry and pesticides; food and drugs; hazardous and solid wastes; and recycling. Fossil fuels; nuclear, solar, geothermal, and other

types of energy. This course is not open to students who have taken CHEM 10114, 10116, or 10118.

CHEM 10113. General Chemistry I-T Lecture and Laboratory

(4-0-4)

Corequisite(s): CHEM 11113 CHEM 12113

Introduction to the principles and concepts of chemistry and its application in the world. Topics include periodic properties of the elements, reaction stoichiometry, atomic theory, molecular structure and bonding, acids and bases, reduction-oxidation reactions, gas-laws, thermochemistry, equilibrium, and chemical kinetics. Lectures, demonstrations, laboratory experiments, and tutorial sections are integrated to promote a deeper understanding of chemistry fundamentals and to develop the analytical skills necessary for solving problems. In the weekly tutorials, students work in small groups at solving problems collaboratively. The general topics, textbook, and laboratory are the same as those for CHEM 10117-10118. CHEM 10113 will serve as a prerequisite course to all upper-level courses that list CHEM 10117 or CHEM 10125 as a prerequisite.

CHEM 11113. General Chemistry I-T Lab

(0-0-0)

Corequisite(s): CHEM 10113 CHEM 12113

General Chemistry I-T lecture course; lecture and lab together are 4 credits (Lecture = 4; Lab = 0). The lab introduces experimental chemistry with examples from all areas of chemistry. The experiments range from traditional wet chemistry to modern instrumental analysis. The lab consists of prelab lecture and individual laboratory work. In both semesters, computers are integrated into the experiments. The computer programs are intended to promote certain problem-solving skills and provide experimental simulation not possible within the time constraints of the normal laboratory period.

CHEM 12113. General Chemistry I-T Tutorial

(0-0-0)

Corequisite(s): CHEM 10113 CHEM 11113

Weekly tutorial that accompanies CHEM 10113 General Chemistry I-T lecture and lab; students work in small groups at solving problems collaboratively.

CHEM 10114. General Chemistry II-T Lecture and Laboratory

(4-0-4)

Prerequisite(s): see online Course Catalog for details.

Introduction to the principles and concepts of chemistry and its application in the world. Topics include periodic properties of the elements, reaction stoichiometry, atomic theory, molecular structure and bonding, acids and bases, reduction-oxidation reactions, gas-laws, thermochemistry, equilibrium, and chemical kinetics. Lectures, demonstrations, laboratory experiments, and tutorial sections are integrated to promote a deeper understanding of chemistry fundamentals and to develop the analytical skills necessary for solving problems. In the weekly tutorials, students work in small groups at solving problems collaboratively. The general topics, textbook and laboratory are the same as those for CHEM 10117-10118. CHEM 10114 will serve as a prerequisite course to all upper-level courses that list CHEM 10118 or CHEM 10126 as a prerequisite.

CHEM 11114. General Chemistry II-T Lecture, Tutorial, and Laboratory

(0-0-0)

Corequisite(s): CHEM 10114

General Chemistry II-T lecture course; lecture and lab together are 4 credits (Lecture = 4; Lab = 0). The lab introduces experimental chemistry with examples from all areas of chemistry. The experiments range from traditional wet chemistry to modern instrumental analysis. The lab consists of prelab lecture and individual laboratory work. In both semesters, computers are integrated into the experiments. The computer programs are intended to promote certain problem-solving skills and provide experimental simulation not possible within the time constraints of the normal laboratory period.

CHEM 12114. General Chemistry II-T Lecture, Tutorial, and Laboratory

(0-0-0)

Corequisite(s): CHEM 10114

Weekly tutorial that accompanies CHEM 10114. General Chemistry II-T lecture and lab; students work in small groups at solving problems collaboratively.

CHEM 10115. General Chemistry I Lecture

(3-0-3)

Designed for first-year students intending to major in science and engineering. This lecture course covers classical/modern chemistry, with applications, in the approximate order: stoichiometry and classical atomic theory of chemistry; periodic properties; gas laws; chemical equilibrium; solution chemistry (acids and bases, solubility, physical properties of solution); thermochemistry; chemical kinetics; modern quantum theory of atomic and molecular structure and periodic properties. Descriptive chemistry is included throughout in all developments. Frequent live demonstrations and classroom computer use emphasize the unifying experimental and theoretical aspects of the subject.

CHEM 10116. General Chemistry II Lecture

(3-0-3)

Prerequisite(s): see online Course Catalog for details.

The second semester of General Chemistry. Designed for first-year students intending to major in science and engineering. This lecture course covers classical/modern chemistry, with applications, in the approximate order: stoichiometry and classical atomic theory of chemistry; periodic properties; gas laws; chemical equilibrium; solution chemistry (acids and bases, solubility, physical properties of solution); thermochemistry; chemical kinetics; modern quantum theory of atomic and molecular structure and periodic properties. Descriptive chemistry is included throughout in all developments. Frequent live demonstrations and classroom computer use emphasize the unifying experimental and theoretical aspects of the subject.

CHEM 10117. General Chemistry I Lecture and Laboratory

(4-0-4)

Corequisite(s): CHEM 11117

Designed for first-year students intending to major in science and engineering. This lecture course covers classical/modern chemistry, with applications, in the approximate order: stoichiometry and classical atomic theory of chemistry; periodic properties; gas laws; chemical equilibrium; solution chemistry (acids and bases, solubility, physical properties of solution); thermochemistry; chemical kinetics; modern quantum theory of atomic and molecular structure and periodic properties. Descriptive chemistry is included throughout in all developments. Frequent live demonstrations and classroom computer use emphasize the unifying experimental and theoretical aspects of the subject.

CHEM 11117. General Chemistry I Lab

(0-0-0)

Corequisite(s): CHEM 10117

The second semester of General Chemistry Lab that accompanies CHEM 10117 General Chemistry I lecture course; lecture and lab together are 4 credits (Lecture = 4; Lab = 0). The lab introduces experimental chemistry with examples from all areas of chemistry. The experiments range from traditional wet chemistry to modern instrumental analysis. The lab consists of prelab lecture and individual laboratory work. In both semesters, computers are integrated into the experiments. The computer programs are intended to promote certain problem-solving skills and provide experimental simulation not possible within the time constraints of the normal laboratory period.

CHEM 10118. General Chemistry II Lecture and Laboratory

(4-0-4)

Prerequisite(s): see online Course Catalog for details

Corequisite(s): CHEM 11118

The second semester of General Chemistry. Designed for first-year students intending to major in science and engineering. This lecture course covers classical/modern chemistry, with applications, in the approximate order: stoichiometry and classical atomic theory of chemistry; periodic properties; gas laws; chemical equilibrium; solution chemistry (acids and bases, solubility, physical properties of solution); thermochemistry; chemical kinetics; modern quantum theory of atomic and molecular structure and periodic properties. Descriptive chemistry is included throughout in all developments. Frequent live demonstrations and classroom computer use emphasize the unifying experimental and theoretical aspects of the subject.

CHEM 11118. General Chemistry II Lecture and Laboratory

(0-0-0)

Corequisite(s): CHEM 10118

The second semester of General Chemistry Lab that accompanies CHEM 10118 General Chemistry II lecture course; lecture and lab together are 4 credits

(Lecture = 4; Lab = 0). The lab introduces experimental chemistry with examples from all areas of chemistry. The experiments range from traditional wet chemistry to modern instrumental analysis. The lab consists of prelab lecture and individual laboratory work. In both semesters, computers are integrated into the experiments. The computer programs are intended to promote certain problem-solving skills and provide experimental simulation not possible within the time constraints of the normal laboratory period.

CHEM 11119. General Chemistry Laboratory
(1-0-1)
Prerequisite(s): (CHEM 10115 or CHEM 115)
A laboratory identical to that presented in conjunction with CHEM 10117-10118. Designed for students needing laboratory but having previously taken CHEM 10115-10116.

CHEM 11120. General Chemistry Laboratory
(1-0-1)
Prerequisite(s): see online Course Catalog for details.
A laboratory identical to that presented in conjunction with CHEM 10117-10118. Designed for students needing laboratory but having previously taken CHEM 10115-10116.

CHEM 10121. General Chemistry: Fundamental Principles and Biological Processes
(4-0-4)
Corequisite(s): CHEM 11121
Designed for first-year students intending to major in engineering. In the first semester, the fundamental principles of chemistry are presented including atomic and molecular structure, molecular properties, periodic trends in reactivity, solution chemistry, thermodynamics, and kinetics. Quantitative aspects are stressed. A laboratory is offered with this part of the course. In the second semester, these topics are woven into key themes of modern biology, including protein structure and function, gene structure and manipulation, and basics of biotechnology. Emphasis is placed on common themes rather than biological details, and examples are drawn from biological systems of interest to engineers. This course will serve as a prerequisite course to all upper-level courses that list CHEM 10118 or CHEM 126 as a prerequisite.

CHEM 11121. General Chemistry I Laboratory
(0-0-0)
Corequisite(s): CHEM 10121
A laboratory identical to that presented in conjunction with CHEM 10117-10118. This lab accompanies CHEM 10121 lecture course.

CHEM 10122. General Chemistry: Fundamental Principles and Biological Processes
(3-0-3)
Prerequisite(s): (CHEM 10121 or CHEM 121)
Designed for first-year students intending to major in engineering. In the first semester, the fundamental principles of chemistry are presented, including atomic and molecular structure, molecular properties, periodic trends in reactivity, solution chemistry, thermodynamics and kinetics. Quantitative aspects are stressed. A laboratory is offered with this part of the course. In the second semester, these topics are woven into key themes of modern biology, including protein structure and function, gene structure and manipulation, and basics of biotechnology. Emphasis is placed on common themes rather than biological details, and examples are drawn from biological systems of interest to engineers. This course will serve as a prerequisite course to all upper-level courses that list CHEM 10118 or CHEM 10126 as a prerequisite.

CHEM 10181. Introduction to Chemical Principles
(4-0-4)
Corequisite(s): CHEM 11181 CHEM 12181 MATH 10550
This course provides a thorough grounding in the fundamental principles governing chemical structure and reactivity. Topics to be discussed include the quantum mechanical structure of atoms, models of chemical bonding, chemical equilibrium, acidity and basicity, and thermochemistry and thermodynamics. Recommended for students with a special interest in the subject, especially those intending to major in chemistry or biochemistry. Lectures will be supplemented with a weekly tutorial session.

SUMMARY OF MINIMAL REQUIREMENTS FOR THE DEGREE OF BACHELOR OF SCIENCE IN CHEMISTRY AND BIOCHEMISTRY

	Chemistry Career Program	*Chemistry Combination Program*	*Biochemistry Program*
Chemistry	42	42	30
Biochemistry	3	3	8
Biological Sciences	—	—	19
Mathematics	11.5	11.5	11.5
Physics	11.5	11.5	8
Science Electives	6	3	0
Total Required Science	74	71	76.5
Program Electives	—	15	—
Total	**74**	**86**	**76.5**
Language	Intermediate Level Competency		
FYC 13100	3	3	3
Philosophy[+]	6	6	6
Theology[+]	6	6	6
Literature/Fine Arts[+]	3	3	3
History[+]	3	3	3
Social Sciences[+]	3	3	3
Free Electives	14[++]	2[++]	14[++]
	124	**124**	**124.5**

[+] *One of these courses must be a University Seminar 180.*

[++] *Assumes intermediate-level competency in language was achieved by taking three 3-credit courses.*

CHEM 11181. Introduction to Chemical Principles Laboratory
(0-0-0)
Corequisite(s): CHEM 10181 CHEM 12181
A laboratory to accompany CHEM 10181 that will stress quantitative measurements.

CHEM 12181. Introduction to Chemical Principles Tutorial
(0-0-0)
Corequisite(s): CHEM 10181 CHEM 11181
New tutorial course that accompanies Chem 10181. Weekly tutorial where students work at solving problems collaboratively.

CHEM 10182. Organic Structure and Mechanism
(3-0-3)
Basic principles of organic chemistry, including fundamental aspects of organic and biological structures and bonding, stereochemistry, the effect of structure on physical and chemical properties, and applications of spectroscopic methods to assign structures. A detailed analysis of organic chemical reactivity, including reactive intermediates and mechanistic principles. Introductory applications of reactions in synthesis. Intended primarily for chemistry and biochemistry majors. Lectures will be supplemented with a weekly tutorial session.

CHEM 11182. Organic Structure and Mechanism Laboratory
(0-3-1)
A laboratory to accompany CHEM 10182 that will emphasize fundamental organic techniques.

CHEM 23201. Chemistry Seminar
(1-0-1)
To be taken either semester of the sophomore through senior years. Introduction to the communication of scientific knowledge.

CHEM 23202. Chemistry Seminar
(1-0-1)
To be taken either semester of the sophomore through senior years. Introduction to the communication of scientific knowledge.

CHEM 20204. Environmental Chemistry
(3-0-3)
Discussion of basic chemical processes occurring in the environment, particularly those relating to the impact of humanity's technological enterprise.

CHEM 23212. Biochemistry Seminar
(1-0-0)
A zero-credit seminar course offered in the fall term for sophomore biochemistry majors only. The seminar seeks to acquaint the biochemistry majors with 1) the biochemistry faculty members; 2) the types of research programs in biochemistry that are being carried out in the department; and 3) some general biochemistry concepts. Each meeting will be conducted by a different member of the biochemistry faculty.

CHEM 20223. Elementary Organic Chemistry I
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
Corequisite(s): CHEM 21223
Elements and principles of organic chemistry, with emphasis on structure-reactivity relationships.

CHEM 21223. Elementary Organic Chemistry Laboratory I
(1-0-1)
Corequisite(s):CHEM 20223
Introduction to organic laboratory techniques and reactions.

CHEM 20224. Elementary Organic Chemistry II
(3-0-3)
Prerequisite(s): (CHEM 20223 or CHEM 223)
Corequisite(s):CHEM 21224
Elements and principles of organic chemistry, with emphasis on structure-reactivity relationships.

CHEM 21224. Elementary Organic Chemistry Laboratory II
(1-0-1)
Corequisite(s):CHEM 20224
Organic reactions and procedures.

CHEM 20235. Organic Chemistry M I
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
Corequisite(s): CHEM 21235
A thorough treatment of the basic principles of organic chemistry, including modern structural concepts, the effect of structure on physical and chemical properties, reactions, and their mechanisms and applications in synthesis. Intended primarily for chemistry majors.

CHEM 20247. Organic Chemistry I
(4-0-4)
Prerequisite(s): see online Course Catalog for details.
Corequisite(s): CHEM 21247
Basic principles of organic chemistry, including structure, stereochemistry, reaction mechanisms, synthesis, and reactions of important classes of organic compounds and their relationships to biochemical and biological systems. For students having an interest in chemistry as it relates to the life sciences.

CHEM 21247. Organic Chemistry Laboratory I
(1-0-1)
Corequisite(s): CHEM 20247
Introduction to organic laboratory techniques and reactions.

CHEM 20248. Organic Chemistry II
(4-0-4)
Prerequisite(s): (CHEM 20247 or CHEM 247)
Corequisite(s): CHEM 21248
Basic principles of organic chemistry, including structure, stereochemistry, reaction mechanisms, synthesis, and reactions of important classes of organic compounds and their relationships to biochemical and biological systems. For students having an interest in chemistry as it relates to the life sciences.

CHEM 21248. Organic Chemistry Laboratory II
(1-0-1)
Corequisite(s): CHEM 20248
Organic reactions and procedures.

CHEM 20283. Organic Reactions and Applications
(3-0-3)
A second semester covering the basic principles of organic chemistry, including structures, bonding, physical and chemical properties, reactive intermediates, and reaction mechanisms. Additional emphasis on applications of reactions in synthesis and relationships to biochemical systems and other associated areas of current interest. Intended primarily for chemistry and biochemistry majors.

CHEM 21283. Organic Reactions and Applications Laboratory
(0-3-1)
A laboratory to accompany CHEM 20283 that will emphasize organic techniques and synthesis.

CHEM 20284. Chemistry Across the Periodic Table
(3-0-3)
This course will extend general principles with an in-depth view of the rest of the periodic table. Topics covered include: bonding across the periodic table, chemistry of the s- and p-blocks, d-block and coordination chemistry, as well as chemical reactivity, kinetics, catalysis, and redox/electrochemistry.

CHEM 21284. Chemistry Across the Periodic Table Laboratory
(0-6-2)
Advanced integration of several techniques, including multistep organic and inorganic synthesis, measurement of properties of inorganic compounds, and studies of chemical reactivity using methods discussed in lecture.

CHEM 30321. Physical Chemistry I
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
A rigorous course in the fundamentals of physical chemistry, including chemical thermodynamics, kinetics, quantum mechanics, and the elements of atomic and molecular structure.

CHEM 31321. Physical Chemistry Laboratory I
(2-0-2)
Prerequisite(s): see online Course Catalog for details.
A course in the experimental aspects of physical chemistry using modern techniques of measurement. The first semester emphasizes thermodynamic and kinetic measurements. The second semester emphasizes spectroscopic measurements, including electronic, infrared, Raman and nuclear magnetic resonance spectroscopies, and measurements in reaction dynamics.

CHEM 30322. Physical Chemistry II
(3-0-3)
Prerequisite(s): (CHEM 30321 or CHEM 321)
For science majors only. Second semester of Physical Chemistry. A rigorous course in the fundamentals

of physical chemistry, including chemical thermodynamics, kinetics, quantum mechanics, and the elements of atomic and molecular structure.

CHEM 31322. Physical Chemistry Laboratory II
(2-0-2)
Prerequisite(s): (CHEM 31321 or CHEM 321L)
Corequisite(s): CHEM 30322
A course in the experimental aspects of physical chemistry, using modern techniques of measurement. The first semester emphasizes thermodynamic and kinetic measurements. The second semester emphasizes spectroscopic measurements, including electronic, infrared, Raman and nuclear magnetic resonance spectroscopies, and measurements in reaction dynamics.

CHEM 30324. Physical Chemistry for Engineers
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
A course in the fundamentals of physical chemistry, emphasizing theoretical and experimental aspects of reaction kinetics, an introduction to quantum theory and a critical appreciation of the nature of the chemical bond. The course also explores how spectroscopic techniques allow us to gain insight into the structure and properties of molecules.

CHEM 30331. Chemistry in Service of the Community
(1-0-1)
Prerequisite(s): Pre/Co-Req CHEM 30333 or Pre/Co-Req CHEM 333
Addressing the problem of lead contamination in the community, students will visit area homes and collect paint, dust, and soil samples. After analyzing these samples in CHEM 31333, students will help homeowners reduce the health risks associated with exposing young children to lead.

