Bioinformatics, Ph.D.

COLLEGE OF SCIENCE AND TECHNOLOGY

Learn more about the Doctor of Philosophy in Bioinformatics.

About the Program

Bioinformatics is a field of study that lies primarily at the intersection of the biological and computational sciences and includes significant elements of biochemistry, mathematics, and statistics. The shared theme of this broad discipline is the application of sophisticated computing technologies to address questions on typically massive amounts of biological data.

The Bioinformatics Ph.D. program is a joint venture between the Departments of Biology, Chemistry, and Computer and Information Sciences, pulling together the exceptional breadth and depth of teaching and research faculty in the College of Science and Technology. The program offers strong doctoral candidates an alternative to the Biology Ph.D. program for those interested in studying computational genomics in the research labs of faculty in biology, chemistry, and computer science. Students gain rigorous advanced training in this expanding field through broad preparation in coursework related to the major research areas in bioinformatics.

While the program is administered through the Department of Biology, faculty from several departments in the College of Science and Technology teach coursework. Thus, a student’s primary advisor may be faculty in a department other than Biology.

Time Limit for Degree Completion: 7 years

Campus Location: Main

Full-Time/Part-Time Status: The degree program can be completed on a full- or part-time basis.

Interdisciplinary Study: The program itself is explicitly interdisciplinary, with students needing to be versatile in a wealth of computational and data-science contexts. Students are expected to develop specialized knowledge in one or more areas of the life sciences, as well as develop expertise in computational approaches to analyzing large amounts of data.

Areas of Specialization: Students focus on one of four main areas of concentration:

- Biological Data Analysis
- Evolutionary Genomics
- Evolutionary Medicine
- Structural Bioinformatics

Job Prospects: This program produces well-trained bioinformaticians who can be employed across a broad range of informatics fields, including the health professions, pharmaceutical and biotechnology, governmental agencies, as well as academia.

Non-Matriculated Student Policy: Non-matriculated students may enroll in a total of three courses (9 credits) with permission of the instructor and the department.

Financing Opportunities: Temple University offers a limited number of fellowships to support outstanding students in the doctoral program. Fellowships typically provide support, including a stipend and tuition, for two years.

Additional support is available in the form of Teaching and Research Assistantships. The principal duties of a Teaching Assistant include assisting faculty in the classroom; offering field and laboratory instruction; preparing materials for demonstration; conducting tutorials and laboratory sessions; and grading labs, quizzes, and tests. Attendance at weekly laboratory preparation sessions is required. The duties of a Research Assistant vary depending on the faculty member or principal investigator who is directing a specific research project. The appropriate project(s) are determined by consultation between the student and the student's academic and research advisors. Research Assistants are expected to devote 20 hours per week to research obligations. Both Teaching and Research Assistantships typically provide a nine-month academic-year stipend and full tuition remission (up to 9 credits per term), but are generally awarded on a per term basis. Summer stipends are also available. Assistantships are awarded competitively.

Admission Requirements and Deadlines

Application Deadline:

Fall: January 5; November 15 international

To be considered for a University fellowship, applications must be completed by January 5. Late applications may be considered for admission.

APPLY ONLINE to this graduate program.
Letters of Reference:
Number Required: 3

From Whom: Letters of recommendation should be obtained from college/university faculty whose research and teaching are in relevant areas, and who are familiar with the applicant's academic and/or research or computational abilities.

Coursework Required for Admission Consideration: Applicants should have a solid background in Biology or Biochemistry, and have had significant experience in computer programming. Alternately, a student may have a solid background in computer science and significant exposure to the life sciences, particularly genomics or structural biochemistry. Other backgrounds are considered if the applicant has broad experience across two or more STEM fields.

Master's Degree in Discipline/Related Discipline: A master's degree is not required.

Bachelor's Degree in Discipline/Related Discipline: A baccalaureate degree in a STEM field is required.

Statement of Goals: In approximately 500 to 1,000 words, describe your interest in Temple's program, computational background, research goals, and academic and research achievements.

Standardized Test Scores:
GRE: Required, with combined minimum score of 305 on the quantitative and verbal reasoning sections.

Applicants who earned their baccalaureate degree from an institution where the language of instruction was other than English, with the exception of those who subsequently earned a master's degree at a U.S. institution, must report scores for a standardized test of English that meet these minimums:
- TOEFL iBT: 90
- IELTS Academic: 6.5
- Duolingo: 110
- PTE Academic: 61

Transfer Credit: Graduate credits from an accredited institution may be transferred into the Bioinformatics program. The credits must be equivalent to coursework offered by the College of Science and Technology at Temple University. A grade of "B" or better must have been earned for the credits to transfer. The Bioinformatics Steering Committee makes recommendations to the Biology Department Chair for transferring credits on an individual basis. The maximum number of credits a student may transfer is 6.

Advanced Standing: Students who enter the Ph.D. program with a master's degree may be considered for advanced standing. The Steering Committee recommends the awarding of advanced standing on a case-by-case basis. The credits must be equivalent to coursework offered at Temple, with a grade of "B" or better having been earned in the course(s). The maximum number of advanced standing credits awarded is 15.

Program Requirements

General Program Requirements:
Number of Credits Required Beyond the Baccalaureate: 36

Required Courses:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOL 5131</td>
<td>Topics in Bioinformatics (Topics in Bioinformatics)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Three BIOL or CHEM courses at the 5000-level or above</td>
<td>9</td>
</tr>
<tr>
<td>Advanced Study Courses</td>
<td></td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Four courses at the 5000-level or above ¹</td>
<td></td>
</tr>
<tr>
<td>Research Courses</td>
<td></td>
<td>12</td>
</tr>
<tr>
<td>BIOL 9994</td>
<td>Preliminary Examination Preparation</td>
<td></td>
</tr>
<tr>
<td>BIOL 9998</td>
<td>Pre-Dissertation Research / Elevation to Candidacy</td>
<td></td>
</tr>
<tr>
<td>BIOL 9999</td>
<td>Dissertation Research</td>
<td></td>
</tr>
</tbody>
</table>

Total Credit Hours: 36

¹ With the approval of the advisor and Program Coordinator, students select graduate courses in their area of interest within the bioinformatics field. No more than two courses may be taken outside of the College of Science and Technology.

Additional Requirements:
All graduate-level courses must be passed with a "B-" or better.

All Ph.D. candidates must have experience teaching at Temple University. A minimum teaching requirement of one term may be satisfied by serving as a Teaching Assistant in a Bioinformatics-affiliated department.

Attendance at scheduled departmental colloquia is required.

Culminating Events:

Preliminary Examination:
The student independently prepares a written proposal and submits it to the Graduate Committee by April 1 of the student's fourth term. The proposal should follow the general format of a postdoctoral proposal to a federal granting agency (e.g., NIH). It should include background surrounding a particular research problem, including literature related to the problem, and a detailed methodological plan for investigating the problem. The sections of the written proposal should include Title; Abstract (not to exceed 300 words); Specific Aims; Background and Significance; Preliminary Data; Experimental Design (including Rationale, Specific Methods, Interpretation of Possible Results, and Pitfalls and Alternative Strategies); and References. The preliminary exam proposal should be 15 to 20 pages in length. The research advisor is not to make direct contributions.