CHEM 30333. Analytical Chemistry
(2-0-2)
Prerequisite(s): see online Course Catalog for details.
Corequisite(s): CHEM 31333
Volumetric and gravimetric analysis and methods of separation integrated with instrumental analysis.

CHEM 31333. Analytical Chemistry Laboratory
(2-0-2)
Corequisite(s): CHEM 30333
A laboratory course in the techniques of analytical chemistry.

CHEM 30337. Physical Chemistry for the Life Sciences
(3-0-3)
Introduction to the fundamental principles of physical chemistry with application to modern biological problems. Emphases will include classical and statistical thermodynamics and a survey of biological spectroscopy.

CHEM 30341. Fundamentals of Biochemistry
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
Corequisite(s): CHEM 31341
This course is offered for undergraduate biochemistry majors and is generally taken in the junior year. The course covers the basic chemical and physical principles of the primary biomolecules: protein, carbohydrates, lipids and nucleic acids. The structures and properties of these molecules and their relevance to biological processes will be integrated.

CHEM 31341. Fundamentals of Biochemistry Laboratory
(2-0-2)
Corequisite(s): CHEM 30341
This course is designed to let students explore some of the many techniques that are utilized in characterizing proteins, lipids, carbohydrates and nucleic acids. It exposes students to many modern biochemical and instrumental methods for elucidating the structural and functional properties of these important types of molecules. Biochemistry majors only.

CHEM 30342. Intermediary Metabolism
(3-0-3)
Prerequisite(s): (CHEM 30341 or CHEM 341)
This course is offered for undergraduate biochemistry majors. The course is a study of the major metabolic processes involving energy storage and utilization, emphasizing the relationships between biomolecular structure and metabolic function. Throughput, regulation, and integration of pathways are presented.

CHEM 40420. Principles of Biochemistry
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
A general treatment of the various areas of modern biochemistry including protein structure and function, bioenergetics, molecular basis of genetic and developmental processes, cellular mechanisms and intermediary metabolism. Fall and spring

CHEM 40434. Physical Methods of Chemistry
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
A course in molecular structure examined through the theory and interpretation of spectra. The focus is on infrared spectroscopy, mass spectrometry, nuclear magnetic resonance spectroscopy, and X-ray crystallography, with exposure to other techniques such as two-dimensional NMR, Raman spectroscopy, optical spectroscopy, and electron spin resonance. Spring

CHEM 40443. Inorganic Chemistry
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
Group Theory, Molecular Orbital Theory, structure, and spectroscopy are used as vehicles for the introduction of molecules from inorganic, organometallic, solid state, and organic chemistry. Fall

CHEM 41443. Advanced Inorganic Chemistry Laboratory
(2-0-2)
Prerequisite(s): (CHEM 40443 or CHEM 443)
The preparation of main group inorganic, coordination and organometallic compounds, including air-sensitive manipulations and the use of vacuum-line techniques. Characterization of inorganic compounds by spectroscopic and electrochemical methods.

CHEM 46497. Directed Readings
(V-0-V)
In-depth study of topics not covered or only briefly covered in other courses. Readings, problems and reports.

CHEM 48498. Undergraduate Research
(0 V-V)
Research in collaboration with members of the faculty. A written progress report must be submitted each semester, and all participating students must make an oral presentation of their work in the spring semester of senior year.

CHEM 50531. Molecular Biology I
(3-0-3)
The first of a two-semester sequence that provides an introduction to molecular biology, molecular genetics, and nucleic acid biochemistry. Topics include: physical chemistry of nucleic acids, bacterial genetics, principles of cloning, DNA replication and recombination, prokaryotic and eukaryotic transcription, and RNA processing and translation. Listed also as BIOS 60531. (Fall)

Graduate courses in chemistry are open to qualified advanced undergraduate students, subject to the approval of the department chair. These courses are listed in the *Graduate School Bulletin of Information*.

Environmental Sciences

Director, Associate Professor of Biological Sciences:
Paul R. Grimstad

Program in Environmental Sciences. The form and function of planet Earth have been changed as a result of the activities of humans. Current concerns, such as environmental pollution and global warming, are the results of complex processes. It is now important for people in all walks of life to be aware of how we interact with the Earth and how environmental changes will affect us in the future.

The environmental sciences major is an interdisciplinary program designed to build sensitivity and breadth in environmental areas. The curriculum is designed to expose students to a scientific view of our environment from biological, chemical and geological perspectives. Particular emphasis is placed on understanding how humans interact chemically and biologically with the environment. Material and energy resource limitations, chemical and thermal pollution, and effects of environmental pollution on public health are major considerations within the environmental sciences curriculum. Emphasis is also placed on understanding interactions between human societies and the environment from social, ethical, economic, anthropological, and governmental points of view. Students are also encouraged to strengthen their mathematical and computational skills and to participate voluntarily in environmentally oriented research projects or summer internships.

The First Major. College of Science students who major in Environmental Sciences will earn the degree of bachelor of science. Students following the Environmental Sciences first major program complete a total of 69 credits of science. A second major in Environmental Science is also offered to students in the College of Arts and Letters or in the Mendoza College of Business.

The Second Major for Arts and Letters and Business: Most students in the College of Arts and Letters or in the Mendoza College of Business may participate in the Environmental Sciences Program as a second major. Second majors are required to complete a minimum of 37 credits of science. Students considering this program should investigate options brought to a first major by adding course work in environmental sciences. For example, students majoring in government and in environmental sciences could consider postgraduate study or careers in *public policy.* Students majoring in economics and in environmental sciences would have a good background for the developing field of *environmental economics.* A second major in Environmental Sciences also complements majors in the other sociological fields of anthropology, psychology, or sociology. Similarly, business students will likely find environmental sciences to be useful background when working with local or federal governments on issues of *environmental compliance* or when considering the impact of business decisions on the environment (*environmental assessment).* All students are urged to discuss their long-range career plans with advisors in both majors.

Relationship with Other Programs: The Environmental Sciences Major Program has a special collaborative relationship with the Science, Technology, and Values (STV) Concentration program housed in the Reilly Center in O'Shaughnessy Hall. Many of the courses required of environmental sciences first majors are also crosslisted as STV courses. Thus, students in the STV program from across the university are expected to benefit in the curricular endeavors of the Environmental Sciences Program. Environmental sciences first majors often enroll in the STV program. (Environmental science students with flexibility in their program may have room to complete a STV concentration by taking STV courses beyond those required by the first major or university requirements.) However, arts and letters students with second majors in environmental science will be encouraged to participate in further interdisciplinary course work through the STV concentration. Second majors are especially encouraged to take the capstone course, SC 491, Current Topics in Environmental Science, as part of the STV concentration.

Related Options: A similar bachelor's degree program, Environmental Geosciences (ENVG), is offered by the College of Engineering.

Also available through the College of Engineering is the Environmental Geosciences minor. Note, for students in ES (or SCBU, SCCO, and SCED): the College of Science will allow the course SC/ENVG 20110 to count toward both the science major and this major. Any courses taken for completion of this minor may not also be counted as science electives or science requirements for a science major.

Bachelor of Science with a Major in Environmental Sciences

All environmental sciences first majors take the following courses in science:

General Biology (BIOS 10161–10162 AND 11161–11162 or 20201–20202 and 21201–21202)[1]
General Chemistry (CHEM 10117–10118)[1]
Calculus (MATH 10350–10360 or 10550–10560)[1, 2, 3]
Physical Geology (SC 20110)
Physics (PHYS 10310–10320 or 30210–30220)
Biostatistics (BIOS 40411)
Ecology (BIOS 30312 and 31312)
Chemistry elective[4]
Current Topics in Environmental Science (SC 40491)

Students also will choose science electives chosen from an approved list,[5] completing a required minimum total of 69 credits in science.

Also required for the major are the following non-science courses:

An ethics course with emphasis on environmental biology or life science issues, i.e., **Environmental Ethics** or **Science, Technology, and Society**, or other approved arts and letters courses.[6]

Introduction to Economics (ECON 10010 or 12101)[7,8]

Students are also urged to choose their electives from a recommended list of arts and letters courses.[9]

Requirements for the program are summarized in the table in this section.

Notes:

1. Equivalent or higher-level sequences in science may be substituted, e.g., CHEM 10113–10114 or CHEM 10125–10126 for CHEM 10117–10118 or MATH 10850–10860 for MATH 10550–10560.
2. Students interested in the area of *ecological modeling* are strongly urged to take MATH 10550–10560 for their mathematics requirement. Other mathematics courses should be taken as science electives.
3. Students who have completed only six hours of mathematics in their first year may transfer into the program, but they will be required to complete a mathematics sequence equivalent to MATH 10350–10360 or MATH 10550–10560. Students having taken MATH 10250, 10110 (or 10260 or 10270) may do this by taking MATH 10360, while those who have taken only one semester of lower-level calculus should take both MATH 10350, 10360. (See also the discussion on science degree credit found later in this section of the *Bulletin.*)
4. The chemistry elective requirement is satisfied by either one first course in organic chemistry (CHEM 20223, 21223 or CHEM 20235, 21235 or CHEM 20247, 21247) or Inorganic Chemistry (CHEM 30243) or by Analytical Chemistry (CHEM 30333, 31333).
5. The following are the primary approved science electives for this program:

Botany (BIOS 30304)
Evolution (BIOS 30305)
The History of Life (BIOS 30310)
Plant Science (BIOS 30325)
Principles of Microbiology (BIOS 30401)
Animal Behavior (BIOS 30407)
Aquatic Ecology (BIOS 30420)
Stream Ecology (BIOS 60527)
Numerous other BIOS courses as designated by the ES director, including 60000-level graduate courses are accepted.
Environmental Chemistry (CHEM 20204)
Further Chemistry electives (from Note 4 above)
Second course in organic chemistry (CHEM 20224, 21224 or 20248, 21248 or 20236, 21236)
Principles of Biochemistry (CHEM 40420)
Computer Programming and Problem Solving (MATH 20210)
Calculus III (MATH 20550)
Introduction to Linear Algebra and Differential Equations (MATH 20580)
Differential Equations (MATH 30650)

Topics in Computing
Historical Geology (SC 20120)
Physical Geology (ENVG 20110)
Environmental Geosciences (SC 10100 or 20100)
Mineralogy and Optical Mineralogy (SC 20220)
Environmental Geology (SC 30111)
Sedimentation and Stratigraphy (SC 30230)
Geochemistry
Paleontology (SC 40350)

Other SC courses as approved by the ES director may be included as they become available. Select courses offered in International Studies Programs (UC-Dublin, UWA-Perth) also may be counted toward the ES science electives as well as select ENVG courses not crosslisted with SC, with permission of the ES director.

Students interested in attending graduate school in environmental sciences should consider taking science electives beyond requirements of this major. For example, for admission into some graduate programs, a year of organic chemistry would be a requirement. Deviations from the approved list of science electives must be approved by the advisor for the major.

6. For this major, the University requirement of a second philosophy or theology or other University-required course will be fulfilled by one of these courses.
7. The economics requirement for this major is fulfilled by taking Introduction to Economics (microeconomics) either in the first year (ECON 10100) or in the second through fourth years (ECON 20010). *Note, the course ECON 13181 (Social Science University Seminar) will not fulfill the economics requirement for this major.*
8. For this major, the University social science requirement will be fulfilled by the required economics course.
9. Numerous STV courses are recommended as electives, including:

Environment and Environmentalism in History (STV 30175)
Self, Society and the Environment (STV 40319)

And others as approved by the ES director. The STV courses may be taken either under the STV label or from the primary departmental crosslist.

Sample Curriculum (BS Degree Majors):

First Year

*First Semester**	
CHEM 10117. General Chemistry I	4
MATH 10350. Calculus A	4
FYC 13100	3
Theology**	3
History**	3
Physical Education/ROTC	—
	17

Second Semester	
CHEM 10118. General Chemistry II	4
MATH 10360. Calculus B	4
Fine Arts/Literature**	3
Philosophy**	3
ECON 10010 or 20010	3
Physical Education/ROTC	—
	17

Sophomore Year

First Semester	
BIOS 20201. General Biology A*	3
BIOS 21201. General Biology A Lab	1
SC 20110. Physical Geology	4
Language	3
ES Ethics req.	3
	14

Second Semester	
BIOS 20202. General Biology B*	3
BIOS 21202. General Biology B Lab	1
CHEM elective or science elective	3–4
Language	3
Elective[9]	3
	13–14

Junior Year

First Semester	
BIOS 30312, 31312 General Ecology	4
PHYS 30210. General Physics I	4
Elective (or Language)	3
Theology	3
Elective[9]	3
	17

Second Semester	
BIOS 40411. Biostatistics	4
PHYS 30220. General Physics II	4
Science Elective	3
Electives[9]	6
	17

Senior Year

First Semester	
CHEM elective or science elective	3–5
Science Elective	3–4
Science Elective	3
Electives[9]	6
	15–18

SUMMARY OF REQUIREMENTS FOR GRADUATION FOR ENVIRONMENTAL SCIENCES MAJOR

	Credits
Biological Sciences	16
Chemistry	11–13
Geology	4
Mathematics	8
Physics	8
SC 40491	3
Science Electives	17–19
Total Science	**69**
Language	Intermediate Level Competency
FYC 13100	3
Philosophy*	6
Theology*	6
History*	3
Social Science	3
Literature/Fine Arts*	3
Free Electives	22**
	124

* *One of these courses must be a University Seminar 13181*

** *Assumes intermediate-level competency in language was achieved by taking three 3-credit courses.*

Second Semester	
Science Elective	4
Science Elective	3
SC 40491	3
Electives[9]	4
	14

Ideally, students who decide to major in environmental sciences before beginning their first year should take BIOS 10161–10162. This will allow for an additional year of relevant science and other electives to be included in their total curriculum. See notes accompanying BIOS 10161–10162 and BIOS 20201–20202 for additional information.

** One of these must be a University Seminar.

Environmental Sciences As a Second Major.

Most students in the College of Arts and Letters or in the Mendoza College of Business may participate in the Environmental Sciences Program as second majors. Students who are considering the environmental sciences second major must have a first major in one of the departments of the College of Arts and Letters or the Mendoza College of Business. Because of the sizable overlap in requirements, students in the College of Arts and Letters who have a second major in preprofessional studies will not be allowed to add this second major program.

The requirements for second majors consist of the following science courses:

General Biology (BIOS 10161, 11161 and 10162, 11162 or BIOS 20201–20202 and 21201, 21201 and 21202, 21202)[1]
Ecology (BIOS 30312, 31312)
General Chemistry (CHEM 10117–10118)[1,10]
Environmental Chemistry (CHEM 20204) or approved alternative
Geology (SC 20100)
Physics[11]
Biostatistics (BIOS 40411)[12]
Biology or Geology elective (3 or 4 credits)[13]
The total required course work requires a minimum total of 37 credits in science.

Note, the same policy applies for Environmental Sciences first and second majors: All College of Science courses specified by the major program must be taken at the University of Notre Dame. (An exception is made for any science courses taken for this major through an approved Notre Dame International Studies Program.)

Notes (a continuation from above):

10. As is the case for science first majors, six credits of the science course work in this program will also be counted toward the student's university science requirement.
11. This requirement is satisfied by either one first course in physics (PHYS 10111 or 10310 or 10411 or 30210) or an approved survey course: Concepts of Energy and the Environment (PHYS 10052) or Energy and Society (PHYS 20051) and others as designated.
12. Although mathematics course work is not specifically required of this program, several required courses (BIOS 40411 or some of the first courses in physics) do have a prerequisite of one year of calculus (MATH 10350–10360 or equivalent). For all students in the College of Arts and Letters or the Mendoza College of Business, the mathematics sequence MATH 10350–10360 is acceptable for completion of the university mathematics requirement; thus, this sequence is recommended for students considering Environmental Sciences as a second major. *Students lacking this mathematics background may have to take further course work in mathematics to meet the prerequisites in mathematics of courses in this program.*
13. Chosen from approved biology or geology electives listed in note 6 above.

Sample Curriculum (Second Majors):

Students should remember that all science major programs require course work that builds upon prerequisites and thus require careful planning. A suggested curriculum for second majors is given below. *Note: Only the courses for the second major are listed.*

First Year*

First Semester	
CHEM 10117. General Chemistry I	4
Second Semester	
CHEM 10118. General Chemistry II	4

Sophomore Year

First Semester	
BIOS 20201. General Biology A	3
BIOS 21201: General Biology A Lab	1
Second Semester	
BIOS 20202. General Biology B	3
BIOS 21202: General Biology B Lab	1

Junior Year

First Semester	
SC 20110. Physical Geology	4
PHYS requirement	3/4
Second Semester	
BIOS 40411. Biostatistics	4
CHEM or SC/ENVG requirement	3

Senior Year

First Semester	
BIOS 30312, 31312. General Ecology	4
Second Semester	
BIOS or ENVG or SC elective	3–4

*MATH 10350–10360 or equivalent are **not** included in the minimum total of 37 credits in this sequence; satisfies the University math requirement.

**Students may take CHEM 20204 (Environmental Chemistry) or SC 20100 (Environmental Geosciences) or SC 30111 (Environmental Geology) or other approved CHEM, ENVG, or SC electives.

***Students whose final requirement is a three-credit class in BIOS, ENVG, or SC may take SC 40491 to complete the major with the permission of the director of the ES major.

Mathematics

Chair:
William G. Dwyer
Associate Chair:
Alex A. Himonas
Director of Graduate Studies:
Julia Knight
Director of Undergraduate Studies:
Matthew J. Gursky
William J. Hank Family Professor of Mathematics:
William G. Dwyer
Charles L. Huisking Professor of Mathematics:
Julia F. Knight
John and Margaret McAndrews Professor of Mathematics:
Francois Ledrappier
Vincent J. Duncan and Annamarie Micus Duncan Professor of Mathematics:
Andrew Sommese
Notre Dame Professor of Applied Mathematics:
Joachim J. Rosenthal
John A. Zahm, CSC, Professor of Mathematics
Stephen A. Stolz
Professors:
Mark S. Alber; Steven A. Buechler; Jianguo Cao; Peter A. Cholak; Francis X. Connolly; Leonid Faybusovich; Matthew Gursky; Alexander J. Hahn; Qing Han; Alex A. Himonas; Alan Howard (emeritus); Bei Hu; Juan Migliore; Timothy O'Meara (Kenna Professor of Mathematics, emeritus, and provost emeritus); Richard R. Otter (emeritus); Barth Pollak (emeritus); Mei-Chi Shaw; Brian Smyth; Dennis M. Snow; Nancy K. Stanton; Wilhelm Stoll (Duncan Professor of Mathematics, emeritus); Laurence R. Taylor; E. Bruce Williams; Pit-Mann Wong; Warren J. Wong (emeritus); Frederico Xavier
Associate Professors:
Mario Borelli (emeritus); John E. Derwent (emeritus); Jeffrey A. Diller; Matthew J. Dyer; Samuel R. Evens; Michael Gekhtman; Abraham Goetz (emeritus); Brian C. Hall; Xiabo Liu; Cecil B. Mast (emeritus); Gerard K. Misiolek; Liviu Nicolaescu; Claudia Polini; Sergei Starchenko; Vladeta Vuckovic (emeritus)
Assistant Professors:
Katrina D. Barron; Richard Hind; David P. Nicholls;

Program of Studies. Mathematics has had a profound effect upon civilization since ancient times, when the legend originally inscribed on the entrance to Plato's academy was "Let no one ignorant of geometry enter here." It was equally true during the medieval period, when arithmetic and geometry constituted two of the seven subjects considered essential for a liberal education. It has been said that the second most influential book in the span of Western civilization—after the Bible— is Euclid's *Elements.* Although mathematics is usually associated with science and technology in the modern mind, it seems apparent from the writings of the great mathematicians of the 17th and 18th centuries that religious belief played a great role in their pursuit of mathematics. They saw the "system of the world" obeying mathematical laws and as a consequence felt impelled to study mathematics so as to better appreciate the world's Creator.

Mathematics continues to have a profound influence in our century. From the theory of relativity, with its applications to the study of the large-scale structure of the universe, to the development of the modern computer, with its manifold applications in science, technology and business, mathematics has played a fundamental role. It is surely the most universal of all scientific tools, and the student equipped with a strong mathematical background will be in the enviable position of being able to employ his or her expertise in any area in which rigorous thought and precision of results are mandated.

The department is dedicated to the development of undergraduate studies, to the teaching of mathematics to scientists, engineers and teachers, to graduate education and research, and to the discovery of new mathematics. The entire faculty is involved with undergraduate affairs, and students have the opportunity of associating with scholars of international repute. Mathematics at Notre Dame provides students with a discipline of the mind and a stimulation of the imagination par excellence.

Programs in mathematics prepare students for graduate studies or for professional work in fields in which mathematics plays a dominant role. They provide an excellent preparation for law school, medical school, business school and secondary school teaching. Graduates may enter careers in research institutes or industrial or government positions.

In addition to its undergraduate programs, the department offers programs of graduate study leading to the degree of doctor of philosophy, as described in the Graduate School *Bulletin of Information.*

The department recognizes that, besides those students who wish to pursue a career devoted primarily to mathematical research and teaching, many will wish to take positions in business, industry or government where they will be using their mathematical skills in close collaboration with engineers as well as biological, physical and social scientists. These students will find among the listed programs one well suited to their needs. Besides these programs a student may, in consultation with the director of undergraduate studies and the department chair, create a program especially tailored to his or her career goals.

Bachelor of Science with a Major in Mathematics. The mathematics curriculum at Notre Dame includes nine course sequences or areas of concentration within the College of Science. These programs are designed to accommodate the academic and professional interests of all mathematics majors. Brief descriptions are given below, and more detailed descriptions of these programs are available on request from the Department of Mathematics.

C*ollege Requirements.* All must take the following College of Science courses: CHEM 10117, 10118; PHYS 10310, 10320; and an additional science elective.

A student who takes two semesters of organic chemistry or two semesters of general biology is only required to take PHYS 30210-30220.

Mathematics Honors Program
This program is suited to students who are interested in graduate work in one of the mathematical sciences and to those whose career plans require a strong background in modern mathematics.
Honors Calculus I (MATH 10850)
Honors Calculus II (MATH 10860)
Honors Calculus III (MATH 20850)
Honors Calculus IV (MATH 20860)
Honors Algebra I (MATH 20810)
Honors Algebra II (MATH 20820)
Honors Algebra III (MATH 30810)
Honors Algebra IV (MATH 30820)
Honors Analysis I (MATH 30850)
Honors Analysis II (MATH 30860)
Electives (12 credit hours with six at the 40000 level)

Mathematics Courses for the Other Programs
All other mathematics programs (except the computing program) require the following mathematics core courses:
Calculus I (MATH 10550)
Calculus II (MATH 10560)
Calculus III (MATH 20550)
Ordinary Differential Equations (MATH 20750)
Linear Algebra (MATH 20610)
Introduction to Abstract Math (MATH 20630)
Algebra (MATH 30710)
Real Analysis (MATH 30750)
Computer Programming (MATH 20210)

In addition to this basic sequence, the following courses are required for each program:

Mathematics Career Program
This program is designed to give students a general background in mathematics. In addition to the basic sequence of courses listed above, 12 hours of mathematics electives are required, at least three of which are at the 40000 level.

Applied Mathematics Program
This program is designed for students interested in the broader area of applied mathematics. In addition to taking the core mathematics courses, the student is required to take 15 credits from the following list of courses, six credits of which must be at the 40000 level: MATH 30210, MATH 30390, MATH 30530, MATH 30540; MATH 40210, MATH 40390, MATH 40480, MATH 40730, MATH 40750, and MATH 40710.

Mathematics and Life Sciences Program
This program is designed for mathematics majors who are interested in life-science-oriented careers. The following mathematics courses are required in addition to the basic sequence of courses listed above:

Introduction to Probability (MATH 30530)
Mathematical Statistics (MATH 30540)
Elective in Mathematics (three credit hours at the 40000 level)

The following College of Science courses are required:
Organic Chemistry (CHEM 20223, 21223; 20224, 21224)
General Biology (BIOS 20201, 21201; 20202, 21202)
Genetics (BIOS 20303, 21303)

Mathematics and Computing Program
This program is designed for students who plan to pursue graduate study or industrial careers in computing science. All of the mathematics core courses listed above except MATH 20210 are required, as well as 15 hours of mathematics electives, at least three hours of which are at the 40000 level.

In addition, the student must complete one of the following sequences of computing courses:

Software design option: CSE 20211, CSE 20212, CSE 20110, CSE 30331, CSE 30246, fourth elective
Theory option: CSE 20211, CSE 20212, CSE 20110, CSE 30331, CSE 40411, CSE 40113
Theory and compilers option: CSE 20211, CSE 20212, CSE 20110, CSE 30331, CSE 40411, CSE 40443
Computer architecture option: CSE 20211, CSE20212, CSE 20221, CSE 20321, CSE 30322, fourth elective

Mathematics Education Program
This program is designed for students who plan a career in secondary education. The following mathematics courses are required in addition to the basic sequence listed above:
Introduction to Probability (MATH 30530)
Mathematical Statistics (MATH 30540)
Elective in Geometry (three credit hours)
Elective in Mathematics (three credit hours)
(One of these classes must be at the 40000 level)
The following education courses are to be taken at Saint Mary's College: EDUC 201, 220, 340, 350, 356, 404, 451, and 475.

Mathematics and Business Administration Program
This program is designed to prepare students for a career in business or in the actuarial profession. The following mathematics courses are required in addition to the basic sequence:
Introduction to Probability (MATH 30530)
Mathematical Statistics (MATH 30540)
Introduction to Operations Research (MATH 30210)

Elective in Mathematics (three credits at the 40000 level)

Also required are ECON 20010 or its equivalent and the following courses from the College of Business: ACCT 20100, FIN 20100, MARK 20100, MGT 20200, and one course from the following list: ACCT 20200, FIN 30210, FIN 30220, FIN 30600, MGT 30610, MGT 40750, MARK 30110.

Mathematics and Engineering Science Program
This program is designed for students interested in applied or industrial mathematics. In addition to the mathematics core courses, the student is required to take one of MATH 40480, MATH 40390 or MATH 40750, and nine more credits of mathematics electives. The student must also complete one of the following two sequences of engineering classes:

Thermal option: AME 20221, AME 20222, AME 30031, AME 20231, AME 30334
Structures and design option: AME 20221, CE 20170, AME 20231, CE 30200, CE 30356

Mathematics and Social Science Program
This program is designed for students planning graduate school or a career in one of the social sciences with a strong mathematics and statistics background. In addition to the basic sequence, the following mathematics courses are required:
Introduction to Probability (MATH 30530)
Mathematical Statistics (MATH 30540)
Introduction to Operations Research (MATH 30210)
Elective in Mathematics (three credits at the 40000 level)
Moreover, the student must elect introductory courses in three of the social sciences, SOC 30902 and two courses at the 30000 or 40000 level in one of the social sciences.

Mathematics as a Second Major
Students in the Mendoza College of Business or the College of Arts and Letters may pursue a second major in mathematics by completing all mathematics courses required for the career mathematics concentration. See the list below. To list mathematics as a second major on the transcript, the student must satisfy all of the requirements for a major in some department of the Mendoza College of Business or the College of Arts and Letters.

MATH 10550–10560–20550. Calculus I-III	11.5
MATH 20750. Ordinary Differential Equations	3.5
MATH 20210. Computer Programming and Problem Solving	3
MATH 20610. Linear Algebra	3
MATH 20630. Introduction to Abstract Math	3
MATH 30710. Algebra	3
MATH 30750. Real Analysis	3
Mathematics electives	9*
Mathematics elective at the 40000 level	3*
	42 credits

* Students majoring in finance and business economics may reduce the number of mathematics electives to nine credits total by taking the following courses: MATH 30530, MATH 30540, and MATH 60850.

Sample Curriculum
(Mathematics Career Program):

First Year

First Semester

MATH 10550. Calculus I	4
CHEM 10117. General Chemistry I	4
PHYS 10310. General Physics I	4
History or Social Science[1]	3
FYC 13100	3
Physical Education or ROTC	—
	18

Second Semester

MATH 10560. Calculus II	4
CHEM 10118. General Chemistry II	4
PHYS 10320. General Physics II	4
History or Social Science[1]	3
Philosophy or Theology	3
Physical Education or ROTC	—
	18

Sophomore Year

First Semester

MATH 20610. Linear Algebra	3
MATH 20550. Calculus III	3.5
Language	3
Philosophy or Theology	3
Science Elective	3
	15.5

Second Semester

MATH 20210. Computer Programming and Problem Solving	3
MATH 20630. Introduction to Abstract Math	3
MATH 20750. Ordinary Differential Equations	3.5
Language	3
Philosophy or Theology	3
	15.5

Junior Year

First Semester

MATH 30710. Algebra	3
Mathematics elective	3
Language	3
Philosophy or Theology	3
Elective	3
	15

Second Semester

MATH 30750. Real Analysis	3
Literature or Fine Arts	3
Electives	9
	15

Senior Year

First Semester

Mathematics electives	6
Electives	9
	15

Second Semester

Mathematics elective	3
Electives	9
	12

[1] The student should take three general requirement courses during the first year, including one course that is designated a University Seminar 180. It is recommended that one course in history or social science be taken in the first year and one philosophy and one theology course be taken by the end of the sophomore year.

Mathematics Course Descriptions. The following course descriptions give the number and title of each course. Lecture hours per week, laboratory and/or tutorial hours per week, and credits each semester are in parentheses.

MATH 10005. Processes of Mathematical Thought

(3-0-3)

For students in arts and letters or business administration. A study of mathematical thought as an analytical tool to solve real-life problems. The class is divided into teams, each analyzing a topic from such areas as commercial games, consensus within diversity, governmental economic planning, and chaos theory. Teams will present their findings in a seminar format. This course satisfies one semester of the University science requirement but does not count toward the University mathematics requirement.

MATH 10015. Mathematical Way of Thinking

(3-1-3)

Topics in undergraduate mathematics.

MATH 10110. Principles of Finite Mathematics

(3-0-3)

For students in arts and letters. For first-year students who lack the necessary background for MATH 10120. (Students who take this course cannot take MATH 10120. Topics include the fundamental principles of counting systematically, probability, statistics, linear programming, optimization problems, game theory and mathematical finance, population problems, and coding information. There is a wealth of applications of these topics to contemporary social, economic, and political issues appealing to liberal arts students. Also, these topics broaden a student's mathematical horizon in an interesting direction not covered by calculus, which deals mostly with continuous models.

MATH 10120. Finite Mathematics

(3-0-3) Kelley

For students in arts and letters or as an elective for students in business administration. Topics include the fundamental principles of counting systematically, probability, statistics, linear programming, optimization problems, game theory, and mathematical finance. Other topics that may be covered include population problems, difference equations and modeling, and coding information. There is a wealth of applications of these topics to contemporary social, economic, and political issues appealing to liberal arts students. Also, these topics broaden a student's mathematical horizon in an interesting direction not covered by calculus, which deals mostly with continuous models.

SUMMARY OF REQUIREMENTS FOR THE DEGREE OF BACHELOR OF SCIENCE IN MATHEMATICS

(For other programs see the Department of Mathematics)

	Mathematics Honors Program	*Mathematics Career Program*	*Mathematics and Computing Program*	*Mathematics and Life Sciences Program*
Mathematics	46	42	42	39
Chemistry	8	8	8	16
Physics	8	8	8	8
Biological Sciences	—	—	—	12
Science Elective	3	3	3	—
Language	Intermediate Level Competency			
FYC 13100	3	3	3	3
Philosophy*	6	6	6	6
Theology*	6	6	6	6
Social Sciences*	3	3	3	3
History*	3	3	3	3
Literature/Fine Arts*	3	3	3	3
Engineering	—	—	15	—
Free Electives	26**	30**	15**	16**
	124	124	124	124

** One of these courses must be a University Seminar 180.*

*** Assumes intermediate level competency in language was achieved by taking three three-credit courses.*

MATH 10130. Beginning Logic

(3-0-3) Lippel

For students in arts and letters. Provide the students with some formal tools for analyzing arguments. By writing proofs in a formal system, students see the importance of stating the basic premises in an argument and giving intermediate steps that lead to the conclusion. They learn strategies for thinking up proofs. They see that proof checking is, in principle, something that a machine could do. Students learn truth tables and see an effective procedure that they could apply to any argument stated in propositional logic, to determine whether the conclusion follows logically from the premises. There is nothing like truth tables for predicate logic. Students get to experience doing what mathematicians do, trying to determine whether a particular conclusion follows from some premises by searching simultaneously for a proof or a counterexample. Writing papers gives students an opportunity to explore other topics in logic of their interest.

MATH 10140. Elements of Statistics

(3-0-3) Borelli

This course is aimed to those students who may or may not plan to use statistics in their chosen careers, but wish nevertheless to become informed and astute consumers. Topics include: statistical decision making, sampling, data representation, random variables, least square regression lines, elementary probability theory, conditional probabilities, independence, and Bayes' rule. The methodology will focus on a "hands-on" approach, with use of computer simulation and representation. Concepts and terminology will be introduced only after thorough exposure to situations that necessitate the concepts and terms. Care will be exercised to select a variety of situations from the many fields where statistics are used in modern society. Examples will be taken from biology and

medicine (e.g., drug testing, wild animal counts), the social sciences, psychology, and economics.

MATH 10240. Principles of Calculus
(3-0-3) Stob
For students in arts and letters. Note: Credit is not given for both this course and any other calculus course. A terminal course introducing the principles of calculus. Topics include basic properties of functions, derivatives and integrals, with interesting real-life applications throughout. This course is not intended to prepare students for more advanced work in calculus.

MATH 10250. Elements of Calculus I
(3-0-3)
For students in arts and letters, architecture, or business. A study of basic calculus as part of a liberal education. It emphasizes conceptual learning and stresses the connections between mathematics and modern society. Topics include functions, limits, derivatives, and an introduction to integral, with interesting real-life applications throughout. Students are familiarized with the many different interpretations of the derivative as a rate of change, and the integral as a total rate of change. This enables them to learn and practice modeling in a variety of situations from economics the social and the life sciences.

MATH 10260. Elements of Calculus II for Business
(3-0-3) Gekhtman, Korovnichenko, Mouktonglang
Prerequisite(s): See online Course Catalog for details.
Credit is not given for both MATH 10280 and either of the following courses: MATH 10260 and MATH 10360. For students in business. An introduction to mathematical concepts, techniques, and ideas that are useful in understanding and solving problems that arise in economics and business. Most mathematical concepts are introduced through interesting business problems. Furthermore, by using available computer technology, real-life problems, that may lead to non-trivial computations and graphics,are considered. Topics include integration, differential equations, Taylor polynomial approximations, unconstrained and constrained optimization for functions of several variables, probability and statistics, with interesting real-life applications throughout.

MATH 10270. Elementary Calculus in Action
(3-0-3)
Prerequisite(s): See online Course Catalog for details.
A second calculus course for Arts and Letters and Architecture students. This course uses typical mathematical strategies of elementary calculus and shows these "in action" with studies of the suspension bridge, various nuclear clocks, growth patterns of human and bacterial populations, the dynamics of money, and basic economics.

MATH 10350. Calculus A
(3-1-4)
Corequisite(s): MATH 12350
Primarily for students in science whose programs require a one-year terminal course in calculus of one variable but also open to students in arts and letters. Topics include sets, functions, limits, continuity, derivatives, integrals, and applications.

MATH 12350. Calculus A Tutorial
(0-1-0) *Corequisite(s)*: MATH 10350
Perfecting problem-solving skills in smaller group settings.

MATH 10360. Calculus B
(3-1-4) Kirwin, Xavier
Prerequisite(s): See online Course Catalog for details.
Corequisite(s): MATH 12360
Primarily for students in science whose programs require a one-year terminal course in calculus of one variable but also open to students in arts and letters. Topics include sets, functions, limits, continuity, derivatives, integrals, and applications.

MATH 12360. Calculus B Tutorial
(0-1-0)
Corequisite(s): MATH 10360
Perfecting problem-solving skills in smaller group settings.

MATH 10450. Honors Mathematics I
(4-0-4) Hahn
Corequisite(s): MATH 12450
A survey of several mathematical topics, emphasizing the relevance of mathematics to many diverse areas of study. Calculus is also studied at the level of MATH 10350–10360.

MATH 12450. Honors Mathematics Tutorial
(0-1-0) *Corequisite(s)*:
MATH 10450

Perfecting problem-solving skills in smaller group settings.

MATH 10460. Honors Mathematics II
(4-0-4)
Prerequisite(s): MATH 10450 or MATH 195
Corequisite(s): MATH 12460
A survey of several mathematical topics, emphasizing the relevance of mathematics to many diverse areas of study. Calculus is also studied at the level of MATH 10350–10360.