The Area Committee has two weeks in which to review the written proposal, and the student is allowed only one re-write. If the proposal is not accepted after the first re-write, the student is considered to have failed the exam. If the written proposal is accepted, an oral examination is scheduled through the department and held within two weeks. The oral examination tests the student's understanding of the background and substance of the research proposal and her/his understanding of the area of specialization in which the research is embedded.

The preliminary examination is administered by the Preliminary Examination Committee. The student's primary research advisor is allowed to attend but must remain silent unless called upon by the Committee for clarification or advice. A minimum of three examiners serve on the Preliminary Examination Committee, and one of the following grades is assigned: Pass or Fail. The evaluators look for a breadth and depth of understanding of specific research areas, a critical application of that knowledge to specific biological phenomena, and an ability to write a proposal in a manner consistent with scientists in the student's specialization. The student is notified of the grade the day the exam is taken. A passing grade requires a 2/3 majority of the Preliminary Examination Committee. If a student receives a grade of Fail, s/he may retake the exam one additional time. Examinations that are to be retaken must be completed before October 1 of the following academic year.

Dissertation:
The doctoral dissertation is an original bioinformatics study that demonstrates the student's knowledge of research methods and mastery of her/his primary area of research.

The Doctoral Examination Committee is to consist of a formal departmental colloquium open to the public, but conducted by the Doctoral Advisory Committee. The student then meets with the Dissertation Examining Committee after the colloquium for the dissertation defense. The penultimate version of the dissertation must be approved by the Doctoral Advisory Committee at least two weeks before the Graduate School deadline for submission of final copies.

The scheduling of the dissertation defense is to be arranged by the dissertation advisor. The Graduate School must be notified at least ten working days in advance. Announcements of the dissertation defense are posted around the Biology Department and the host department as well as advertised via e-mail or listserv.

Contacts

Program Web Address:
https://www.temple.edu/academics/degree-programs/bioinformatics-phd-st-binf-phd

Department Information:
Dept. of Biology
255 Biology-Life Sciences Building
1900 N. 12th Street
Philadelphia, PA 19122-6078
phdbioinform@temple.edu
215-204-8877
Submission Address for Application Materials:
https://cst.temple.edu/academics/graduate-programs/apply-now

Department Contacts:

Admissions:
Sandhya Verma
phdbioinform@temple.edu
215-204-8854

Program Director:
Rob J. Kulathinal
robkulathinal@temple.edu
215-204-0620

Department Chairperson:
Robert Sanders
robert.sanders@temple.edu
215-204-8851

Biology Courses

BIOL 5101. Evolution. 3 Credit Hours.
A lecture and discussion course for upper-level science majors and graduate students. Topics covered include Darwinism and neo-Darwinian theory, including adaptation, natural selection, sexual selection, and speciation.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

BIOL 5111. Genomics in Medicine. 3 Credit Hours.
The completion of the Human Genome Project in 2003 began a revolution in the treatment of human disease. More than 10 years later, the promise of personalized genome-guided medical treatment is becoming reality. This course will explore how genomic information has enhanced our understanding of human genetic variation and disease susceptibility. Students will develop familiarity with main areas in genomic medicine through lectures from intramural and extramural experts, and they will be involved in classroom discussions. Students at the graduate level will complete an independent project focused on a particular disease topic, integrating literature review with new analyses of published data.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

BIOL 5112. Fundamentals of Genomic Evolutionary Medicine. 3 Credit Hours.
Modern evolutionary theory offers a conceptual framework for understanding human health and disease. In this course we will examine human disease in evolutionary contexts with a focus on modern techniques and genome-scale datasets. We ask: What can evolution teach us about human populations? How can we understand disease from molecular evolutionary perspectives? What are the relative roles of negative and positive selection in disease? How do we apply evolutionary principles in diagnosing diseases and developing better treatments? Students will conduct case studies of a variety of diseases and phenotypes in a group setting. Students at the graduate level will complete an independent research project and assume leadership roles in group presentations.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
College Restrictions: Must be enrolled in one of the following Colleges: Engineering, College of Public Health, Medicine, Lewis Katz School, Science & Technology.
Repeatability: This course may not be repeated for additional credits.
Biol 5114. Evolutionary Ecology. 3 Credit Hours.
In this course we will explore the interface of ecology and evolution. The field of evolutionary ecology deals broadly with questions such as: What are the ecological causes of evolution? How do ecological interactions shape the evolution of traits and origination (or extinction) of species? How does evolutionary history shape species interactions and community structure? How might evolution influence community or ecosystem processes? The class will cover fundamental theories and approaches used to address questions in evolutionary ecology, including molecular tools, modeling, manipulative field studies, and laboratory- or field-based common garden studies. Students will be engaged through a combination of lectures, inquiry-based activities, and small group discussions.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Biol 5128. Genomics and Infectious Disease Dynamics. 3 Credit Hours.
Events such as the emergence of avian flu have increased public awareness about the need for incorporating ecology and evolution in decision-making processes that involve infectious diseases. It is evident for the public health community that molecular information, together with concepts from ecology and evolutionary biology, allows for testing of hypotheses and exploration of scenarios that otherwise could not be investigated by traditional epidemiological approaches. Understanding the ecological and evolutionary dynamics of infectious diseases requires the integration of information across organizational levels at various temporal and/or spatial scales. This requirement, together with novel molecular evolution, genomics, and mathematical modeling approaches, has positioned research on Genomics and Infectious Diseases Dynamics at the forefront of Public Health Genomics. The goal of this class is to discuss some of the biological processes leading to the emergence and re-emergence of infectious diseases stressing on evolutionary concepts within an epidemiological context. Basic concepts will be provided by the instructor as part of formal lectures. Our general objective (integrating evolutionary biology into epidemiology) will be fulfilled by discussing research articles. Such discussions will take place during the second half of the semester. “Emerging” perspectives such as One Health and Public Health Genomics will be integrated into the lectures and discussions.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Biol 5131. Topics in Bioinformatics. 3 Credit Hours.
This course will be a keystone required course for all incoming students in a Bioinformatics Ph.D. program. Bioinformatics is a rapidly expanding research area at the intersections of biology, chemistry, mathematics/statistics, and computer science. The shared theme of this broad discipline is the application of sophisticated computing technologies to address questions on typically massive amounts of biological data. Because of the dynamic and broad nature of the field, a course is needed that will introduce new students to the breadth of the field while at the same time introducing topics at a level of depth and rigor appropriate for a Ph.D. program. This will be a team taught course, with one coordinator and up to seven research-active instructors. The course would consist of seven modules, each two weeks in length. Every year, the coordinator will identify faculty and topics so as to present a diverse cross-section of cutting-edge Bioinformatics. An important goal of this course is that it will introduce students to a broad sample of the faculty who are active in the Bioinformatics Ph.D. program.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

College Restrictions: Must be enrolled in one of the following Colleges: Science & Technology.