MATH 12460. Honors Mathematics II Tutorial
(0-1-0)
Corequisite(s): MATH 10460
Perfecting problem-solving skills in smaller group settings.

MATH 10550. Calculus I
(3-1-4) Han, Hu
Corequisite(s): MATH 12550
For students in science and engineering. Topics include sets, functions, limits, continuity, derivatives, integrals, and applications. Also covered are transcendental functions and their inverses, infinite sequences and series, parameterized curves in the plane, and polar coordinates.

MATH 12550. Calculus I Tutorial
(0-1-0)
Corequisite(s): MATH 10550
Perfecting problem-solving skills in smaller group settings.

MATH 10560. Calculus II
(3-1-4) Hind, Kirwin, Snow, Starchenko
Prerequisite(s): See online Course Catalog for details.
Corequisite(s): MATH 12560
For students in science and engineering. Topics include sets, functions, limits, continuity, derivatives, integrals, and applications. Also covered are transcendental functions and their inverses, infinite sequences and series, parameterized curves in the plane, and polar coordinates.

MATH 12560. Calculus II Tutorial
(0-1-0)
Corequisite(s): MATH 10560
Perfecting problem-solving skills in smaller group settings.

MATH 10850. Honors Calculus I
(4-0-4) Hu, Liu
Corequisite(s): MATH 12850
Required of honors mathematics majors. A rigorous course in differential and integral calculus of one variable. Topics include an axiomatic formulation of the real numbers, mathematical induction, infima and suprema, functions, continuity, derivatives, integrals, infinite sequences and series, transcendental functions and their inverses, and applications. The course stresses careful mathematical definitions and emphasizes the proofs of the standard theorems of the subject.

MATH 12850. Honors Calculus I Tutorial
(0-1-0)
Corequisite(s): MATH 10850
Perfecting problem-solving skills in smaller group settings.

MATH 10860. Honors Calculus II
(4-0-4)
Prerequisite(s): MATH 10850 or MATH 165
Corequisite(s): MATH 12860
Required of honors mathematics majors. A rigorous course in differential and integral calculus of one variable. Topics include an axiomatic formulation of the real numbers, mathematical induction, infima and suprema, functions, continuity, derivatives, integrals, infinite sequences and series, transcendental functions and their inverses, and applications. The course stresses careful mathematical definitions and emphasizes the proofs of the standard theorems of the subject.

MATH 12860. Honors Calculus II Tutorial
(0-1-0)
Corequisite(s): MATH 10860
Perfecting problem-solving skills in smaller group settings.

MATH 20210. Computer Programming and Problem Solving
(3-0-3) Snow
Prerequisite(s): See online Course Catalog for details.
An introduction to solving mathematical problems using computer programming in high-level languages such as C.

MATH 20340. Introduction to Statistics
(3-0-3)
Prerequisite(s): See online Course Catalog for details.
An introduction to the principles of statistical inference following a brief introduction to probability theory. This course does not count as a science or mathematics elective for mathematics majors. NOTE: Students may not take both BIOS 40411 (411) and MATH 20340 (214). Not open to students who have taken MATH 30540 (324).

MATH 20550. Calculus III
(3-1-3.5) Cao, Cholak, Harper
Prerequisite(s): See online Course Catalog for details.
Corequisite(s): MATH 22550
A comprehensive treatment of differential and integral calculus of several variables. Topics include space curves, surfaces, functions of several variables, partial derivatives, multiple integrals, line integrals, surface integrals, Stokes theorem, and applications.

MATH 22550. Calculus III Tutorial
(0-1-0)
Corequisite(s): MATH 20550
Perfecting problem-solving skills in smaller group settings.

MATH 20570. Mathematical Methods in Physics I
(3-0-3.5) Newman
Prerequisite(s): See online Course Catalog for details.
Corequisite(s): MATH 22570
A study of methods of mathematical physics. Topics include matrices, linear algebra (including matrices and determinants), vector and tensor analysis, vector calculus, curvilinear coordinates, series, ordinary differential equations, partial differential equations, orthogonal functions and vector spaces, special functions (including Bessel, Legendre, and Hermite), calculus of variations, Fourier series, and group theory. Weekly tutorial sessions. Cross-listed with PHYS 20451 (271).

MATH 22570. Mathematical Methods in Physics I
(0-1-0)
Corequisite(s): MATH 20570
Perfecting problem-solving skills in smaller group settings.

MATH 20580. Introduction to Linear Algebra and Differential Equations
(3-1-3.5) Cholak, Williams
Prerequisite(s): See online Course Catalog for details.
Corequisite(s): MATH 22580
An introduction to linear algebra and to first-and second-order differential equations. Topics include elementary matrices, LU factorization, QR factorization, the matrix of a linear transformation, change of basis, eigenvalues and eigenvectors, solving first-order differential equations and second-order linear differential equations, and initial value problems. This course is part of a two-course sequence that continues with Math 30650 (325). Credit is not given for both Math 20580 (228) and Math 20710 (221).

MATH 22580. Linear Algebra and Differential Equations Tutorial
(0-1-0)
Corequisite(s): MATH 20580
Perfecting problem-solving skills in smaller group settings.

MATH 20610. Linear Algebra
(3-0-3) Stolz
Open to all students. An introduction to vector spaces, matrices, linear transformations, inner products, determinants and eigenvalues. Emphasis is given to careful mathematical definitions and understanding the basic theorems of the subject. Credit is not given for both MATH 20710 (221) and MATH 20580 (228).

MATH 20630. Introduction to Mathematical Reasoning
(3-0-3) Diller
This course serves as a transition to upper-level math courses. The general subject is numbers of all sorts-integers, rationals, reals, etc. The main point will be to treat everything the way a mathematician would. That is, we will give precise definitions of the objects we consider and careful statements of the assertions we make about them. And, most importantly, we will justify our assertions by giving mathematical proofs. Topics covered include basic language of sets, common methods of proof, integers, factorization, modular arithmetic, rational numbers, completeness, real numbers, cardinality, limits, and continuity.

MATH 20750. Ordinary Differential Equations
(3-1-3.5)
Corequisite(s): MATH 22750
An introduction to differential equations. Topics include first-order equations, n-th order linear equations, power series methods, systems of first order linear equations, non-linear systems and stability. Credit is not given for both MATH 20750 (230) and MATH 30650 (325).

MATH 22750. Oridinary Differential Equations Tutorial
(0-1-0)
Corequisite(s): MATH 20750
Perfecting problem-solving skills in smaller group settings.

MATH 20810. Honors Algebra I
(3-0-3) Smyth
A comprehensive treatment of vector spaces, linear transformations, inner products, determinants, eigenvalues, tensor and exterior algebras, spectral decompositions of finite-dimensional symmetric operators, and canonical forms of matrices. The course stresses careful mathematical definitions and emphasizes the proofs of the standard theorems of the subject.

MATH 20820. Honors Algebra II
(3-0-3)
Prerequisite(s): MATH 20810 or MATH 261
A comprehensive treatment of vector spaces, linear transformations, inner products, determinants, eigenvalues, tensor and exterior algebras, spectral decompositions of finite-dimensional symmetric operators, and canonical forms of matrices. The course stresses careful mathematical definitions and emphasizes the proofs of the standard theorems of the subject.

MATH 20850. Honors Calculus III
(4-0-4) Connolly
Corequisite(s): MATH 22850
Required of honors mathematics majors. A rigorous course in differential and integral calculus of several variables. Topics include functions of several variables, the inverse function theorem, partial derivatives, multiple integrals, line integrals, surface integrals, Stokes' theorem, an introduction to ordinary differential equations and applications. The course stresses careful mathematical definitions and emphasizes the proofs of the standard theorems of the subject.

MATH 22850. Honor Calculus III Tutorial
(0-1-0)
Corequisite(s): MATH 20850
Perfecting problem-solving skills in smaller group settings.

MATH 20860. Honors Calculus IV
(4-0-4)
Prerequisite(s): MATH 20850 or MATH 265
Corequisite(s): MATH 22860
Required of honors mathematics majors. A rigorous course in differential and integral calculus of several variables. Topics include functions of several variables, the inverse function theorem, partial derivatives, multiple integrals, line integrals, surface integrals, Stokes' theorem, an introduction to ordinary differential equations and applications. The course stresses careful mathematical definitions and emphasizes the proofs of the standard theorems of the subject.

MATH 22860. Honors Calculus IV Tutorial
(0-1-0)
Corequisite(s): MATH 20860
Perfecting problem-solving skills in smaller group settings.

MATH 30210. Introduction to Operations Research
(3-0-3) Faybusovich
Prerequisite(s): See online Course Catalog for details.
An introduction to linear programming, duality theory, simplex algorithm, the transportation problem, network analysis, dynamic programming and game theory.

MATH 30390. Introduction to Numerical Methods
(3-0-3)
Prerequisite(s): See online Course Catalog for details.
An introduction to numerical methods for solving algebraic and differential equations. Topics include numerical solution of systems of linear equations, approximating functions with polynomials and splines, solutions of nonlinear equations, numerical integration, numerical solution of ordinary differential equations and eigenvalue problems. Some computer programming is required. Credit is not given for both MATH 30390 (318) and MATH 40390 (423).

MATH 30530. Introduction to Probability
(3-0-3) Stanton
Prerequisite(s): MATH 20850 or MATH 265
An introduction to the theory of probability, with applications to the physical sciences and engineering. Topics include discrete and continuous random variables, conditional probability and independent events, generating functions, special discrete and continuous random variables, laws of large numbers and the central limit theorem. The course emphasizes computations with the standard distributions of probability theory and classical applications of them.

MATH 30540. Mathematical Statistics
(3-0-3)
Prerequisite(s): MATH 30530 or MATH 323
An introduction to mathematical statistics. Topics include distributions involved in random sampling, estimators and their properties, confidence intervals, hypothesis testing including the goodness-of-fit test and contingency tables, the general linear model and analysis of variance.

MATH 30650. Differential Equations
(3-0-3) Karolinskiy, Shaw
Prerequisite(s): See online Course Catalog for details.
A second course in differential equations. Topics include higher order linear equations, numerical methods, Laplace transforms, linear systems, non-linear systems and stability, and an introduction to partial differential equations and Fourier series. Credit is not given for both MATH 20750 (230) and MATH 30650 (325).

MATH 30705. Algebraic Structures
(3-0-3)
Prerequisite(s): See online Course Catalog for details.
An introduction to groups, rings and fields, homomorphisms, ideals, polynomial rings and extensions fields Emphasis is given to careful mathematical definitions and understanding the basic theorems of the subject.

MATH 30710. Algebra
(3-0-3) Barron
Prerequisite(s): See online Course Catalog for details.
An introduction to groups, rings and fields. Topics include permutations, divisibility, modular arithmetic, cryptography, cyclic and dihedral groups, Lagrange's theorem, homomorphisms, ideals, integral and Euclidean domains, extension fields.

MATH 30745. Real Analysis I
(3-0-3)
Prerequisite(s): See online Course Catalog for details.
A precise treatment of fundamentals of differential and integral calculus. Topics include sequences, limits, continuity, differentiability, convergence of sequences of functions, infinite series, and the Riemann-Stieltjes integral. Emphasis is given to careful mathematical definitions and understanding the basic theorems of the subject.

MATH 30750. Real Analysis
(3-0-3) Misiolek
Prerequisite(s): MATH 20630 or MATH 223
A rigorous treatment of differential and integral calculus. Topics include a review of sequences and continuity, differentiability, Taylor's theorem, integration, the fundamental theorem of Calculus, pointwise and uniform convergence, and power series. Additional topics are likely and will depend on the instructor. Emphasis throughout will be on careful mathematical definitions and thorough understanding of basic results.

MATH 30755. Real Analysis II
(3-0-3)
Prerequisite(s): MATH 30745 or MATH 335
A precise treatment of fundamentals of differential and integral calculus. Topics include sequences, limits, continuity, differentiability, convergence of sequences of functions, infinite series, and the Riemann-Stieltjes integral. Emphasis is given to careful mathematical definitions and understanding the basic theorems of the subject.

MATH 30810. Honors Algebra III
(3-0-3) Starchenko
Prerequisite(s): MATH 20820 or MATH 262
A comprehensive treatment of groups, polynomials, rings, homomorphisms, isomorphism theorems, field theory, and Galois theory. The course stresses careful mathematical definitions and emphasizes the proofs of the standard theorems of the subject.

MATH 30820. Honors Algebra IV
(3-0-3)
Prerequisite(s): MATH 30810 or MATH 361
Required of honors mathematics majors. A comprehensive treatment of groups, polynomials, rings, homomorphisms, isomorphism theorems, field theory, and Galois theory. The course stresses careful mathematical definitions and emphasizes the proofs of the standard theorems of the subject.

MATH 30850. Honors Analysis I
(3-0-3) Nicolaescu
Prerequisite(s): MATH 20860 or MATH 266
Required of honors mathematics majors. An advanced course in mathematical analysis in one and several variables. Topics include an axiomatic formulation of the real and complex number systems, compactness, connectedness, metric spaces, limits, continuity, infinite sequences and series, differentiation, the Riemann-Stieltjes integral, the Stone-Weierstrass theorem, the implicit function theorem, differential forms, partitions of unity, simplexes and chains, and Stokes' theorem.

MATH 30860. Honors Analysis II
(3-0-3)
Prerequisite(s): MATH 30850 or MATH 365
Required of honors mathematics majors. An advanced course in mathematical analysis in one and several variables. Topics include an axiomatic formulation of the real and complex number systems, compactness, connectedness, metric spaces, limits, continuity, infinite sequences and series, differentiation, the Riemann-Stieltjes integral, the Stone-Weierstrass theorem, the implicit function theorem, differential forms, partitions of unity, simplexes and chains, and Stokes' theorem.

MATH 40210. Basic Combinatorics
(3-0-3) Smarandache
An introduction to the theory of combinatorics. Topics include permutations, multinomial coefficients, the theory of enumerative combinatorics, pairing problems, recurrence relations, the inclusion-exclusion principle, graph theory, algebraic coding theory and symbolic dynamics.

MATH 40390. Numerical Analysis
(3-0-3) Akai
Prerequisite(s): See online Course Catalog for details.
An introduction to the numerical solution of ordinary and partial differential equations. Topics include the finite difference method, projection methods, cubic splines, interpolation, numerical integration methods, analysis of numerical errors, numerical linear algebra and eigenvalue problems, and continuation methods.

MATH 40480. Complex Variables
(3-0-3)
Prerequisite(s): MATH 20850 or MATH 265
An introduction to the theory of functions of one complex variable. Topics include analytic functions, Cauchy integral theorems, power series, Laurent series, poles and residues, applications of conformal mapping, and Schwarz-Christoffel transformations.

MATH 40520. Theory of Numbers
(3-0-3)
Prerequisite(s): See online Course Catalog for details.
An introduction to elementary number theory. Topics include the Euclidean algorithm, congruencies, primitive roots and indices, quadratic residues, quadratic reciprocity, distribution of primes, and Waring's problem.

MATH 40710. Computability and Logic
(3-0-3)
Prerequisite(s): MATH 20850 or MATH 265
An introduction to formal notions of computability. Topics include finite automata, regular languages and expressions, pushdown automata, context-free grammars and languages, Turing machines, primitive recursive and ?-recursive functions, Church's Thesis, and absolutely unsolvable problems.

MATH 40720. Topics in Algebra
(3-0-3)
Prerequisite(s): See online Course Catalog for details. Topics in algebra, number theory and algebraic geometry.

MATH 40730. Topics in Applied Mathematics
(3-0-3)
Prerequisite(s): See online Course Catalog for details. Introductory course on applied mathematics methods with emphasis on modeling of physical, mechanical and biological problems in terms of differential equations and stochastic dynamical systems. Students will be working in groups on several projects and will present them in class at the end of the course.

MATH 40740. Topology
(3-0-3) Taylor
Prerequisite(s): MATH 20850 or MATH 265)An introduction to topology. Topics include the theory of surfaces, knot theory, and the theory of metric spaces.

MATH 40750. Partial Differential Equations
(3-0-3)
Prerequisite(s): See online Course Catalog for details. An introduction to partial differential equations. Topics include Fourier series, solutions of boundary value problems for the heat equation, wave equation and Laplace's equation, Fourier transforms, and applications to solving heat, wave and Laplace's equations in unbounded domains.

MATH 40760. Differential Geometry
(3-0-3) Smyth
Prerequisite(s): See online Course Catalog for details. An introduction to differential geometry. Topics include analysis of curves and surfaces in space, the first and second fundamental forms of surfaces, torsion, curvature and the Gauss-Bonnet theorem.

MATH 46800. Directed Readings
(V-0-V)
Prerequisite(s): Consent of director of undergraduate studies in mathematics.

MATH 48900. Thesis
(V-0-V)
Seniors in the mathematics program have the option of writing a senior thesis on a more advanced subject than is provided in the normal undergraduate courses. A program of readings on the topic must be begun with a faculty advisor by the spring semester of the junior year.

MATH 50510. Computer Programming/ Problem Solving
(3-0-3) Snow
An introduction to solving mathematical problems using computer programming in high-level languages such as C.

MATH 50590. Foundations of Computational Mathematics
(3-0-3)
The course is a solid theoretical introduction to numerical analysis. Topics covered include polynomial interpolation, least squares, numerical integration, numerical linear algebra, and an introduction to numerical solutions of ordinary and partial differential equations.

MATH 50730. Mathematical Modeling
(3-0-3)
Introductory course on applied mathematics methods with emphasis on modeling of physical, mechanical, and biological problems in terms of differential equations and stochastic dynamical systems. Students will be working in groups on several projects and will present them in class at the end of the course.

MATH 56800. Directed Readings
(V-0-V)
Readings not covered in the curriculum that relate to the student's area of interest.

MATH 60550. Topics in Graduate Mathematics
(20-0-0)
This course will introduce students to the "metamathematical" branch of proof theory, which is a descendent of Hilbert's program. We will consider some "low-level" syntactic tools that are used to study formal theories, including cut-elimination, double-negation translations, realizability, and the Dialectica interpretation. Then we will apply these tools to various theories of arithmetic to demonstrate what can be learned from a proof-theoretic analysis. The goal of the course will be to provide an introduction to the fundamental methods of proof theory that will make the general literature more accessible, and to convey a sense of contemporary research.

Certain graduate courses in mathematics are open to qualified advanced undergraduates, subject to the approval of the director of undergraduate studies. Other graduate courses are described in the *Graduate School Bulletin of Information.*

Physics

Chair:
Ani Aprahamian
Director of Graduate Studies:
Kathie E. Newman
Director of Undergraduate Studies:
Margaret Dobrowolska-Furdyna
Frank M. Freimann Professor of Physics:
Walter R. Johnson
Frank M. Freimann Professor of Physics:
Michael C.F. Wiescher
Emil T. Hofman Professor of Physics:
Albert-Laszlo Barabasi
Aurora and Tom Marquez Professor of Physics:
Jacek K. Furdyna
Grace-Rupley II Professor of Physics:
Ikaros I. Bigi
Professors:
Ani Aprahamian; Gerald B. Arnold; H. Gordon Berry; Howard A. Blackstead; Samir K. Bose (emeritus); Cornelius P. Browne (emeritus); Bruce A. Bunker; Neal M. Cason; Paul R. Chagnon (emeritus); Sperry E. Darden (emeritus); Margaret Dobrowolska-Furdyna; Stefan G. Frauendorf; Emerson G. Funk (emeritus); Umesh Garg; Anthony K. Hyder; Gerald L. Jones; V. Paul Kenney (emeritus); James J. Kolata; A. Eugene Livingston; John M. LoSecco; Eugene R. Marshalek (emeritus); Grant Mathews; William D. McGlinn (emeritus); James Merz; John W. Mihelich (emeritus); Kathie E. Newman; John A. Poirier (emeritus); Terrence W. Rettig; Randal C. Ruchti; Steven T. Ruggiero; Jonathan R. Sapirstein; William D. Shephard (emeritus); Walter J. Tomasch (emeritus); Mitchell R. Wayne
Associate Professors:
Peter M. Garnavich; Boldizsar Jankó; Colin Jessop; Christopher F. Kolda; Paul E. Shanley (emeritus); Carol E. Tanner
Assistant Professors:
Dinshaw Balsara; Philippe Collon; Morten Eskildsen; J. Christopher Houk; Anna Goussiou; Michael D. Hildreth

Program of Studies. Physics is the study and the description of the structure and the behavior of the physical universe. As such, it is fundamental to all physical sciences, pure and applied. A knowledge of physics is basic to an understanding of astronomy, chemistry, geology and even biology in that physics contributes to the interpretation and detailed description of many of the natural phenomena which constitute the proper subjects of investigation in these sciences.

In addition to the undergraduate curricula, the Department of Physics offers programs for graduate study leading to the degrees of master of science and doctor of philosophy, as described in the *Graduate School Bulletin of Information.*

Bachelor of Science with a Major in Physics.
The physics curriculum at Notre Dame consists of five course sequences or programs. These programs are designed to accommodate the academic and professional interests of the majority of physics majors. Students with alternative interests are encouraged to discuss special programs with the departmental chair.

All physics majors take the following basic sequence of courses:
General Physics (PHYS 10411, 11411, 10422, 11422, 20431, 21431))
Intermediate Classical Mechanics (PHYS 20454)
Mathematical Methods in Physics (PHYS 20451, 22451, 20452, 22452)
Sophomore Seminar (PHYS 23411)
Modern Physics (PHYS 20464, 30465)
Electricity and Magnetism (PHYS 30471)
Junior Seminar (PHYS 33411)
Modern Physics Lab I (PHYS 40441, 41441)
Senior Seminar (PHYS 43411)
General Chemistry (CHEM 10117, 10118)
Mathematics (MATH 10550, 10560, 20550, or MATH 10850, 10860, 20850, and 20860)
Physics or Mathematics three-credit elective (as defined below)

In addition to the basic sequence of courses, the following courses are required for each program.

Career Program
The Career Program is designed for students who intend to do graduate work in physics or in astronomy, or who intend to seek employment as professional physicists at the bachelor level.

In addition to the physics core courses, majors in the career program are required to complete the additional following courses:
Thermal Physics (PHYS 30461)
Electromagnetic Waves (PHYS 30472)
Modern Physics Lab II (PHYS 40442, 41442)
Quantum Mechanics I (PHYS 40453)

The other physics or mathematics three-credit elective is selected with the advisor's consent from the following: MATH 40480, and physics courses numbered 30432, 31432, 30405, 40454, 50472, 50445. Students are strongly encouraged to follow the sample curriculum that follows.

(The required physics or mathematics three-credit elective for the other physics programs is to be selected with the advisor's consent from the additional required courses for physics career majors or from the physics and mathematics three-credit elective list for the Physics Career Program.)

Physics-in-Medicine Program
Students in this program may prepare for professional schools in medicine, medical physics, biophysics, etc., with appropriate selection of electives.

In addition to the physics core courses, majors in physics-in-medicine must complete the following courses, which total 19 credit hours.
General Biology A and B (BIOS 20201, 21201, and 20202, 21202)
Genetics (BIOS 20303)
Organic Chemistry I and II (CHEM 20223, 21223, 20224, and 21224)
Thermal Physics is a recommended elective for this program. Additional electives recommended to augment this program are BIOS 30344, Cell Biology; BIOS 30341, Physiology; CHEM 40420, Biochemistry; and PHYS 40371, Medical Physics.

Physics and Computing Program
Students interested in concentrating in computer science while obtaining a major in physics may choose the Physics and Computing Program. In addition to the physics core courses, these students will complete at least 15 credit hours in the Department of Computer Science and Engineering. Students may choose from among four standard course sequences or alternatively may, with the consent of their advisor and the chair of the CSE department, arrange an individualized course sequence. Physics 30405, Numerical Methods, is a recommended physics elective for students in this program.

Applied Physics Program
In addition to the physics core courses, the Applied Physics Program requires at least 15 additional credits, to be selected with the advisor's approval from the following. These may include any of the physics and mathematics elective courses listed above and any courses offered by the Department of Electrical Engineering that deal with electrical properties of materials. Classes include, but are not restricted to, Electrophysics I and II (EE 30347 and 30357), Electronic Transport Theory (EE 466) and Electronic Properties of Materials (EE 476).

Physics Education Program
In addition to the physics core courses, majors in the Physics Education Program must complete the following courses, which total 33 credit hours.

(Education courses are offered at Saint Mary's College):
EDUC 201F: Teaching in a Multicultural Society
EDUC 220. Applied Media and Instructional Technology
EDUC 340. Curriculum and General Methods for Secondary School Teaching
EDUC 350. Educational Psychology: Human Growth and Development of the Adolescent
EDUC 356. Educational Psychology: Educating Exceptional Leaders
EDUC 404. Reading in the Content Area
EDUC 449. Teaching Science in the Secondary School
EDUC 475. Student Teaching in the Secondary School (spring of senior year)

Furthermore, majors in the physics education program must complete a minimum of four additional credits selected, with the advisor's approval, from courses offered in the College of Science, outside the departments of physics and mathematics or in geological sciences.

Physics As a Second Major
The requirement for physics as a second major, for students in the colleges of engineering, arts and letters or business, consists of the physics core courses listed above, except General Chemistry. To list physics as a second major on the transcript, the student must satisfy all of the requirements for a major in some other department and college of the University.
Sample Curriculum (Career Program):

First Year

First Semester	
FYC 13100	3
MATH 10550	4
PHYS 10411, 11411	4
History or Social Science[1]	3
CHEM 10117	4
Physical Education or ROTC	0
	18

Second Semester	
Philosophy or Theology[1]	3
MATH 10560	4
PHYS 20431, 21431	4
History or Social Science[1]	3
CHEM 10118	4
Physical Education or ROTC	0
	18

Sophomore Year

First Semester	
PHYS 10422, 11422	4
MATH 20550	3.5
PHYS 20451, 22451	3.5
PHYS 23411	1
Language	3
Philosophy or Theology	3
	18

Second Semester	
PHYS 20454	3
PHYS 20464	4
PHYS 20452, 22452	3.5
Language	3
Philosophy or Theology	3
	16.5

Junior Year

First Semester	
PHYS 30461	3
PHYS 30471	3
PHYS 40453	4
PHYS 33411	1
Language	3
	14

Second Semester	
PHYS 30432	3
PHYS 30405	3
PHYS 30472	3
MATH 40480	3
Literature or Fine Arts	3
	15

Senior Year

First Semester	
PHYS 50445	3
PHYS 40441, 41441	3
PHYS 43411	1
PHYS 30465	3
Elective	3
Philosophy or Theology	3
	16
Second Semester	
PHYS 40442, 41442	3
PHYS 50472	3
PHYS 40454	3
Electives	6
	15

[1] *The student should take three general requirement courses during the first year, including one course that is designated a University Seminar.*

Physics Course Descriptions. The following course descriptions give the number and title of each course. Lecture hours per week, laboratory and/or tutorial hours per week, and credits each semester are in parentheses.

PHYS 08699. Directed Research: Particle Physics

(V-0-V)

Directed Research course for high school students combining coverage of topics in particle physics with participation in experimental research in ongoing experiments conducted by particle physics faculty. Students maintain a research logbook and submit a written research summary at the conclusion of the research period.

PHYS 08798. Directed Research in Nucleaer Astrophysics

(V-0-V)

Directed Research course for high school students combining coverage of topics in nuclear astrophysics with participation in experimental research in ongoing experiments conducted by nuclear astrophysics faculty. Students maintain a research logbook and submit a written research summary at the conclusion of the research period.

PHYS 10011. Concepts of Physics I

(3-0-3)

This course is intended for students who will not be majoring in science or in engineering. A study of some of the major concepts and laws of classical and modern physics, in some historical context, provides the student with a foundation for understanding, at a conceptual level, the natural phenomena and technological devices encountered in everyday experience. PHYS 10011 will include a study of motion and Newton's laws, momentum and energy, the structure of matter, thermodynamics, and relativity. This course fulfills the University science requirement.

PHYS 10022. Concepts of Physics II

(3-0-3)

This course is intended for students who will not be majoring in science or in engineering. A study of some of the major concepts and laws of classical and modern physics, in some historical context, provides the student with a foundation for understanding, at a conceptual level, the natural phenomena and technological devices encountered in everyday experience. PHYS 10022 will cover wave motion, electromagnetism, light, and the quantum nature of the atomic and subatomic world. PHYS 10011 is not a prerequisite for PHYS 10022. This course fulfills the University science requirement.

PHYS 10052. Concepts of Energy and the Environment

(3-0-3)

A course developing the basic ideas of energy and power and their applications. The fossil fuels are considered together with their limitations, particularly as related to global warming, pollution, and their nonrenewable character. The advantages and disadvantages of nuclear power are studied and compared with alternative energy sources such as solar energy, wind, and geothermal and hydroelectric power. Various aspects of energy storage and energy conservation are also considered. This course is designed for the non-specialist. It is open to first-year students only. It satisfies one semester of the University science requirement, but PHYS 10052 and PHYS 20051 may not both be counted toward that requirement.

PHYS 10062. Science Literacy

(3-0-3)

A course emphasizing science literacy that provides the tools for a basic understanding of scientific developments and their potential consequences. Developments in many areas of science will be discussed, including biology, chemistry, physics, astronomy, engineering, and computer science, with the view that basic physical laws serves as a common thread between them. Topics covered include the mechanisms of scientific discovery, the impact of scientific discoveries on society, science and ethics, and the tools of contemporary science. The course focuses on concepts rather than formulas and concentrates primarily on examples taken from current scientific developments. This course satisfies one semester of the University science requirement. If taken by science or engineering students, this course counts as a general elective.

PHYS 10111. Principles of Physics I

(3-0-3) Livingston

PHYS 10111 is a prerequisite to PHYS 10122. A course intended for students who desire a grounding in all the major principles of physics but who plan to major in some area other than science or engineering. The ability to apply these principles to the solution of problems is a major goal of the course. The following topics are normally included; kinematics and dynamics of a particle, work, energy, momentum, harmonic motion, gravitation, and circular orbits; wave motion, interference, standing waves, the Doppler effect; and temperature, heat, first law of thermodynamics, and kinetic theory of gases. Additional material will be at the discretion of the instructor. The division between PHYS 10111 and 10122 will depend on the order of presentation. This course fulfills the University science requirement.

PHYS 10122. Principles of Physics II

(3-0-3)

Prerequisite(s): (PHYS 10111 or PHYS 115)

PHYS 10111 is a prerequisite to PHYS 10122. A course intended for students who desire a grounding in all the major principles of physics but who plan to major in some area other than science or engineering. The ability to apply these principles to the solution of problems is a major goal of the course. The following topics are normally included; electric charge, Coulomb's law, electric field and potential, current, resistance, and DC circuits; magnetic force, and electromagnetic induction; the nature of light, the spectrum; photons, photoelectric effect, Compton scattering, deBroglie waves, energy levels, X-rays; nuclei and radioactivity; and special relativity. Additional material will be at the discretion of the instructor. The division between PHYS 10111 and 10122 will depend on the order of presentation. This course fulfills the University science requirement.

PHYS 10140. Descriptive Astronomy

(3-0-3) Mathews

A description of the motions and structure of the earth, moon, and planets; an exposition of the modern theories of solar and stellar structure, nebulae, and galaxies; basics of stellar evolution, black holes, quasars, and other recent developments; an introduction to cosmology. This course includes elementary observational projects. The course fulfills one semester of the University science requirement.

PHYS 10240. Elementary Cosmology

(3-0-3) Rettig

An elective course for students planning to major in the arts and letters or business. It is designed to acquaint the non-mathematically inclined student with the most important discoveries in physics of the last few decades and how they have altered our perceptions of the origin and structure of the universe. This course examines such questions as: "Where did the universe come from?" "Why do scientists feel sure that it was born in a cosmic fireball called the Big Bang?" and "Where did the Big Bang itself come from?" This is a reading-intensive course based on popularizations of science written for the curious and intelligent layperson. The emphasis will be on class discussion of the readings. One book report and a term paper are required in addition to examinations. This course satisfies one semester of the University science requirement. If taken by science students, this course counts as general elective credit.

PHYS 10262. Physical Methods in Art and Archaeology

(3-0-3)

A course that gives an overview of the various physics-based analysis and dating techniques used in art and archaeology. The course will cover topics such

as X-ray fluorescence and X-ray absorption, proton-induced X-ray emission, neutron-induced activation analysis, radiocarbon dating, accelerator mass spectroscopy, luminescence dating, and methods of archeometry. Multiple examples of the use of the techniques in art and archaeology will be given, e.g., under X-ray techniques and accelerator mass spectrometry, the analysis of ancient coins and violin varnish and the Iceman and the Turin Shroud are used respectively as examples. Physics principles of the methods and techniques will be taught in a descriptive manner. This course is intended for students in arts and letters or business and satisfies one semester of the University science requirement. If taken by science or engineering students, this course counts as a general elective credit.

PHYS 10310. General Physics I-M

(4-0-4) Ruggiero
Prerequisite(s): see online Course Catalog for details.
Corequisite(s): PHYS 11310 PHYS 12310
The first course in a two-semester sequence in general physics. Topics include the kinematics and mechanics of a particle; work, energy and momentum, and associated conservation laws; rotation, torque and angular momentum; oscillations and wave motions. A course designed for students of science and engineering. Laboratory meetings in alternating weeks only. Weekly tutorial sessions.

PHYS 11310. General Physics I Laboratory

(0-1-0)
Corequisite(s): PHYS 10310 PHYS 12310
The laboratory is a corequisite for PHYS 10310

PHYS 12310. General Physics I Tutorial

(0-1-0)
Corequisite(s): PHYS 10310 PHYS 11310
The tutorial is a corequisite for PHYS 10310

PHYS 10320. General Physics II-M

(4-0-4) Balsara, Jessop
Prerequisite(s): see online Course Catalog for details.
Corequisite(s): PHYS 11320 PHYS 12320
The second course in a two-semester sequence in general physics. Topics include electro-statics, electric current, and circuits; magnetism, electromagnetic induction, and waves; and geometrical optics. A course designed for students of science and engineering. Laboratory meetings in alternating weeks only. Weekly tutorial sessions.

PHYS 11320. General Physics II Laboratory

(0-1-0)
Prerequisite(s): see online Course Catalog for details.
Corequisite(s): PHYS 10320 PHYS 12320
The laboratory is a corequisite for PHYS 10320

PHYS 12320. General Physics II Tutorial

(0-1-0)
Corequisite(s): PHYS 10320 PHYS 11320
The tutorial is a corequisite for PHYS 10320

PHYS 10342. Modern Physics from Quarks to Quasars

(3-0-3)
Restricted to first-year Arts and Letters intents in the Honors Program. This course emphasizes themes of modern physics and will be organized around the concepts of symmetry and physical laws. For example, how do symmetries observed in nature lead to fundamental laws of conservation of energy and momentum? Examples from areas of modern physics such as cosmology and astrophysics are used to bring these topics to life. We consider questions such as: "What happens if one travels alongside a beam of light?" (which leads us into special relativity); "Why is the night sky so dark?" (the Big Bang); "What is matter?"; "What is mass"; "What are forces?" The course is a mix of lecture, discussions, and lab/demonstrations.

PHYS 17372. Topics in Biophysics

(3-0-3)
This course provides an overview of how the laws of physics can be used to explain biological systems and of the physical principles that underlie modern imaging techniques (MRI, CAT, etc.). Examples to be discussed include bioelectrical processes, e.g., the heart, transport across cell membranes, and electrosensing by eels. Vision, hearing, blood circulation, and respiration are explained as biophysical processes. The course presents principles in a descriptive manner; no previous formal study of biology is required or assumed. For students majoring in the College of Arts and Letters or the Mendoza College of Business, this course satisfies one semester of the University science requirement. For other students, this course counts as a general elective.

PHYS 10411. General Physics I-M

(4-0-4) Garg
Prerequisite(s): see online Course Catalog for details.
Corequisite(s): PHYS 11411
The first semester of a three-semester sequence in general physics. Topics include the kinematics and mechanics of a particle; work, energy, and momentum, and associated conservation laws; rotation, torque, and angular momentum; oscillations and wave motions. A course designed for students intending to enter the Department of Physics. Laboratory meetings each week.

PHYS 11411. General Physics I-M Laboratory

(0-2-0)
Corequisite(s): PHYS 10411
The laboratory is a corequisite for PHYS 10411

PHYS 10422. General Physics II-M

(4-0-4)
Prerequisite(s): (PHYS 10411 or PHYS 151)
Corequisite(s): PHYS 11422
The second semester of a three-semester sequence in general physics. Topics include the kinematics and mechanics of a particle; work, energy and momentum, and associated conservation laws; rotation, torque and angular momentum; oscillations and wave motions; electrostatics, electric current and circuits; magnetism, electromagnetic induction and waves; geometrical optics. A course designed for students intending to enter the Department of Physics. Laboratory meetings each week.