Repeatability: This course may not be repeated for additional credits.

Biol 5225. Evolutionary Genetics Genomics. 3 Credit Hours.
This class covers fundamental principles of population and comparative genetics with special attention given to recent advances in genomics. The scope of the class ranges from understanding variation at the population level to addressing species-level questions. Topics covered include classical population genetics, quantitative genetics, comparative genomics, phylogenomics and speciation. Lectures, assignments and discussions will explore theoretical and recent empirical advances.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Biol 5226. Innovative Biomodels and Concepts. 3 Credit Hours.
The aim of this course is to familiarize students with current concepts, models, and cutting-edge technologies applicable in different biindustries. The scope of topics ranges from the implementation of discoveries stemming from molecular genetics, cell biology and nanotechnology in different industries to integration of omics techniques in personalized medicine, drug discovery and pharmacovigilance. Note: Non-STEM graduates will be required to enroll as non-matriculated in at least two Biology Foundation courses recommended by the PSM in Bioinnovation Steering Committee.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.
BIOL 5227. Biomarkers and Biotargets: Research and Commercialization. 3 Credit Hours.
This course focuses on the evolution of biomarker and biotarget research, with emphasis on biomarker validation and biotarget druggability. The students will analyze real-life examples of biomarkers and biotargets in medicine, drug development, and environmental science. The formation of therapeutic target databases and development of multi-target agents will be critically evaluated. Note: Non-STEM graduates will be required to enroll as non-matriculated in at least two Biology Foundation courses recommended by the PSM in Bioinnovation Steering Committee.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5228. Epigenetics, Genetics: Applications in Drug Design and Drug Response. 3 Credit Hours.
This course focuses on applications of current epigenetics knowledge in health industries. Special emphasis is on epigenetic and genetic testing in clinical settings, epigenetic and genetic determinants of drug response as well as drug- and environment-induced modulation of epigenetic status. Note: Non-STEM graduates will be required to enroll as non-matriculated in at least two Biology Foundation courses recommended by the PSM in Bioinnovation Steering Committee.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5229. Systems Biology: Principles and Applications. 3 Credit Hours.
This course provides an overview of Systems Biology technologies and the scientific challenges in applicability of system biology paradigms in the analysis of biological processes. Topics covered include the use of genome-scale in silico models and dissecting transcriptional control networks. By successfully completing this course, the students will obtain background on theoretical and modeling techniques, and software platforms for Systems Biology. Note: Non-STEM graduates will be required to enroll as non-matriculated in at least two Biology Foundation courses recommended by the PSM in Bioinnovation Steering Committee.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5232. Behavioral Genetics. 3 Credit Hours.
This course is an introduction to the interdisciplinary field - behavioral genetics - that combines behavioral sciences and genetics and unifies the long-standing debate on what underlies complex human behavior: "nurture" or "nature." This course will discuss the genetic approaches used to dissect out the genetic determinant of complex human traits. For example, students will learn about genes that influence learning and memory, intelligence (IQ), cognitive disabilities, personality disorders, psychopathology, antisocial behavior, substance abuse, and sexual orientation. In addition, the interplay of environment and genetic factors that create individual differences in behavior will be explored. Because this field represents the intersection between what is known and what might be known in the future about complex and potentially controversial behaviors and characteristics, students will be encouraged to discuss contemporary ethical issues regarding human behavior in realm of the scientific evidence presented.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5233. Effective Dissemination of Bio-discoveries through Traditional and New Media. 1.5 Credit Hour.
The students will learn contemporary methods of effective dissemination of research findings and concepts to professional and lay audiences. Current real-life findings will be presented through slide and video development, press releases, and the use of social media. In addition, the students will learn the ways to communicate scientific data through abstracts, posters, and papers and will critically analyze the content and style of selected scientific material. Furthermore, different types of funding proposals will be reviewed and grant development will be practiced.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5234. Bioinnovation Seminar. 1.5 Credit Hour.
This course includes lectures and seminars on current topics in bioinnovation presented by experts in different disciplines and it will include seminars at the Fox School of Business and Management. By successfully completing this course, the students will obtain up-to-date knowledge of bioinnovative models.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.
BIOL 5235. Milestones in Clinical Translation of Biodiscoveries. 1.5 Credit Hour.
The goal of this course is to familiarize the students with clinical trial design and principles of pharmacovigilance. Topics will include clinical trial phases and examples of clinical trial design for selected biologic drugs. Case studies of drug safety-driven FDA decisions will also be evaluated. The comparison between regulatory requirements of the U.S. and international agencies will be discussed.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5236. Bioadvanced Screening in Health Disparity. 1.5 Credit Hour.
This course focuses on the effects of nutrients, bioactive food components and environment on public health, medical treatments and applications for improving human health.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5237. Virtual Reality in Bioindustry and Medicine. 1.5 Credit Hour.
The goal of this course is to provide the students with a background on Virtual Reality and its applications in medicine, laboratory research, training and education in bioindustry.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5239. Dissemination of Biodiscoveries and Virtual Reality in Medicine. 3 Credit Hours.
The students will learn contemporary methods of effective dissemination of research findings and concepts to professional and lay audiences. Current real-life findings will be presented through slide and video development, press releases, and the use of social media. Furthermore, this course will provide the students with a background on Virtual Reality and its applications in medicine, laboratory research, training and education in bioindustry.

Level Registration Restrictions: May not be enrolled in one of the following Levels: Undergraduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5241. Genomics and Evolutionary Biology of Parasites and Other Dependent Species. 3 Credit Hours.
All known multicellular organisms harbor diverse assemblages of dependent species, many of which are considered parasites or pathogens. Yet, in spite of a growing awareness of the importance of dependent species in biodiversity and medicine, many studies are limited to assessing the consequences to their hosts. The goal of this seminar is to discuss some of the biological processes leading to the diversity of dependent species and their functional/evolutionary relationships with their hosts. This general objective will be fulfilled by discussing research articles on the genomics and evolution of dependent species, many of them considered parasites or pathogens. Students are also expected to gain proficiency in writing scientific review papers.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5254. Animal Behavior. 3 Credit Hours.
This course will examine how animals behave, and investigate the proximate (neurological and developmental) and ultimate (functional and evolutionary) explanations for these behaviors. The ecological and evolutionary processes that shape animal behavior will be examined through the study of classic theories and major principles of animal behavior, including a weighing of the experimental and observational evidence for each idea. Concepts will be illustrated with examples from a wide range of taxonomic groups of animals in diverse ecosystems, and emerging theories in animal behavior will be discussed. We will conclude with applications of animal behavior for conservation.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5275. Ecology of Invasive Species. 3 Credit Hours.
Species that are transported by humans from their native range and successfully establish and spread in a new environment are called invasive species. Invasive species can cause significant ecological and economic impacts and are a growing threat to native species and ecosystems across the globe. Recognition of this problem has led to a recent surge in research on invasive species and a better understanding of the ecology of invasions and approaches for improved prevention and control. Yet many challenges still hinder scientific and applied advancements in this emerging field. In this course we will investigate these challenges and the science of invasive species using interactive activities and student-driven projects.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.
BIOL 5301. Cell Biology. 3 Credit Hours.
Advanced knowledge in cell biology will be discussed. Topics include macromolecules, cell structure, cell motility, bio-membrane, endo- and exocytosis, nucleocytoplasmic transport, visualizing cells and macromolecules with advanced microscopy imaging. Current journal articles reporting recent developments in modern cell biology will be also covered.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5307. Conservation Biology. 3 Credit Hours.
The Earth harbors an incredible diversity of species and communities, most still poorly understood by science. This biodiversity is essential to the functioning of natural ecosystems and provides a wide array of priceless services to people today and a treasure of benefits for the future. Yet human threats to biodiversity have led us to the brink of the sixth major extinction event in Earth’s history. Which populations, species, communities, and ecoregions are most diverse? Which are most threatened, and by which human activities? What is the contribution of biodiversity to human livelihoods? What does the science suggest is needed to conserve biodiversity? How might this best be done given social, economic, and political realities? These questions and more will be examined in this course, focusing on the key principles of conservation biology and the application of those principles to local, national, and international examples.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5311. Herpetology. 4 Credit Hours.
Herpetology Reptiles and amphibians comprise nearly 7,400 species and can be found on every major and minor landmass in the world except Antarctica. This course will provide a broad, evolutionary survey of the major groups of reptiles and amphibians (“herps”). We will cover topics about their basic biology, including anatomy, physiology, ecology, behavior, and conservation. The laboratory will emphasize taxonomic characters and identification of living and preserved specimens, with emphasis on species found in North America. Additionally several field trips (conducted during lab hours and spring break) will reinforce course material through hands-on experience.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5312. Biostatistics. 3 Credit Hours.
Biostatistics is an important part of the research activities related to biological and medical issues. Statistics is used to analyze phenomena with random properties and is often essential to draw the right conclusions based on a data set. The course will be designed to cover different statistical methods for data analysis mainly applied to medical and biological problems. Advanced undergraduate and graduate students with interests in medicine and biomedical research will benefit most from the course. However statistical methods that can be applied to behavioral science and ecology will also be covered.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5321. Plant Community Ecology. 3 Credit Hours.
This class focuses on fundamental principles in community ecology as they relate to plant systems. The scope of the class ranges from plant-environment interactions and species interactions, to the relationship among communities at larger spatial scales. Lectures and small group discussions will also highlight theoretical and empirical advances made in ecology through classic and contemporary studies of plant communities.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5322. Biology of Plants. 3 Credit Hours.
This course examines current knowledge of higher plants, with an emphasis on Arabidopsis and maize. Topics include plant reproduction, self-incompatibility, polyploidy in plants, sex chromosomes in plants, chloroplast structure and function, light and dark reaction of photosynthesis, nitrogen fixation, phytochromes, DNA and histone methylation and epigenetics, embryonic pattern formation in plants, chemical signaling in plants, leaf morphogenesis, flower development, and stem cell populations in plants.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.
BIOL 5323. Global Change Science: Analytics with R. 3 Credit Hours.
Learn how researchers use data to tackle global problems such as climate change, mass extinction, pandemics, and poverty. Explore interdisciplinary data, from economics to public health, and learn a marketable skill: R, an intuitive computer language. The course is project based, no prior coding experience is necessary, and no tests are given. Instead, student assessment is on project progress and communication of a global change problem of their choice. The most successful students leave class with the quantitative skills to go out and solve our most pressing problems.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5325. Research Techniques in Molecular Biology. 3 Credit Hours.
Instruction in the techniques used in modern molecular biology and molecular genetics. This course takes a problem-oriented approach toward teaching the methods of DNA and RNA analysis that are used in determining the structure and function of genes. Practical experience in the preparation of DNA, modern cloning methods, restriction enzyme mapping, hybridization analysis, DNA sequencing, and PCR techniques will be provided. Students will carry out a research project during the course. NOTE: Biology 3324 is highly recommended, but not required. Also note: Prior to Spring 2017, the course title was "Recombinant DNA Techniques."

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5335. Polar Biology - Life at the Extremes. 3 Credit Hours.
"Polar Biology - Life at the Extremes" is an introduction to polar environments and the biology of aquatic and terrestrial organisms adapted to live in the Arctic and Antarctic. Similarities and differences between the poles as well as anthropogenic impacts on these remote environments will be addressed. Comparisons to other extreme environments will be included.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5337. Comparative Biomechanics. 3 Credit Hours.
An overview of biomechanics with emphasis on locomotion. Students gain a working knowledge of the breadth of biomechanical study ranging across organismal and environmental scales.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5338. Epigenetics. 3 Credit Hours.
The term "epigenetics" describes a heritable effect on chromosome or gene function that is not accompanied by a change in DNA sequence. Recent findings suggest an important role of epigenetics in both normal development and cancer. This course provides an overview of the field and examines selected phenomena in several eukaryotes, mechanisms regulating these effects, and their phenotypic consequences when normal regulation is lost. Topics include gene regulation through chromatin modification (acetylation, methylation), genomic imprinting, mechanisms of silencing (including small interfering RNAs), and the role of epigenetics in human diseases and cancer.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5358. Cellular/Molecular Neuroscience. 3 Credit Hours.
The course will focus on the molecular and cellular basis of neurological processing. The fundamentals of action potential generation, synaptic and receptor potentials generation and neuron-neuron communication will be discussed. The contemporary understanding of sensory processing will be covered in great detail with a particular focus on molecular sensors of light, sound, odorants, taste and touch and the signal transduction pathways that underlie the five senses.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.
BIOL 5361. Molecular Neuropharmacology. 3 Credit Hours.
In this course we will examine how drugs interact with the nervous system. We will focus specifically on the cellular and molecular actions of drugs on synaptic transmission, as a mechanism for understanding the structure and function of the synapse. In addition, we will discuss how toxins and venoms affect synaptic transmission in nature as well as how they have been (and continue to be) used as research tools. We will study the neural substrates of drug action and the sequence of events from how a drug binds initially to its molecular target(s), the resulting changes in the function of its target, the influence of these changes on biochemical networks in neurons, the subsequent alterations in neuronal output, and in the circuit, including non-neuronal cells. Students will be able to appreciate the progress in the discovery of drugs used to treat in the clinic complex behaviors as well as major neural disorders (neuroinflammation, pain, migraine, sleep, neurodegeneration, addictive disorders, schizophrenia, etc.). In addition, we will learn about the process of drug approval (preclinical, clinical trials, drug monitoring, and FDA's role).