PHYS 11422. General Physics II-M Lab

(0-2-0)
Corequisite(s): PHYS 10422
The laboratory is a corequisite for PHYS 10422

PHYS 20051. Energy and Society

(3-0-3) Dobrowolska-Furdyna
A course developing the basic ideas of energy and power and their applications from a quantitative and qualitative viewpoint. The fossil fuels (coal, oil, natural gas) are studied together with their societal limitations (pollution, global warming, diminishing supply). Nuclear power is similarly studied in the context of the societal concerns that arise (radiation, reactor accidents, nuclear weapons proliferation, high-level waste disposal). The opportunities as well as the risks presented by alternative energy resources, in particular solar energy, wind, geothermal, and hydropower, together with various aspects of energy conservation, are developed and discussed. This course is designed for the non-specialist and satisfies one semester of the University science requirement.

PHYS 20061. Nuclear Warfare

(3-0-3) Wiescher
Nuclear phenomena; nuclear fission and fusion. Nuclear weapons. Effects of blast, shock, thermal radiation, prompt and delayed nuclear radiation. Fire, fallout, ozone-layer depletion, electromagnetic pulse, "nuclear winter." Medical consequences, physical damage, effects on the individual and on society. Defensive measures and their feasibility. Scenarios for war and peace, proliferation of nuclear weapons material, recent diplomatic history. US Bishops' Pastoral Letter. The course is open to all students and counts for science majors as a general elective credit.

PHYS 20140. Descriptive Astronomy

(3-0-3) Mathews
A description of the motions and structure of the Earth, moon, and planets. An exposition of the modern theories of solar and stellar structure, nebulae, and galaxies. Basics of stellar evolution, black holes, quasars, and other recent developments. An introduction to cosmology. This course includes elementary observational projects. The course fulfills one semester of the University science requirement.

PHYS 20230. Elements of Modern Physics

(1-0-1)
Prerequisite(s): see online Course Catalog for details.
Corequisite(s): PHYS 21230
A laboratory course stressing experiments in atomic, nuclear, and solid state physics.

PHYS 21230. Modrn Physic Laboratory

(0-4-2)
Corequisite(s): PHYS 20230
The laboratory is a corequisite for PHYS 20230

SUMMARY OF REQUIREMENTS FOR THE DEGREE OF BACHELOR OF SCIENCE IN PHYSICS

	Career Program	*Applied Physics*	*Physics and Computing*	*Physics in Medicine*	*Physics Education*
Mathematics	11.5–14.5	11.5–14.5	11.5–14.5	11.5–14.5	11.5–14.5
Physics	51–54	36–51*	39–42*	39–42*	39–42*
Chemistry	8	8	8	16	8
Biology	—	—	—	11	4**
Language	Intermediate Level				
FYC 13100	3	3	3	3	3
Philosophy+	6	6	6	6	6
Theology+	6	6	6	6	6
History+	3	3	3	3	3
Social Sciences+	3	3	3	3	3
Literature/Fine Arts+	3	3	3	3	3
Education	—	—	—	—	33
Computing Science	—	—	15	—	—
Electrical Engineering	—	3–15	—	—	—
Free Electives	17.5++	17.5++*	14.5++*	10.5++	0++
	124	124	124	124	131.5

* *Students must take a minimum of 60 credit hours in science.*

** *Or any science other than mathematics or physics.*

\+ *One of these courses must be a University Seminar.*

++ *Assumes intermediate-level competency in language was achieved by taking three three-credit courses.*

PHYS 20290. General Physic III
(3-0-3)
Corequisite(s): PHYS 21290
A third-semester in general physics

PHYS 21290. General Physics III Laboratory
(0-1-0.5)
Corequisite(s): PHYS 20290
The laboratory is a corequisite for PHYS 20290

PHYS 20330. General Physics III
(3.5-0-3.5) Wayne
Prerequisite(s): see online Course Catalog for details.
Corequisite(s): PHYS 21330
A third semester in general physics. Topics include (1) interference and diffraction; (2) quanta and the wave-particle duality; (3) introduction to quantum mechanics; (4) atomic, nuclear, and particle physics; (5) physics of the solid state; and (6) astrophysics and cosmology. A course designed for students of science and engineering. Laboratory meetings in alternating weeks only.

PHYS 21330. General Physics III Laboratory
(0-1-0)
Corequisite(s): PHYS 20330
The laboratory is a corequisite for PHYS 20330

PHYS 23411. Sophomore Seminar
(1-0-1) Kolda
A discussion of current topics in physics by staff members.

PHYS 20421. Scientific Programming
(3-0-3)
Prerequisite(s): (PHYS 10422 or PHYS 152)
The principal goal of this course is to develop a good level of competence and experience in the use of computers as a tool for scientific studies. The course is intended primarily for physics majors. Topics covered will include (1) the FORTRAN language; (2) graphical presentation of results including user-written programs and graphics packages; (3) the use of scientific libraries of sub-routines; (4) the use of other scientific programs such as algebraic manipulators; and (5) the use of spreadsheets for problem solving, etc. Course work will include the use of high-end UNIX workstations.

PHYS 20431. General Physics III-M
(4-0-4) Collon
Prerequisite(s): see online Course Catalog for details.
Corequisite(s): PHYS 21431
The third semester of a three-semester course in general physics. Topics include classical thermodynamics, fluids, and acoustics; interference and diffraction; special and general relativity; introduction to quantum physics. The course is intended primarily for sophomore physics majors but is open to other qualified students. Laboratory meetings each weeks.

PHYS 21431. General Physics III-M Lab
(0-2-0)
Corequisite(s): PHYS 20431
The laboratory is a co-requisite for PHYS 20431

PHYS 20451. Mathematical Methods in Phys I
(3.5-0-3.5)
Newman

A study of methods of mathematical physics. Topics include matrices, linear algebra (including matrices and determinants), vector and tensor analysis, vector calculus, curvilinear coordinates, series, ordinary differential equations, partial differential equations, orthogonal functions and vector spaces, special functions (including Bessel, Legendre, and Hermite), calculus of variations, Fourier series, and group theory. Weekly tutorial sessions.

PHYS 22451. Mathematical Methods in Phys I
(0-1-0)
The tutorial is a corequisite for PHYS 20451

PHYS 20455. Mechanics I
(3-0-3)
Prerequisite(s): (PHYS 10422 or PHYS 152)
Newtonian mechanics of a particle in one, two, and three dimensions; oscillations; non-inertial reference frames; gravitation; central forces; systems of particles; kinematics and dynamics of rigid body motion; Lagrangious, Hamilton's equations.

PHYS 20458. Mechanics II
(3-0-3)
Prerequisite(s): (PHYS 20455 or PHYS 250)
Conservation laws for systems of particles; coupled oscillations; rotating coordinate systems; one-dimensional wave motion; gravitation; kinematics and dynamics of rigid body motion; Lagrange's equations.

PHYS 20464. Modern Physics I
(4-0-4)
Prerequisite(s): see online Course Catalog for details.
Special relativity, foundations of quantum concepts. Properties of atoms. Interactions of electromagnetic fields with atoms. Wave mechanics and the Schroedinger equation. Atomic structure and atomic spectra. Atomic wave functions. Fine structure and Zeeman effect. Multiplet analysis. Exclusion principle, periodic table and spectra of multielectron atoms.

Introduction to the statistical physics of quantum mechanical systems.

PHYS 30210. Physics I
(3-2-4) Howk, Sun
Prerequisite(s): see online Course Catalog for details.
Corequisite(s): PHYS 31210
The basic principles of mechanics, fluid mechanics, thermal physics, wave motion, and sound. Primarily for students in the life sciences. Laboratory meetings each week.

PHYS 31210. Physics I Laboratory
(0-0-0)
Corequisite(s): PHYS 30210
The laboratory is a corequisite for PHYS 30210

PHYS 30220. Physics II
(4-0-4) Tanner
Corequisite(s): PHYS 31220
The basic principles of electricity, magnetism, optics, and modern physics. Primarily for students in the life sciences. Laboratory meetings each week.

PHYS 31220. Physics II Laboratory
(0-2-0)
Corequisite(s): PHYS 30220
The laboratory is a corequisite for PHYS 30220

PHYS 37341. Topics in Astronomy and Astrophysics
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
This course is designed to provide undergraduate science and engineering majors in any department a fundamental background in current topics of astronomy and astrophysics. Astronomy is a science that uses physics to interpret astronomical events. This field is rapidly developing. Each year brings an increased number of significant and exciting discoveries based on data from a variety of spacecraft, rockets, balloons, and a whole new technology of ground-based observatories and detectors. The course will provide quantitative insights into astrophysical topics of interest such as the structure and evolution of stars, the dynamics of cosmic gases, nucleosynthesis, black holes, galaxy formation, cosmology, the missing mass problem, the size and mass of cosmic objects, the large-scale behavior of the universe, quasars, evolution of the solar system, and the search for planetary systems around other stars. Each topic will be developed and evaluated along with the most recent work in these areas. This is an approved science elective.

PHYS 30389. Philosophical Issues in Physics
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
This course is intended for non-science students who desire to begin an examination of the origins of the modern laws of physics and for science students who wish to know the actual route to the discovery and the broader implications of the formal theories with which they are already familiar. The historical background to and philosophical questions associated with major laws of physics will be discussed, in large measure by examining directly relevant excerpts from the writings of some of the creators of seminal concepts and theories in physics. The latter part of the course will concentrate on historical and philosophical issues related to relativity and especially to quantum theory and its interpretation. This course is accepted as a science elective in the College of Science.

PHYS 30405. Numerical Methods
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
Elements of numerical analysis: functional equations, polynomial approximations, numerical differentiation, numerical integration. Numerical solution of differential equations: first-order equations, initial value determination, applications to mechanics and electricity, and eigenvalue problems for second-order linear differential equations. Elementary methods for solving partial differential equations: relaxation methods, variational methods. This course is intended primarily for physics majors but is open to students from other departments who have adequate backgrounds in mathematics and physics.

PHYS 33411. Junior Seminar
(1-0-1) Aprahamian
A discussion of current topics in physics by staff members.

PHYS 30432. Lasers and Modern Optics
(2-0-2)
Corequisite(s): PHYS 31432
Principles and practical aspects of laser operation and applications in modern optics. Propagation of plane electromagnetic waves. Diffraction and interference of light. Gaussian beam propagation and optical resonators. Theory of laser oscillation. Gas, solid, semiconductor, and dye lasers. Detectors of optical radiation. Nonlinear optics. Applications in research and industry. Laboratory exercises include polarization, interference, Fourier optics, holography, gas, diode and turnable lasers, and harmonic generation. A course primarily intended for physics majors.

PHYS 31432. Lasers and Modern Optics
(0-3-1)
Corequisite(s): PHYS 30432
Principles and practical aspects of laser operation and applications in modern optics. Propagation of plane electromagnetic waves. Diffraction and interference of light. Gaussian beam propagation and optical resonators. Theory of laser oscillation. Gas, solid, semiconductor, and dye lasers. Detectors of optical radiation. Nonlinear optics. Applications in research and industry. Laboratory exercises include polarization, interference, Fourier optics, holography, gas, diode and turnable lasers, and harmonic generation. A course primarily intended for physics majors.

PHYS 30461. Thermal Physics
(3-0-3) Bunker
Prerequisite(s): see online Course Catalog for details.
Physical thermodynamics, kinetic theory, and an introduction to statistical mechanics.

PHYS 30465. Modern Physics II
(4-0-4)
Prerequisite(s): (PHYS 20464 or PHYS 260)
A continuation of Modern Physics I. Topics in quantum physics. Molecular bonding and spin valence. Molecular spectra. Bonding, energy levels and band structure in solids. Ionic crystals, metals and semiconductors. Thermal, electric, magnetic and optical properties of solids. Quantum numbers of particles, basic forces, the particle zoo. Stable nuclei, nuclear structure and models, nuclear decay and reactions, energy levels, fission, fusion. Particle scattering. Production, detection and properties of elementary particles.

PHYS 30471. Electricity and Magnetism
(3-0-3) Frauendorf
Prerequisite(s): see online Course Catalog for details.
Electro-and magnetostatics. Laplace's and Poisson's equations. Boundary value problems. Multipole fields. Dielectric and magnetic phenomena. Maxwell's equations.

PHYS 30472. Relativity: Special and General
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
An introduction to relativity, both special and general. Special relativity: Lorentz transformations of events, geometry of space-time, relativistic kinetics, Lorenz transformation of electromagnetic fields. General relativity: gravity and light, principle of general covariance, Einstein's field equation, Schwarzchild solution, precession of perihelions of planets, deflection of light, black holes.

PHYS 40371. Medical Physics
(3-0-3) Garnavich
Prerequisite(s): see online Course Catalog for details.
Topics involving the applications of physics in medicine and biology are selected from the following: external and internal forces on the body; heat and temperature equilibrium; physics of hearing; physics of vision; nerve conduction; muscle contraction; electric potentials of the brain; physics of cardiovascular and pulmonary systems; ionizing radiations and their effects; nuclear medicine; radiotherapy; physics of some biological instruments. An elective course for preprofessional students, but open to other students.

PHYS 40403. Methods of Theoretical Physics
(3-0-3) Sapirstein
A study of the methods of mathematical physics. Topics include linear vector spaces, matrices, group theory, complex variable theory, infinite series, special functions, and differential equations.

PHYS 43411. Senior Seminar
(1-0-1) Newman
A discussion of current topics in physics by students and staff members.

PHYS 40432. Modern Physics II
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
A continuation of modern physics I.

PHYS 40441. Modern Physics Laboratory I
(0-0-0) Blackstead
Prerequisite(s): (PHYS 30465 or PHYS 361)
A laboratory course stressing experiments in atomic, nuclear, and solid-state physics. The course is designed to introduce the student to experiments and methods closely related to modern-day research. Students will be introduced to the fundamentals of semiconductor devices and the construction and use of such devices.

PHYS 41441. Modern Physics Laboratory
(0-4-3)
Prerequisite(s): (PHYS 30465 or PHYS 361)
The laboratory is a corequisite for PHYS 40441

PHYS 40442. Modern Physics Laboratory I
(1-0-1)
Corequisite(s): PHYS 41442
A laboratory course stressing experiments in atomic, nuclear, and solid-state physics. The course is designed to introduce the student to experiments and methods closely related to modern-day research. Students will be introduced to the fundamentals of semiconductor devices and the construction and use of such devices.

PHYS 41442. Modern Physics Laboratory II
(0-4-2)
Corequisite(s): PHYS 40442
The laboratory is a corequisite for PHYS 40442

PHYS 40452. Thermal Physics
(3-0-3)
Prerequisite(s): (PHYS 40432 or PHYS 432)
Physical thermodynamics, kinetic theory, and an introduction to statistical mechanics.

PHYS 40453. Introduction to Quantum Mechanics I
(3-0-3) Kolda
The experimental basis for the wave picture of matter and the fundamental ideas of quantum mechanics.

PHYS 40454. Introduction to Quantum Mechanics II
(3-0-3)
Prerequisite(s): (PHYS 40453 or PHYS 453)
The experimental basis for the wave picture of matter and the fundamental ideas of quantum mechanics. An elective course for senior physics majors.

PHYS 48480. Undergraduate Research
(V-0-V)
Research in collaboration with members of the faculty. Three to 15 hours each week, arranged individually for each student. One to five credits.

PHYS 46490. Directed Readings
(V-0-V)
Study of topics not covered or only briefly covered in other courses. Readings, problems and reports.

PHYS 50445. Astrophysics
(3-0-3)Bennett
Prerequisite(s): see online Course Catalog for details.
A study of the physical problems associated with stellar motions; energy generation and radiation; astronomical distances; celestial mechanics; galactic dynamics; cosmic rays; interstellar matter; thermodynamics; and equations of state of various stellar models. Observational techniques and methods of computation will be discussed. An elective course for senior physics majors and other qualified students.

PHYS 50472. Relativity: Special and General
(3-0-3)
An introduction to relativity, both special and general. Special relativity: Lorentz transformations of events, geometry of space-time, relativistic kinetics (energy-momentum), Lorentz transformations of electromagnetic fields. General relativity: gravity and light, principle of general covariance, Einstein's field equations, Schwarzchild solution, precession of perihelions of planets, deflection of light, black holes. An elective course for senior physics majors.

Certain graduate courses in physics are open to qualified advanced undergraduates, subject to the approval of the chair of the department. These courses are listed in the Graduate School *Bulletin of Information*.

Preprofessional Studies

Interim Chair:
Rev. James K. Foster, CSC. MD
Professional Specialist:
Rudolph M. Navari, MD, PhD

Program of Studies. The Department of Preprofessional Studies offers several programs in the two major sequences, namely the program sequence in premedical science studies and the programs in the Collegiate Sequence.

All of the programs are quite flexible and allow the student to design a curriculum, in consultation with the chair or the associate dean in the College of Science, to enable the student to enter the profession best suited for his or her talents. The program in premedical science studies enables the student to obtain an excellent preparation to enter any of the professions of medicine, dentistry or the other ancillary fields of the healing professions. The interdisciplinary programs of the collegiate sequence have been designed to offer significant flexibility to prepare students for the professions of Science-education, Science-business, and Science-computing. All of the programs allow for a strong science background while also allowing a diverse background in the arts and humanities for individuals with a desire to obtain a broad educational background.

The major goal of this department is to provide an education in the best of liberal traditions of scientific thought and analysis, which the student can utilize for career opportunities in a variety of fields.

The program sequence in premedical science studies is a special program within the Department of Preprofessional Studies for students preparing to enter the professions of medicine, dentistry, osteopathy, veterinary medicine, podiatry, optometry, or other allied-health professions.

Notre Dame has been recognized as an accredited institution for premedical studies for more than 100 years. A proper selection of courses leading to the degree of bachelor of science will qualify the student for admission to any medical school in the world. A year before his or her expected entrance to medical school, the student takes the Medical College Admission Test, which is given twice a year at several hundred sites throughout the country, including Notre Dame. Students taking this test should have completed the basic courses in chemistry, biology and physics. The curricula leading to the degree of bachelor of science in other departments in the College of Science also satisfy the requirements for admission to medical or dental school.

Information concerning the requirements for admission to schools of medicine, dentistry, osteopathy, veterinary medicine, optometry and podiatry, as well as information on several ancillary health careers, is available from the office of the Department of Preprofessional Studies, 239 Nieuwland Science Hall.