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

BIOL 5366. Stem Cell Biology. 3 Credit Hours.
The purpose of this course is two-fold. The first is to present the developmental biology of stem cells, with an overview of the various types of stem cells that exist and an emphasis on embryonic stem cells. The overview will include the important functional differences between embryonic, hematopoietic, and adult stem cells as well as the differences in their biomedical potentials. Techniques such as somatic cell nuclear transfer (SCNT) and other methods for the derivation of stem cell lines will be outlined so that differences that may seem subtle at first glance are clarified. The second purpose is to look into the larger debate on human embryonic stem cell research while continually drawing connections to the established fields of bioethics, politics, and philosophy. The course will ground the issues by looking at the history of the debate over the embryo, with careful attention paid to the language used in arguments. An exploration of important social, ethical, political, and economic issues and how they arose with respect to the stem cell debate will round out the remainder of the course.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

BIOL 5389. Field Research in Community Ecology. 4 Credit Hours.
Many fundamental advances in community ecology have emerged from creative, well-designed field studies in natural ecosystems. Field research is therefore a cornerstone of contemporary community ecology. Through this summer course taught at Temple’s Ambler Campus, students will gain hands-on experience designing and conducting field research in community ecology. While some activities will be in a classroom, most activities will be held outdoors, in the natural environments around Ambler Campus.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

BIOL 5403. Genomics. 3 Credit Hours.
This course will cover the process of gene inheritance and descriptions of genome structure, as well as a discussion of gene content and function across lineages. Students will learn about genome-related technologies, including genome sequencing. They will also learn about how genomes vary across species, as well as the forces driving these evolutionary changes. Students will complete quizzes and exams to demonstrate understanding of the information present in genomes and the processes that drove it.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

BIOL 5411. Structural Bioinformatics I. 3 Credit Hours.
This course will cover the basic concepts of protein structure analysis, with focus on database searching and molecular modeling techniques. A broad qualitative overview of macromolecular structure and protein folding will be provided before addressing the issues of sequence alignment, secondary structure calculation, and tertiary structure prediction. The course will also cover few selected advanced topics such as prediction of quaternary structure, Hidden Markov Models, and other approaches for building probabilistic models of sequence ensembles. Computer-based activities will allow students to develop a strong familiarity with molecular visualization software and web-based tools.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.
BIOL 5416. Tropical Marine Biology: Belize. 4 Credit Hours.
An introduction to the largest coral barrier reef in the Atlantic Ocean. Course lectures begin at Temple (approximately Dec 29-Jan 31; holidays excluded) followed by a week of lectures, field trips and field or laboratory projects in Belize. Lectures include coral biology, reef geology and ecology, coral reef microbiota, food chains and nutrient transfer in coral reefs, reef community organization, the biology of reef fishes, commensal and symbiotic interactions of reef organisms, and other appropriate topics. Group student team projects and lectures are required. Note: Additional requirements include cost of air travel to a foreign country between fall and spring semesters, a current passport, and snorkeling equipment.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5427. Immunology. 3 Credit Hours.
The purpose of the Immunology course is to provide a comprehensive overview of the immune system that in its normal function protects each of us from the harmful effects of microbial invaders. The lectures will describe the general properties and development of immunity, the condition of being protected from infection by microorganisms or the effects of foreign molecules. They will provide systemic coverage of immune responses to viruses, bacteria, protozoa and roundworms as well as the practical aspects of vaccine development. Additional lectures will include a description of various types of primary immunodeficiencies, most prevalent autoimmune disease and cancer.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5428. Virology. 3 Credit Hours.
The role of viruses in human diseases, and their potential as tools for research and clinical interventions. The course will focus on virus-induced diseases in man including polio, rabies, hepatitis, herpes, and influenza; recently discovered viruses such as HIV and HTLV-1 will also be studied. Virus-host interactions and the mechanisms involved in disease progression, therapeutic strategies, and vaccines, strategies for viral entry, evasion of the immune system, transmission, and the subversion of host-cell machinery will be emphasized. Potential uses of viruses as vector for gene therapy of genetic disorders, cancers, and infectious diseases will also be discussed.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5429. Developmental Genetics. 3 Credit Hours.
The role of genes in the determination and differentiation of eukaryotes. Emphasis on the regulation of gene function and on the genetic and molecular interactions which control the processes of development.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5433. Advanced Techniques in Microscopy. 3 Credit Hours.
This course will provide a survey of modern techniques in microscopy. Students will acquire a thorough grounding in general principles of optics and conventional microscopy, and learn the theory of many methods current in biology and medicine, fluorescence, confocal microscopy, video microscopy, and digital image processing and analysis. Note: This course includes extensive laboratory experience.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5436. Freshwater Ecology. 4 Credit Hours.
The interrelationships between biological, chemical, and physical factors in freshwater environments. Lectures and laboratories address general ecological principles (population dynamics, community structure, energy flow, and nutrient cycling) as they apply to plants and animals in lakes, ponds, streams and wetlands. Note: Students are required to participate in up to two field trips, one of which includes weekend travel.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5452. Systems Neuroscience. 3 Credit Hours.
A comparative survey of vertebrate and invertebrate nervous systems intended to acquaint the student with their structure, function and development at several levels of complexity.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.
**BIOL 5454. Neurological Basis of Animal Behavior. 3 Credit Hours.**
An exploration of the relationship of neural activity and connectivity to behavior. Topics include motor control, object recognition and learning. Examples from both vertebrate and invertebrate species. Analytic and synthetic approaches.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.

**BIOL 5456. Organization and Development of the Nervous System. 3 Credit Hours.**
This course covers developmental, anatomical and integrative aspects of the nervous system. The relationship of form to function will be studied in a variety of systems both invertebrate and vertebrate. The course is intended to complement Neurobiology 352/452 so that students will have a perspective on neuroscience ranging from the molecular to the systems level.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.

**BIOL 5464. Biochemistry of Embryogenesis. 3 Credit Hours.**
This course will compare and contrast key biochemical mechanisms of embryonic development in a variety of model organisms ranging from humans to plants. We will examine the roles of enzymes, peptides, small RNA molecules and chromatin structure during embryogenesis. Topics will include micro RNAs, modification of DNA structure, and effects of mutation on enzyme activity. These basic principles will then be applied to subjects such as cell communication, stem cells, and cloning. Course material will be drawn from the experimental literature.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.

**BIOL 5465. Mammalian Development. 3 Credit Hours.**

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.

**BIOL 5466. Contemporary Biology. 3 Credit Hours.**
This course is typically offered in Fall and Spring.
Advanced discussion of selected topics.
This course is repeatable for credit.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may be repeated for additional credit.

**BIOL 5467. Endocrinology. 3 Credit Hours.**
Broad coverage of "chemical messengers", occurrence, biochemistry, and physiology. Vertebrate endocrinology with minor treatment of invertebrates and plants.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.

**BIOL 5469. Molecular Biology. 3 Credit Hours.**
A background knowledge of biochemistry and basic genetics at the undergraduate level is desirable. Structure, function and interaction of proteins and nucleic acids; building macromolecular complexes; techniques in molecular biology; introduction to molecular genetics and genomics; DNA replication and repair; transcription at the level of both genes and genomes; role of chromatin in gene regulation; non-coding RNAs; RNA processing; RNA interference; protein synthesis and its regulation; introduction to proteomics; transposons; regulatory proteins in eukaryotes.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.

**BIOL 5471. Cell Proliferation. 3 Credit Hours.**
Discussion of cell proliferation and its control; assay systems, comparisons of proliferating cells with nonproliferating cells, controls of cell division and how that control is modified in proliferative diseases such as cancer, the relationships between proliferation and differentiation.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.
BIOL 5474. Physical Biochemistry. 3 Credit Hours.
The course covers those aspects of computer simulation of molecular dynamics, quantum mechanics, and statistical mechanics of use to biochemist and biologist interested in molecular modeling. The course is intended to be computer intensive.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5475. General Biochemistry I. 3 Credit Hours.
Properties of water (pH and buffers); metabolism of carbohydrates, amino acids, fatty acids, and phospholipids properties of biomacromolecules proteins, and nucleic acids; DNA structure and replication; protein synthesis; energy generation; catalysis and control of enzymatic activity and interrelationships among the metabolic pathways.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5476. General Biochemistry II. 3 Credit Hours.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5479. Biotechnology. 3 Credit Hours.
This course is designed to survey current issues in technologies including therapeutics and diagnostics, and to examine consequences of developments in this area. The course is designed in a Problem Based Learning format, where students research critical areas and provide oral and written reports for other members in the class. The course is organized by topics including Concepts in Genetics, Cloning and Ethics, Gene Therapy, Prenatal Diagnosis, Gene Therapy for Cancer, Cell Replacement Therapy, Genomics and Proteomics, Vaccines, Forensics, Plant Biotechnology, and Instrumentation. At the end of the course, each student makes a formal presentation on a specific advance in biotechnology.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5501. Analytical Biotechnology. 1.5 Credit Hour.
This course provides a comprehensive survey of current techniques of biomolecule measurement and analysis using biochemical testing as the basis of measurement in a biotechnology laboratory. The detection, purification, and characterization of biomolecules (proteins, nucleic acids, carbohydrates, and lipids) are major goals in biotechnological research and development. Specific biomolecules serve as markers for the accurate and sensitive diagnosis of disease, and afford drug targets for disease treatment. Biomolecules also can be indicators of harmful (or beneficial) environmental agents and conditions. New, highly sensitive and accurate analytical methods are now available for the detection of diverse biomolecules. Note: Biochemistry Majors who have completed CHEM 4375 or CHEM 4404 with a minimum grade of C may register for BIOL 5501 with permission from instructor.

Level Registration Restrictions: May not be enrolled in one of the following Levels: Undergraduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5502. Microbial Biotechnology. 3 Credit Hours.
Course covers use of microorganisms in biotechnology. Includes recombinant DNA methodology and application of these approaches to production of medicines and for environmental remediation. Synthetic biology and metabolic engineering will also be covered (theory and concepts).

Level Registration Restrictions: May not be enrolled in one of the following Levels: Undergraduate.

College Restrictions: Must be enrolled in one of the following Colleges: Engineering, Medicine, Lewis Katz School, Pharmacy, Science & Technology.

Repeatability: This course may not be repeated for additional credits.
BIOL 5503. Biotechnology Laboratory I. 3 Credit Hours.
The biotechnology laboratory course is designed for students in the Professional Science Master's Program in Biotechnology. Students in the program will be recruited from Science, Technology, Engineering and Math (STEM) undergraduate majors and this hands-on course is designed with this understanding. The course will introduce students to some of the basic laboratory approaches used in the analysis of biologically-active environmental contaminants and in the synthesis of new and existing drugs. The first part of the course will emphasize molecular biological tools useful in drug design and contaminant analysis. The second part of the course will emphasize the chemical analysis of biologically-active compounds. The course will be problem-oriented with small team participation. The course will prepare students for a research project as part of the requirements for completion of the Professional Science Master's in Biotechnology.

Level Registration Restrictions: May not be enrolled in one of the following Levels: Undergraduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5504. Biotechnology Laboratory II. 3 Credit Hours.
The biotechnology laboratory course is designed for students in the Professional Science Master's Program in Biotechnology. Students in the program will be recruited from Science, Technology, Engineering and Math (STEM) undergraduate majors and this hands-on course is designed with this understanding. The first part of the course will introduce students to microorganisms relevant to human and environmental health, for example pathogenic organisms as well as antibiotic-producing organisms. The second part of the course will focus on genomic and proteomic techniques and the use of bioinformatics in drug design, bioremediation and related challenges. The course will be problem-oriented with small team participation. The course will prepare students for a research project as part of the requirements for completion of the Professional Science Master's in Biotechnology.

Level Registration Restrictions: May not be enrolled in one of the following Levels: Undergraduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5505. Ethics Regulation and Policy in Biotechnology. 3 Credit Hours.
The Bioethics, Policy and Regulation course is designed for students in the Professional Science Master's Program in Biotechnology. This course will provide an understanding of ethical decisions, governmental regulations and policies in biotechnology. A case study approach will be used to provide a framework for discussions of policy and ethical decision making. Guest speakers will provide insights from legal and governmental perspectives on emerging and current biotechnology applications.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5506. Professional Development Seminar for PSM in Biotechnology. 1 Credit Hour.
The PSM program prepares graduates for careers in biotechnology-related fields with a strong emphasis on skill areas that include management, policy and regulation in addition to scientific discovery. This course will provide students with career exposure through interviews with professionals in government and industry and will assist students in developing a career plan. Students will develop a white paper on the current state of Biotechnology based on new advances and challenges in the past year. Members of the advisory board will participate in facilitating the course.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of B- in BIOL 5501, BIOL 5503, and BIOL 5505.

BIOL 5509. Computational Genomics. 3 Credit Hours.
This is a course on the application of genome-related concepts to genome sequence data. Students will gain familiarity with both existing software and with basic programming (scripting) skills for problems in genomics. Further, students will come to understand the connections between standard computational and statistical approaches and their underpinnings in those fields increasingly dominated by genomic approaches. These include the fields of molecular evolution, population genetics, molecular genetics, molecular biology, and biochemistry. The course will be a hands-on computational lab course, with students working on problems and assignments in class using their laptop computers.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of B- in BIOL 5403.
BIOL 5511. Ethics in Bioinformatics. 2 Credit Hours.
This course will examine the social, legal, and privacy issues of applying computational approaches to large datasets including those from personal genome projects. The class will expose students to variation-based approaches in genomics, policies and strategies to share genomic data, database management and security, open-access and open-source philosophies, the ethics of collecting, storing, and disseminating human data, and HIPAA, FDA, and IRB regulatory policies for health care professionals and bioinformaticians. Students will be given the opportunity to discuss contemporary case studies, in addition to NIH-sanctioned online training modules (Responsible Conduct in Research).