Bachelor of Science with a Major in Preprofessional Studies —

Premedical Science Sequence

(124 semester hour credits; 64 science hour credits, minimum)

First Year

First Semester

FYC 13000 English Composition	3
MATH 10350	4
CHEM 10117	4
History or Social Science*	3
Philosophy or Theology*	3
Physical Education or ROTC	—
	17

Second Semester

Philosophy or Elective*	3
MATH 10360	4
CHEM 10118	4
History or Social Science*	3
University Seminar	3
Physical Education or ROTC	—
	17

Sophomore Year

First Semester

CHEM 20223. Elementary Organic Chemistry I	3
CHEM 21223. Elementary Organic Chemistry Lab I	1
BIOS 20201. General Biology A	3
BIOS 21201. General Biology A Lab	1
Elective	3
Language	3
	14

Second Semester

CHEM 20224. Elementary Organic Chemistry II	3
CHEM 21224. Elementary Organic Chemistry Lab II	1
BIOS 20202. General Biology B	3
BIOS 21202. General Biology B Lab	1
Elective	3
Language	3
	14

Junior Year

First Semester

Science Elective** (Note 3)	4
Physics (PHYS 30210, 31210)	4
Language or Elective	3
Philosophy or Elective	3
Science Elective	3
	17

Second Semester

Science Elective** (Note 3)	3
Physics (PHYS 30220, 31220)	4
Electives	9
	16

Senior Year

First Semester

Science Elective** (Note 3)	3
Science Elective** (Note 3)	4
Philosophy or Theology or upper-level English Literature (Note 6)	3
Electives	6
	16

Second Semester

Science Elective** (Note 3)	4
Theology	3
Elective	3
Science Elective** (Note 3)	3
	13

** One of these courses must be a University Seminar; the literature University Seminar in English 13186 is recommended (see note 6).*

*** See note 3.*

Notes:

1. Most of the course instruction in the curricula of the Department of Preprofessional Studies is provided by other departments in the College of Science and other colleges of the University.
2. The elective courses in the senior year may include a thesis based on laboratory work performed in a registered course in a given department with the approval of the head of that department, who will specify the number of credits assigned to the thesis.

**3. The choice by the student of elective courses in science for the program in preprofessional studies will be based upon the requirements of the professional schools and upon the lists of courses suggested or recommended by those schools in which the student is interested; the choice will be based also upon the advice and counseling of the chair of the department. From the *Medical and Dental School Requirements Books*, the following courses would be the most highly recommended in addition to the five basic science courses, giving the student applicant the best science background to be a most attractive candidate to any school to which he or she wishes to apply: biochemistry, genetics, physiology, cell biology, developmental biology, physical chemistry, analytical chemistry, and microbiology. Additional courses in higher mathematics, statistics and computer science are recommended for qualified students. Students not only must fulfill their requirements but, in the case of the natural sciences (mathematics, chemistry, biology and physics), also are strongly encouraged to follow the sequence of courses as listed. This sequence is designed in the light of health-related professional school requirements so that one course builds on knowledge gained from a prior course, even one from a different department; it is also structured to maintain a rigorous course load of at least two such courses per semester, with some adjustment possible in the senior year. Summer sessions, transfer credits and other modification in the regular curriculum should not be allowed to disturb this sequence of courses in the natural sciences without good reason.

4. For the selection of non-science electives for the programs, students should know that medicine and the other healing professions need individuals with a diversity of educational backgrounds and a wide variety of talents and interests. All of these schools recognize the desirability of a broad education—a good foundation in the natural sciences (mathematics, chemistry, biology and physics), highly developed communication skills and a solid background in the social sciences and humanities.
5. Recommendation 1 of the recent Report of the Association of American Medical Colleges titled "Physicians for the 21st Century" encourages a broadening of preparation. The department continues to encourage students to follow that recommendation by using the requirements of history and social science, English and the 27 general elective credits "to be an informed participant in contemporary society by understanding its politics, history and economics. To appreciate the many dimensions of human experience requires informed reflection upon the literature, the philosophy and the arts . . . of all people in our society."
6. To fulfill the medical school requirements of two semesters of English, students are required to take FYC 32000-level composition and one literature course taught in English. The literature course can be either a literature University Seminar in English 13186 or an upper-level literature course offered by the English Department and approved by the Department of Preprofessional Studies. Thus, if a student's University Seminar requirement is met by one of the literature options (in English), then the student will not be required to take upper-level English literature. Note, for this major only, a course in fine arts is not acceptable for the University literature/fine arts requirement. (A fine arts course will count as a general elective.)
7. In the curriculum for the program, there are listed the several courses required for the degree, including one semester each of history and social science, a course in literature, two courses in philosophy and two courses in theology. Students should remember that none of the required courses can be taken as a pass/fail option.
8. Students who have completed only six hours of mathematics in the first year of studies may transfer into the program but they will be required to complete a mathematics sequence equivalent to MATH 10350, 10360, or MATH 10550, 10560. Students having taken MATH 10250 (or 10260 or 10270) may do this by taking MATH 10360, while those who have taken only one semester of lower-level calculus should take both MATH 10350, 10360. Those students should see also the discussion on degree credit found later in this section of the *Bulletin.*
9. PHYS 10310–10320 or PHYS 10510–10520 may be substituted for PHYS 30210–31210.
10. Undergraduate Research (BIOS 48498 or SC 48100), Teaching Practicum (BIOS 37495), and Directed Readings (BIOS 48497) count toward the 64-hour preprofessional studies major science requirement; however, a maximum of two credits a semester and a combined total of six credit hours

may be counted in fulfilling the 64-credit-hour science requirement as well as the maximum credit hours counted toward graduation. Directed Readings (SCPP 46397) counts as general elective credit.

11. All students are welcome to join the Preprofessional, Premedical or Predental Societies. In addition, premedical students are encouraged to join AMSA, the American Medical Student Association.
12. All students who have had previous exposure to language will be required to take a placement examination in that language for placement in the proper course if the student wishes to continue in that language for the college requirement. If a student wishes to take a new language, of course, he or she must start from the beginning.
13. Interested parties may obtain additional information including various statistics from the department Web page. See http://preprofessional.nd.edu.

Summary of Requirements for the Degree of Bachelor of Science in Preprofessional Studies

	Credits
Biological Sciences	8
Chemistry	16
Mathematics	8
Physics	8
FYC 13000 level	3
Language Intermediate-Level Competency	
Philosophy*	6
Theology*	6
History*	3
Social Science*	3
Literature (University Seminar 13186 or upper-level English literature; see note 6)	3
Science Electives	24
General Electives	**27
	124

** One of these courses must be a University Seminar.*

*** Assumes Intermediate-Level Competency in Language was achieved by taking three three-credit courses.*

Preprofessional Studies Course Descriptions. The following course descriptions give the number and title of each course. Lecture hours per week, laboratory and/or tutorial hours per week, and credits each semester are in parentheses.

SCPP 10101. Medical Science from Birth to Death

(3-0-3) Foster

First-year students only. The course will give an overview of the medical science behind the technological advances used in various clinical subspecialties, advances that raise ethical questions from the beginning to the end of life. It will provide students with an overview of the biotechnological advances that are in the news, reshaping the scientific culture of modern medicine, and challenging personal and societal human values. This course fulfills one semester of the University science requirement. Fall.

SCPP 30300. Introduction to Clinical Ethics

(3-0-3) Foster

The focus of the course will be an examination of the advances in medicine over the last 30 years that have challenged traditional values and ethical norms, and the institutional processes and procedures in place that facilitate decision-making in the health care setting. It will include a sketch of the most recent advances in the various fields of medicine, followed by an examination of the clinical and ethical questions they raise and how they have affected the physician-patient relationship. Note: This course counts as a general elective. Fall and spring.

SCPP 30311. Introduction to the American Health Care System

(3-0-3) Navari

The course will begin with a short history of the American health care system and will be followed by a discussion of the major components of the system (patients, providers, payers), health insurance coverage, managed care programs, the movement for quality health care, physicians in the changing medical marketplace, health care expenditures, and academic medical centers. This course counts as a general elective. Fall and spring.

SCPP 46397. Directed Readings

(V-0-V) Foster

Permission required. Readings focus on learning how patients, families, and healthcare professionals experience illness and healing, how the stories that patients tell become the basis for diagnosis and therapeutic response, what it's like to go through medical training and grow in identity as a physician, and the nature of the doctor-patient relationship and how it is changing. Fall and spring. Note: This course counts as a general elective.

Collegiate Sequence Programs

The three Collegiate Sequence programs, Science-Business, Science-Computing, and Science-Education, were instituted in 1987. These three programs allow students to obtain a strong science background while simultaneously preparing them for professions in business, computing or education.

Science-Business Collegiate Sequence

The Science-Business Collegiate Sequence in the Department of Preprofessional Studies is an individualized course of study which incorporates courses from the basic areas of business along with the four basic areas of science. This approach enables students to attain a diversified background to enter an MBA program, leading to a position primarily in the scientific or health professions business areas. It is also a complete and sufficient program to enable the BS graduate of the sequence to enter the scientific business market immediately upon graduation.

Information on the areas of public health and hospital administration, as well as the business needs of the pharmaceutical, biological and chemical industries are available in the office of the Department of Preprofessional Studies, 237 Nieuwland Science Hall.

The other departments in the College of Science as well as the colleges of arts and letters and business administration provide all course instruction in the curricula of the Science-Business Collegiate Sequence.

Bachelor of Science with a Major in Science-Business

All Science-business majors take the following basic sequence of science courses:
General Biology (BIOS 20201–20202 and 21201 and 21202)[1]
General Chemistry (CHEM 10117–10118)[1]
Physical Geology (ENVG 20110) and Historical Geology (ENVG 20120)
or
Physical Geology (ENVG 20110) and Organic Chemistry I and Lab (CHEM 20223, 21223)
or
Organic Chemistry I and II and Labs (CHEM 20223–20224, 21223–21224)
Calculus (MATH 10350–10360 or 10550–10560)[1,2]
Physics (PHYS 30210–30220)[3]
Statistics (MATH 20340 or BIOS 40411)
They also are required to take 20–21 credits of science electives,[4] completing a minimum of 64 credits of science courses.

Also required for the major are the following business and economics courses:
Introduction to Economics (ECON 10010 or 20010)[5,6]
Accounting and Accountancy I (ACCT 20100)
Business Finance (FIN 20100)
Introduction to Management (MGT 20200)
Introduction to Marketing (MARK 20100)
One business elective chosen from the following:

- ACCT 20200
- FIN 30210
- FIN 30220
- MGT 30610
- MGT 40750
- MARK 30110

Requirements for the program are summarized in the table above.

Notes:

1. Equivalent or higher-level sequences in science may be substituted, e.g., CHEM 10113–10114 or CHEM 10125–11126 for CHEM 10117–10118 or BIOS 10161–10162 for BIOS 20201–20202 or MATH 10850–10860 for MATH 10550–10560.
2. Students who have completed only six hours of mathematics in their first year may transfer into the program, but they will be required to complete a mathematics sequence equivalent to MATH 10350, 10360 or MATH 10550, 10560. Students having taken MATH 10250, (or 10260 or 10270) may do this by taking MATH 10360, while those who have taken only one semester of lower-level calculus should take both MATH 10350, 10360. (See also the discussion on science degree credit, found later in this section of the *Bulletin*.)
3. PHYS 10310–10320 or PHYS 10411–10422 may be substituted for PHYS 30210–30220.
4. The choice by the student of the elective courses in science for the program will be discussed with

the student and will be based on the future industrial or health professions business interests of the student. Any major-level College of Science courses (i.e., those taken to meet science-major requirements and not those designated as "Recommended University electives") and that are not being used to fulfill other specific graduation requirements can be used to satisfy the "Science Elective" requirement. Major-level geology courses crosslisted as science courses may be taken as science electives. Students are restricted to no more than two credits per semester (six total) for science credit and three credits per semester (nine total) for graduation credit of courses such as Undergraduate Research or Directed Readings.

5. The economics requirement for this major is fulfilled by taking Introduction to Economics either in the first year (ECON 10010) or in the sophomore year (ECON 20010). Students who have taken ECON 20220/20010 (Principles of Economics I) or ECON 20010 (Principles of Economics II) will fulfill this requirement. Note: The course ECON 13181 (Social Science University Seminar) will not fulfill the economics requirement for this major.
6. For this major, the University social science requirement will be fulfilled by the required economics course. Additional social science courses are recommended and will count toward the student's general electives.

Suggested Curriculum for the Degree of Bachelor of Science in the Science-Business Collegiate Sequence (124 semester hour credits: 64 science hour credits, minimum)

First Year

First Semester

CHEM 10117. General Chemistry	4
MATH 10350 or 10550. Calculus (Note 4)	4
FYC 13100	3
Theology*	3
History*	3
Physical Education/ROTC	0
	17

Second Semester

CHEM 10118. General Chemistry	4
MATH 10360 or 10560. Calculus	4
Fine Arts or Literature*	3
Philosophy*	3
ECON 10010*	3
Physical Education/ROTC	0
	17

Sophomore Year

First Semester

BIOS 20201. General Biology A	3
BIOS 21201. General Biology A Lab	1
ENVG 20110. Physical Geology	
or	
CHEM 20223, 21223. (Organic Chemistry I)	4
Language	3
Elective	3
	14

Second Semester

BIOS 20202. General Biology B	3
BIOS 21202. General Biology B Lab	1
Historical Geology (ENVG 20120)	
or	
CHEM 20224, 21224. (Organic Chemistry II)	4
Language	3
Philosophy	3
	14 (13)

Junior Year

First Semester

Science Elective	3
PHYS 30210. General Physics I	4
MARK 20100	3
Theology	3
Elective (or Language)	3
	16

Second Semester

BIOS 40411. Biostatistics or	
MATH 20340. Statistics	4 (3)
PHYS 30220. General Physics II	4
ACCT 20100	3
Elective	3
MGT 20200	3
	17 (16)

Senior Year

First Semester

Science Electives	7
Elective	5
FIN 20100	3
	15

Second Semester

Science Electives	7
Electives	5
Business elective	3
	15

** One of these courses must be a University Seminar.*

Science-Computing Collegiate Sequence

The Science-Computing Collegiate Sequence in the Department of Preprofessional Studies is an individualized course of study which incorporates courses from the four basic areas of science along with a sequence of computing courses. The program will give the student working knowledge of various computer languages and experience using current computer technology. By choosing science electives appropriately, the student has the option of focusing in an area in science of particular interest. Graduates of this program earn a BS degree and are able to enter the scientific computing job market immediately upon graduation.

The other departments in the College of Science as well as the colleges of arts and letters and engineering provide all course instruction in the curricula of the Science-Computing Collegiate Sequence.

Bachelor of Science with a Major in Science—Computing

All Science-computing majors take the following basic sequence of science courses:

General Biology (BIOS 20201–20202 and 21201 and 21202)[1]
General Chemistry (CHEM 10117–10118)[1]
Physical Geology (ENVG 20110) and Historical Geology (ENVG 20120)
or
Physical Geology (ENVG 20110) and Organic Chemistry I and Lab (CHEM 20223, 21223)
or
Organic Chemistry I and II and Labs (CHEM 20223–20224, 21223–21224)
Calculus (MATH 10350–10360 or 10550–10560)[1,2]
Physics (PHYS 30210–30220)[3]
Statistics (MATH 20340 or BIOS 40411)

They also are required to take 20–21 credits of science elective,[4] completing a minimum of 64 credits of science courses.

Please see advisor for infomration on possible sequences in computing.

Requirements for the program are summarized in the table.

Notes:

1. Equivalent or higher-level sequences in science may be substituted, e.g., CHEM 10113–10114 or CHEM 10125–11126 for CHEM 10117–10118 or BIOS 10161–10162 for BIOS 20201–20202 or MATH 10850–10860 for MATH 10550–10560.
2. Students who have completed only six hours of mathematics in their first year may transfer into the program, but they will be required to complete a mathematics sequence equivalent to MATH 10350, 103600 or MATH 10550, 10560. Students having taken MATH 10250 (or 10260 or 10270) may do this by taking MATH 10360, while those who have taken only one semester of lower-level calculus should take both MATH 10350, 10360. (See also the discussion on science degree credit found later in this section of the *Bulletin*.)
3. PHYS 10310–10320 or PHYS 10411–10422 may be substituted for PHYS 30210–30220.
4. The choice by the student of the elective courses in science for the Science-computing program will be based on the student's scientific interest as developed during his or her studies of the four basic areas of science. Any major-level College of Science courses (i.e., those taken to meet science-major requirements and not those designated as "Recommended University electives") and that are not being used to fulfill other specific graduation requirements can be used to satisfy the "Science Elective" requirement. Major-level geology courses crosslisted as science courses may be taken as science electives. Students are restricted to no more than two credits of courses such as Undergraduate Research or Directed Readings in the science elective total.

Suggested Curriculum for the Degreeof Bachelor of Science in the Science-Computing Collegiate Sequence (124 semester hour credits: 64 science hour credits, minimum)

First Year

First Semester

CHEM 10117. General Chemistry	4
MATH 10550. Calculus (Note 5)	4
FYC 13100	3
Theology*	3
History*	3
Physical Education/ROTC	—
	17

Second Semester

CHEM 10118. General Chemistry	4
MATH 10560. Calculus	4
Fine Arts/Literature*	3
Philosophy*	3
Social Science*	3
Physical Education/ROTC	—
	17

Sophomore Year

First Semester

BIOS 20201. General Biology A	3
BIOS 21201. General Biology A Lab	1
ENVG 20110. Physical Geology or CHEM 20223, 21223 (Organic Chemistry I)	4
Language	3
CSE 20211 (Fundamentals of Computing I)	4
	15

Second Semester

BIOS 20202. General Biology B	3
BIOS 21202: General Biology B Lab	1
Historical Geology (ENVG 20120) or CHEM 20224, 21224 (Organic Chemistry II)	4
Language	3
Elective	3
	14

Junior Year

First Semester

Science Elective	4
CSE 20232. Advanced Programming	3
PHYS 30210. General Physics I	4
Theology	3
Elective (or Language)	3
	17

Second Semester

BIOS 30411. Biostatistics or MATH 20340. Statistics	4 (3)
PHYS 30220. General Physics II	4
Electives	6
Philosophy	3
	17 (16)

Senior Year

First Semester

Science Electives	8
CSE 30331. Data Structures	3
CSE 20110.	3
Electives	3
	17

Second Semester

Science Electives	8
CSE 30246. Database Concepts	3
Electives	3
	14

** One of these must be a University Seminar.*

Science-EducationCollegiate Sequence

The Science-Education Collegiate Sequence in the Department of Preprofessional Studies is an individualized course of study which incorporates many courses from the four basic areas of science along with education courses that most states require to give the student the background necessary to receive a certificate to teach in a secondary education system. Information concerning the requirements for secondary education in the various states, as well as the general course requirements for a certificate necessary to teach science in a secondary education program, is available in the College of Science office, 174 Hurley Hall.