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5514. Biological Models in Python. 3 Credit Hours.
This course provides an introduction to the field of computational biology by implementing biological models in the Python programming language. In addition to coverage of the basics of the Python language, topics will include: phylogenetic tree models, implementation of Markov models for biological problems, data structures and algorithms for the analysis of biological sequences, and the use of popular Python modules relevant for biological modeling. Prior basic knowledge of evolutionary theory and of genetics/genomics is expected. Some prior scripting experience is helpful, but students are not required to have an extensive coding background. This is a hands-on computational lab course, with students working on problems in class using their laptop computers.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5521. Nucleic Acid Technologies. 1.5 Credit Hour.
This course provides a focused examination and analysis of the basic structures and properties of RNA and DNA; the enzymes that synthesize or modify these biomolecules; and biotechnological applications. The synthesis and purification of DNA and RNA will be reviewed along with detection methodologies, including enzymatic amplification, array analysis, and amplification-free (direct) approaches. Nucleic acid sequencing technologies, including the analysis of ancient or degraded DNA and emerging nanopore-based sequencing approaches, will be surveyed. Finally, the course will examine how the inherent ability of DNA and RNA to self-assemble can be harnessed to provide novel nanostructures with complex architectures, and that show promise in biomedical and biotechnological applications. Note: Biochemistry Majors who have completed CHEM 4375 or CHEM 4404 or BIOL 5501 with a minimum grade of C may register for BIOL 5521 with permission from instructor.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5522. Introduction to Scientific and Regulatory Writing. 3 Credit Hours.
This course introduces students to the two primary types of medical writing done by/for pharmaceutical and biotech companies. Specifically, students will learn how to research and write abstracts, posters, clinical reports and other research manuscripts, patient education materials, and slide kits. In addition, students will be introduced to the basics of strategic planning and consulting, including the creation of publication plans and meeting planning from a marketing perspective. Students will also learn the fundamentals of regulatory writing. Topics will include overviews of U.S. and international regulatory agencies, product life cycles, the conduct of clinical trials and reporting clinical trial results, and activities and documentation involved with submissions for marketing approval of treatments.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5532. Introduction to Grant Writing. 3 Credit Hours.
This course is designed for students who plan to enter professional careers requiring knowledge of grant writing. The course will teach students the mechanics of proposal writing and the political and social aspects of “grantsmanship” as they develop their skills in identifying sources of grant funding, doing useful research to support their applications, and tailoring their proposals to specific audience interests. There will be several short writing assignments, an exam, and an independent project. Students may also be asked to engage in a collaborative grant project to help build their skills in collaboration.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.
BIOL 5533. Communicating Science to a Broader Audience / Non-Scientists. 3 Credit Hours.
This writing intensive course will be developed as a hybrid class with online and in-class components, with instructor/s interacting with students by editing multiple drafts of a paper requiring the students to communicate a science topic to readers with either no science background or backgrounds in other STEM fields. The learning goal of this course will be emphasizing the communication of scientific theory and concepts to wide-ranging audiences, especially non-scientists. The class will require students to demonstrate the ability to break down complex science into accurate, yet understandable explanations, by writing an article in the style of the New York Times science section, or a science report in a newspaper such as the Philadelphia Inquirer.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 5582. Graduate Independent Study. 1 to 3 Credit Hour.
Explorative study or research initiated by a graduate student with faculty sponsorship and an approved independent study contract.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credits.

BIOL 8001. Teaching of Biology. 2 Credit Hours.
Required of all first-year teaching assistants. Instruction in the art of teaching laboratories and recitations.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 8002. Teaching of Biology. 2 Credit Hours.
Required of all first-year teaching assistants. Instruction in the art of teaching laboratories and recitations.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credits.

BIOL 8003. Introduction to Graduate Research. 3 Credit Hours.
This course will provide entering doctoral students in Biology with a broad perspective on philosophical and scientific reasoning, introduce overarching principles in both bioethics and biostatistics, and initiate student development through exercises that emphasize both written and oral communication skills necessary for a successful career in the sciences.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 8210. Seminar. 1 Credit Hour.
Seminar. Topics will vary.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

BIOL 8220. Seminar. 1 to 4 Credit Hour.
Required Laboratory Research Rotation for all first year graduate students.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

BIOL 8250. Seminar. 3 Credit Hours.
Seminar. Topics will vary.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.
BIOL 8260. Seminar. 2 to 4 Credit Hours.
Seminar. Topics will vary.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

BIOL 8450. Seminar. 3 Credit Hours.
Seminar. Topics will vary.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

BIOL 8510. Seminar in Neuroscience. 3 Credit Hours.
A discussion of recent advances in the clinical and experimental Neurosciences using original research papers or reviews. Particular topics are selected on the basis of student interests and background.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

BIOL 8802. Research Techniques. 4 Credit Hours.
Laboratory instruction in the biochemical and biophysical techniques used to investigate biological problems.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOL 8985. Teaching in Higher Education: Life Sciences. 1 to 3 Credit Hour.
This course focuses on the research on how people learn and best teaching practices, with the aim of preparing students for effective higher education life science teaching.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

BIOL 9283. Directed Readings. 1 to 9 Credit Hour.
Directed study and discussion of the current research literature

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

BIOL 9991. Master’s Research Projects. 1 to 6 Credit Hour.
Short-term, limited research project or laboratory project in the field. This course is not the capstone project course, nor can it be used for thesis based research. The course is for master’s students only, including PSM, MA or MS. This class will not confer full-time program status unless nine credits are taken.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

BIOL 9994. Preliminary Examination Preparation. 1 to 6 Credit Hour.
This course is required for students who are preparing for the preliminary or candidacy examination. Students should enroll after coursework is completed or when preparing for the candidacy exam until the time that the preliminary or candidacy examination is completed. This course will confer full-time status at the minimum credit hour registration limit of one credit. All students must complete a minimum of one credit of this course. Students must complete a total of 6 credit hours of 9994, 9998 and 9999.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.
**BIOL 9995. Capstone Project. 1 to 6 Credit Hour.**
Capstone project for master's students including students in PSM, MA or MS. This class will provide full-time status. Students in PSM programs need to register for at least one credit of this course to fulfill program requirements. Additional credits may be required for specific programs. Students in the MA program may satisfy this course requirement by completing a library thesis. This course will confer full-time status at the minimum credit hour registration limit of one credit.

**Level Registration Restrictions:** May not be enrolled in one of the following Levels: Undergraduate.

**Repeatability:** This course may be repeated for additional credit.

**BIOL 9996. Master's Thesis Research. 1 to 6 Credit Hour.**
Course for master's thesis research. Only intended for students in thesis bearing master's programs. A minimum of one credit is required. This course will confer full-time status at the minimum credit hour registration limit of one credit.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may be repeated for additional credit.

**BIOL 9997. Pre-Dissertation Research / Elevation to Candidacy. 1 to 6 Credit Hour.**
This course is intended for students who are performing research prior to candidacy. Students can register for this course after required courses are completed. This course will confer full-time status at the minimum credit hour registration limit of one credit. Students must be registered for this course during the semester that they are to be elevated to candidacy examination. Students must complete a total of 6 credit hours of 9994, 9998 and 9999.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Student Attribute Restrictions:** Must be enrolled in one of the following Student Attributes: Dissertation Writing Student.