The other departments in the College of Science and the other colleges of the University, as well as the Education Department at Saint Mary's College, provide all course instruction in the curricula of the Science-Education Collegiate Sequence.

Bachelor of Science with a Major in Science-Education

All Science-Education majors take the following basic sequence of science courses:

General Biology (BIOS 20201–20202 and 21201 and 21202)[1]

General Chemistry (CHEM 10117–10118)[1]

Physical Geology (ENVG 20110) and Historical Geology (ENVG 20120)

or

Physical Geology (ENVG 20110) and Organic Chemistry I and Lab (CHEM 20223, 21223)

or

Organic Chemistry I and II and Labs (CHEM 20223, 20224, 21223–21224)

Calculus (MATH 10350–10360 or 10550–10560)[1,2]

Physics (PHYS 30210–30220)[3]

They also are required to take 20 credits of science electives,[4,5] completing a minimum of 60 credits of science courses.

Also required for the major are the following education courses taught by Saint Mary's College:

EDUC 201. Teaching in a Multicultural Society

EDUC 220. Applied Media and Instructional Technology

EDUC 345. Curriculum and Assessment in the High School Setting

EDUC 346. Instructional Strategies and Classroom Management in the High School Setting

EDUC 350. Educational Psychology: Human Growth and Development of the Adolescent

EDUC 356. Educational Psychology: Educating Exceptional Learners

EDUC 449. Teaching Science in the Secondary School

EDUC 475. Student Teaching in the Secondary School (spring of senior year)

The education courses are those required in the State of Indiana but are also those that are required most often by the educational accrediting agencies of most states. The practical teaching experience which is required will also be arranged through the Education Department at Saint Mary's College.

Requirements for the program are summarized in the table found two pages back.

Notes:

1. Equivalent or higher-level sequences in science may be substituted, e.g., CHEM 10113–10114 or CHEM 10125–11126 for CHEM 10117–10118 or BIOS 10161–10162 for BIOS 20201–20202 or MATH 10850–10860 for MATH 10550–10560.
2. Students who have completed only six hours of mathematics in their first year may transfer into the program, but they will be required to complete a mathematics sequence equivalent to MATH 10350, 10360 or MATH 10550, 10560. Students having taken MATH 10250 (or 10260 or 10270) may do this by taking MATH 10360, while those who have taken only one semester of lower-level calculus should take both MATH 10350, 10360. (See also the discussion on science degree credit found in this section.)
3. PHYS 10310–10320 or PHYS 10411–10422 may be substituted for PHYS 30210–30220.
4. The choice by the student of the elective courses in science for the Science-education program will be based upon the requirements and list of courses suggested by the various state educational systems. Since the timing of the course work is particularly constrained for this major, the student should work closely with his or her advisors: an associate dean in the College of Science and an assigned advisor in the Education Department at Saint Mary's College.
5. Any major-level College of Science courses (i.e., those taken to meet science-major requirements and not those designated as "Recommended University electives") and that are not being used to fulfill other specific graduation requirements can be used to satisfy the "Science Elective" requirement. Major-level geology courses crosslisted as science courses may be taken as science electives. Students are restricted to no more than two credits of courses such as Undergraduate Research or Directed Readings in the science elective total.

Suggested Curriculum for the Degree of Bachelor of Science in the Science-Education Collegiate Sequence (124 semester hour credits: 60 science hour credits, minimum)

First Year

First Semester

CHEM 10117. General Chemistry	4
MATH 10350 or 10550. Calculus (Note 6)	4
FYC 13100	3
Theology*	3
History*	3
Physical Education	—
	17

Second Semester

CHEM 10118. General Chemistry	4
MATH 10360 or 10560. Calculus	4
Elective*	3
Philosophy*	3
Social Science*	3
Physical Education	—
	17

Sophomore Year

First Semester

BIOS 20201. General Biology A	3
BIOS 21201. General Biology A Lab	1
ENVG 20110. Physical Geology or CHEM 20223, 21223 (Organic Chemistry I)	4
Language	3
Education 201F (SMC)	3
Elective	3
	17

Second Semester

BIOS 20202. General Biology B	3
BIOS 21202: General Biology B Lab	1
Historical Geology (ENVG 20120) or CHEM 20224, 21224 (Organic Chemistry II)	4
Language	3
Fine Arts/Literature	3
EDUC 220 (SMC)	3
	17

Junior Year

First Semester

PHYS 30210. General Physics I	4
Science Electives	6
EDUC 345 (SMC)	3
EDUC 356 (SMC)	3
	16

Second Semester

PHYS 30220. General Physics II	4
Science Electives	8
EDUC 350 (SMC)	3
EDUC 346 (SMC)	3
	18

SUMMARY OF MINIMAL REQUIREMENTS FOR THE DEGREE OF BACHELOR OF SCIENCE IN A COLLEGEIATE SEQUENCE MAJOR

	Science-Business Program	*Science-Computing Program*	*Science-Education Program*
Biological Sciences	8	8	8
Chemistry	8	8	8
Geology/Organic Chemistry	8	8	8
Mathematics	8	8	8
Physics	8	8	8
Statistics: MATH 214 or BIOS 411	3–4	3–4	0
Science Electives	20–21	20–21	20
Total Required Science	64	64	60
Business Courses	15	0	0
Computing Courses	0	15	0
Education Courses	0	0	33
Language	Intermediate Level Competency		
FYC 110	3	3	3
Philosophy*	6	6	6
Theology*	6	6	6
History*	3	3	3
Social Sciences	3	3	3
Literature/Fine Arts	3	3	3
Free Electives	\2**	12**	0**
Total	124	124	126

* *One of these courses must be a University Seminar 180.*

** *Assumes Intermediate Level Competency in language was achieved by taking three three-credit courses.*

Senior Year

First Semester

Science Electives	6
EDUC 449 (SMC)	3
Philosophy	3
Theology	3
	15

Second Semester

EDUC 475 (SMC)	12
	12

** One of these must be a University Seminar.*

Special Programs

Double Majors in Science

In certain instances, students have the option of pursuing majors in two departments in the College of Science. Combinations that are normally approved include: Biological Sciences with Chemistry, Biological Sciences with Mathematics, Biological Sciences with Physics, Biochemistry with Mathematics, Biochemistry with Physics, Chemistry with Mathematics, Chemistry with Physics, Environmental Sciences (first major) with Mathematics, and Mathematics with Physics. Examples of combinations that are normally forbidden include: Preprofessional Studies and any of the Collegiate Sequence majors with one another or with any other science major, parallel subprograms such as Mathematics and Life Sciences with Physics in Medicine and either of those with Biological Sciences or Biochemistry. All requirements of each major must be met, with no exceptions. Failing to complete a required course terminates that major for a student. Every student who wishes to major in two departments in the College of Science must prepare an agenda of specific courses to be taken, which both advisors and the dean must approve. This should be done as early as possible, but absolutely no later than the seventh day of the senior year. In certain instances, a student may possibly receive approval of a normally forbidden combination of majors, but only if a specific program has been set up by the seventh day of the sophomore year.

All double major programs in science are extremely challenging programs that require that the student take four or five science courses at a time. Thus, only students of superior scholastic ability should consider this as an option.

Students are warned that it is almost certain that completing a double major in two sciences will require total credits well over the college minimum of 124. Conflicts in scheduling of required courses may occur; neither the college nor the departments undertake to reschedule courses for the sake of double majors. For these reasons, it must be emphasized that completing a double major may well require more than four years. Only one degree is awarded (degrees in science do not specify a field).

Dual Degree Program with the Mendoza College of Business

Coordinators:

Hayden Estrada
Director of Admissions
Master of Business Administration Program
Mitchell R. Wayne
Associate Dean, College of Science

Program of Studies. The dual degree five-year program in the Mendoza College of Business and the College of Science enables the student to earn the master of business administration and bachelor of science degrees in a major in one of the five undergraduate departments in the College of Science.

This program, instituted in 1994, offers students the opportunity to better integrate studies in science and in management. The student completing this program will have a background in management as well as the first professional degree in one of the undergraduate majors of the College of Science. Because it is a demanding program, only those students of superior scholastic ability who have the aptitude, motivation and maturity necessary for the combined graduate and undergraduate program should apply. Those with outstanding internship experiences in business will be looked upon favorably. Advisors for the program are available for consultation about the advisability of applying for the program and about meeting the particular needs of students pursuing this program.

The program is open only to those currently enrolled Notre Dame students who have completed three years of an undergraduate science first major. Students interested in making application for the MBA/Science program should apply to the MBA program during their junior year. They should take the GMAT by December of their junior year. All candidates must schedule a personal interview as a part of the MBA admissions process. Students must also declare their intentions to the dean's office in the College of Science and request that a dean's eligibility letter be sent to the MBA Office for them.

An applicant who is not admitted to the dual degree MBA/Science program continues in the undergraduate program and completes his or her science major in the usual four-year period.

As a general guide, it is expected that a student accepted to this program will take two courses for the undergraduate degree during the summer session following his or her junior year. Every dual-degree student is also expected to participate in the orientation for the MBA program. This program will occupy the entire day for the two weeks prior to the first day of classes. Orientation is mandatory for all students beginning the MBA program.

The following schedule of classes is an example of how an MBA/Science program might be accomplished.

First year, sophomore year, junior year:
As outlined for individual science major program in this *Bulletin.*

Summer Session following junior year:

General requirements or electives	6
MBA 503. Excel Workshop*	0
MBA 504. Career Development*	0
Accounting Review Workshop*	0
Math Review Workshop*	0

Senior Year

First Semester

MGT 500. Statistics	3
ACCT 500. Accounting	3
FIN 510. Microeconomic Analysis	3
MBA 500. Management Communication I	1.5
Undergraduate: Science/general requirements	3–7

Second Semester

FIN 500. Financial Management	3
FIN 515. Global Macroeconomic Environment	3
MGT 515. Operations Management	3
MBA 501. Management Communication II	1.5
Undergraduate: Science/general requirements	4–7

Fifth Year

First Semester

MGT 510. Organizational Behavior	3
MARK 500. Marketing Management	3
MBA: Business Ethics Elective	3
MBA: International Business elective	3
Undergraduate: Science/general requirements	3–6

Second Semester

MGT 519. Corporate Strategy and Planning	3
MBA electives	12
Undergraduate: general requirements	3–6

* Occurs during August orientation.

Total: 172 semester hours (124 undergraduate, 48 MBA)
Students involved in the MBA/Science program will complete their undergraduate program while completing MBA requirements. MBA course work will not apply to the undergraduate degree. Sample schedules for particular majors are available from advisors or the dean's office. Students who are behind in the completion of their major requirements are strongly recommended to obtain permission and advising *before* applying to the joint program.

Nondepartmental Courses

Director:
Mitchell R. Wayne
Associate Dean, College of Science

Course Descriptions. The following course descriptions give the number and title of each course. Lecture hours per week, laboratory and/or tutorial hours per week and credits each semester are in parentheses. Note: ENVG 20110, 232, 242, 362, 403, and 457 are taught by the Department of Civil Engineering and Geological Sciences.

SC 10100. Environmental Geosciences
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
This course introduces the student to Earth processes and focuses on how these processes affect people, and how people affect these processes. The course explores the interactions between Earth's biosphere, geosphere, atmosphere, and hydrosphere, with the objective of demonstrating how our physical environment is controlled by geological, biological, and human forces. SC 10100 and SC 20100 are the same course.

SC 10101. The Cosmos, the Earth, and the Genome
(3-0-3)
An introduction to the evolution of our universe, from the Big Bang to the human genome. The course will cover major concepts of cosmology, earth science, and evolutionary biology. Emphasis will be placed on not only our current understanding of those fields, but also on how our understanding itself has evolved over time. This course fulfills one semester of the University science requirement. If taken by science or engineering students, this course counts as general elective credit.

SC 20100. Environmental Geosciences
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
This course introduces the student to Earth processes and focuses on how these processes affect people, and how people affect these processes. The course explores the interactions between Earth's biosphere, geosphere, atmosphere, and hydrosphere, with the objective of demonstrating how our physical environment is controlled by geological, biological, and human forces.

SC 20110. Physical Geology (Lecture and Laboratory)
(3-0-4) Neal
Corequisite(s): SC 21110
An introduction to the Earth and its processes, composition, evolution, and structure. The course introduces the student to mineralogy, petrology, structural geology, oceanography, surficial processes, and environmental geology. Lecture and laboratory meetings.

SC 21110. Physical Geology Laboratory
(0-2-0)
Corequisite(s): SC 20110
The laboratory portion of ENVG/SC 20110.

SC 20200. Mineralogy and Optical Mineralogy
(4-0-4)
Burns

Prerequisite(s): see online Course Catalog for details.
Crystallography and mineral optics: physical and chemical mineralogy-its application to mineral identification in hand-specimen and using the petrographic microscope.

SC 21200. Mineralogy and Optical Mineralogy Lab
(0-2.5-0)
This is the laboratory portion of ENVG 20201.

SC 30230. Sedimentation and Stratigraphy
(4-0-4) Rigby
Prerequisite(s): see online Course Catalog for details.
Sedimentary environments from a physical, biological, and tectonic perspective are explored, along with processes such as lithification. Identification of sedimentary rocks; and interpretation of the succession of layered rocks in North America are emphasized.

SC 43100. Senior Honors Colloquium
(1-0-1)
This is a one-credit seminar consisting of presentations of on-going thesis research as a spur to the successful completion of the senior thesis or research project.

SC 48100. Research Experience for Undergraduates
(V-0-V)
Times and inclusive dates variable depending on specific program elected by the student. Permission required.

SC 48101. Undergraduate Research
(V-0-V)
Times and inclusive dates variable depending on specific program elected by the student. Permission required.

SC 40350. Paleontology
(3-0-3)
Prerequisite(s): see online Course Catalog for details.
The fossil record-morphology, taxonomy, evolution, statistical population systematics, and paleoecology. A one-day field trip is required.

SC 40491. Current Topics in Environmental Science
(3-0-3)
Taught by the director of the ES major. Environmental sciences first and second majors only. The course will be divided into various modules taught by experts on campus. The modules will include environmental law, risk assessment, environmental ethics, advancements in environmental and ecological science, current topics of national interest in environmental science, and others. This course is required of all first majors and recommended of all second majors. Spring.**I**

Science Degree Credit

Courses are generally taken in the College of Science for one of three reasons: (1) for students in either the College of Arts and Letters, or the Mendoza College of Business, or the School of Architecture, to fulfill a University requirement; (2) for students in either the College of Engineering or the College of Science to fulfill a college requirement; and (3) for students in the College of Science, to fulfill a major requirement. As a result, the College of Science offers different sequences of courses which overlap considerably in content but not level. Thus it is possible for a student who has changed his or her college or major to have taken two courses which overlap in content. Both courses will appear on the student's transcript, but only one will count for degree credit.

As a guideline for the student and the student's advisors, listed below are the groups of courses that overlap considerably in content. (Courses within the same group are shown in the same row and are also enclosed within parentheses; courses listed within the same column generally show a typical normal progression through course work.) In every case, only one course per group should be counted for degree credit. Generally, only the course taken last should be counted. Students and advisors are warned not to use these groups when moving between course sequences but rather to seek advice from the offering department or the College of Science office.

For overlap with courses no longer taught in the year of publication of this *Bulletin*, please refer to previous editions of this *Bulletin.*

Biological Sciences

(101/10101	110/10110	156/10156	161/10161	191/0191	201/20201)	
(107/10107		155/10155	162/10162		202/20202)	
(		241/20241	341/30341)			
(		250/20250	303/20303)			
(			342/40342	414/)		

Chemistry and Biochemistry

(101/10101	103/	113/10113	115/10115	117/10117	121/10121	10125)
(102/10102		114/10114	116/10116	118/10118	122/10122	126/10126)
(				223/20223	235/20235	247/20247)
(				224/20224	236/20236	248/20248)
(				420/40420	341/30341	521/60521)
(					342/30342	522/60522)

Mathematics

(104/10120	107/10110)					
(105/10250	111/10240		119/10350	125/10550	165/10850	195/10450)
(	108/10260	110/10270	120/10360	126/10560	166/10860	196/10460)
(				221/20610	228/20580	261/20810)
(				221/20610	228/20580	271/20570)
(				222/30705		262/20820)
(				225/20550		265/20850)
(				226/		266/20860)
(				230/20750	325/30650)	
(				230/20750	325/30650	272/)
(114/10140			230/20340		325/30540)	
(					318/30390	423/40390)

Physics

(101/10011	115/10111	127/	131/10310	141/	151/10411	221/30210)
(		128/	132/10320	142/)		
(102/10022	116/10122	229/20290		241	253/20431	222/30220)
(102/10022	116/10122		132/10320		152/10422	222/30220)
(		230/20230	231/20330		260/20464)	
(104/10052	204/20051)					
(110/10140	210/20140)					
(					271/20451	403/40403)
(					272/20452	403/40403)

Note also that no degree credit is given to any students for MATH 101; additionally, science majors will not receive degree credit for MATH 10120 or MATH 10110.

Officers of Administration

In the College of Science
JOSEPH P. MARINO, PhD
Dean of the College of Science

SR. KATHLEEN CANNON, OP, DMin.
Associate Dean of the College of Science

MITCHELL R. WAYNE, PhD
Associate Dean of the College of Science

JOSEPH E. O'TOUSA, PhD
Associate Dean of the College of Science

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A. GRAHAM LAPPIN, PhD
Chair of the Department of Chemistry and Biochemistry

WILLIAM G. DWYER, PhD
Chair of the Department of Mathematics

ANI APRAHAMIAN, PhD
Chair of the Department of Physics

REV. JAMES K. FOSTER, CSC, MD
Interim Chair, Preprofessional Studies

MORRIS POLLARD, PhD
Director of the Lobund Laboratory

IAN CARMICHAEL, PhD
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MARK A. SUCKOW, D.V.M.
Director of the Freimann Life Sciences Center

RUDOLPH M. NAVARI, M.D., PhD
Director of the Walther Cancer Research Center

FRANCIS J. CASTELLINO, PhD
Director ot the W.M. Keck Center for Transgene Research

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Kenna Director of the Center for Zebrafish Research

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