**Repeatability:** This course may be repeated for additional credit.

**BIOL 9999. Dissertation Research. 1 to 6 Credit Hour.**
The course is for Ph.D. students who have been elevated to candidacy. During the course of their candidacy students must complete a minimum of two credits of dissertation research. This course will confer full-time status at the minimum credit hour registration limit of one credit. Students must complete a total of 6 credit hours of 9994, 9998 and 9999.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may be repeated for additional credit.

---

**Computer & Information Science Courses**

**CIS 5001. Comp-Based Appl Prog. 3 Credit Hours.**
The course emphasizes component-based application programming using the Microsoft Visual Studio Integrated Development Environment (IDE). Students will learn (and practice using) the VB .NET programming language, object-oriented software design techniques, and the principles of good user interface design. Topics include building quality software, including user interfaces to databases (using ADO.NET), sequential files, and graphics tools. Object-oriented concepts such as inheritance, polymorphism, static and dynamic binding, and interface (abstract class) components will be covered. The use of ASP.NET for client-server systems development is also elaborated. Note: Graduate credit will not apply for CIS MS/PHD programs.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.

**CIS 5002. Database Design & Programming. 3 Credit Hours.**
This course provides an in-depth understanding of the modeling, design and implementation of database systems. Students develop an appreciation of the role of data, files and databases in information systems, gain an understanding of database development activities as part of the System Development Life Cycle (SDLC), and become familiar with data modeling concepts. Students are expected to be able to create databases and pose complex SQL queries of relational databases using Oracle and Microsoft Access. Topics include the relational model, E-R and Class Diagrams, normalization, advanced SQL, Oracle Enterprise system transaction processing, concurrency control, and recovery. Also covered are aspects of database administration, data integrity, security and authorization, stored procedures and triggers, the embedding of SQL in procedural languages and scripting languages, multi-tiered architectures, middleware, ODBC web-based databases, and web application integration. Students work in teams to implement large scale information system using a DBMS. CASE tools are used for data modeling. Note: Graduate credit will not apply for CIS MS/PHD programs.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.
CIS 5003. Networking & Operating Systems. 3 Credit Hours.
This course covers the essentials of operating systems and computer networks. Topics include: the processor, data and program representation, computer memory systems, software system support for I/O including support for networking, and a thorough introduction to the TCP/IP protocol suite.
Note: Graduate credit will not apply for CIS MS/PHD programs.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5011. Programming and Data Structure. 3 Credit Hours.
Preparatory course for CIS graduate students who have an insufficient background in data structures, and need a stronger foundation before taking the required core course, Programming Techniques 5511 (formerly 8511). Note: Graduate credit will not apply for CIS MS/PHD programs.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5012. System Software and Operating Systems. 3 Credit Hours.
Preparatory course for CIS graduate students who have an insufficient background in operating systems, and need a stronger foundation before taking the required core course, Operating Systems 5512. Note: Graduate credit will not apply for CIS MS/PHD programs.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5013. Discrete Structure of Computer Science. 3 Credit Hours.
Preparatory course for CIS graduate students who have an insufficient background in discrete structures, and need a stronger foundation before taking the required core course, Automata & Formal Languages 5513. Note: Graduate credit will not apply for CIS MS/PHD programs.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5015. Scripting for Sciences and Business. 3 Credit Hours.
Focus on three scripting languages and multiple operating environments for scientific computing and for business, practical scientific computing projects, and integration of numerical computation with experimental results.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5016. Data Structures and Objects. 3 Credit Hours.
Data structures are the fundamental building blocks for organizing data. This course teaches how to build data structures and what can be done with them, as well as fundamental object oriented concepts. Topics include object oriented programming, lists, stacks, queues, trees, heaps, hash tables, graphs, sorting, and recursion. Note: Students may not receive credit for both CIS 2168 and CIS 5016. This is an MS/IST course. No credit for graduate CS programs without approval from CIS department.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5017. Operating Systems and Architecture. 3 Credit Hours.
This course provides an introduction to computer architecture and operating systems concepts to students without a background in computer systems. The objectives are to introduce the basic concepts for understanding and evaluating operating systems and the most important computer architecture issues impacting operating system design, implementation and selection. Note: Students may not receive credit for both CIS 2229 and CIS 5017. This is an MS/IST course. No credit for graduate CS programs without approval from CIS department.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.
CIS 5105. IT Process Management. 3 Credit Hours.
An introduction to essential techniques for successfully creating, organizing and managing IT projects. The course provides the foundation for more advanced studies in process management and software engineering. Enterprise-wide requirements, long-range planning and managing all aspects of the development process will be emphasized. The course will stress the use of appropriate software tools and process modeling throughout the development lifecycle. Quality assurance techniques are introduced at the outset to guide IT processes and decision making. Note: This is an MS/IST course. No credit for Graduate CS programs.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5106. System Development Processes. 3 Credit Hours.
Methods and tools for the technical development of IT systems are presented and used in case projects. The course follows the normal development lifecycle, starting with the recognition and justification of the need for either a new system or an upgrade to an existing system. It then proceeds through analysis, specification, design, implementation, testing (quality assurance), client training and turnover, and maintenance. The importance of each development stage will be taught within the framework of systems reliability, effectiveness, security, scalability, and development cost. Note: This is an MS/IST course. No credit for Graduate CS programs.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5107. Comp Systems Security&Privacy. 3 Credit Hours.
Computer systems security and information privacy has become a critical area of computer science development and research. This course involves an analysis of the technical difficulties of producing secure computer information systems that provide guaranteed controlled sharing and privacy. Emphasis is on software modeling and design to better ensure the protection of resources (including data and programs) from accidental or malicious modification, destruction, or disclosure. Current systems and methods will be examined and critiqued. The possible certification of such systems will also be investigated. Note: This is an MS/IST course. No credit for Graduate CS programs.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5108. Emerging Technologies. 3 Credit Hours.
The purpose of this course is to provide students with an understanding of maturing and emerging technologies and their likely impact on the networked information paradigm and enterprise management. Both hardware and software technologies will be covered. Students will be introduced to advanced software tools that demonstrate how agency enterprises make use of vast information flows and interconnectivity. Note: This is an MS/IST course. No credit for Graduate CS programs.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5208. Knowledge Management. 3 Credit Hours.
Principles of knowledge management (KM) and their use in locating, evaluating, disseminating, and using information and knowledge. Application of these principles and techniques. Knowledge management incorporates data acquisition, information integrity, and management of knowledge and is crucial to everyone working in any field where information is stored, processed, and used. It places a premium on an IT-intensive organization to invest, cultivate, and fully utilize the intellect and knowledge of all staff. Note: This is an MS/IST course. No credit for Graduate CS programs.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5210. Seminar in Information Science and Technology. 3 Credit Hours.
An intermediate level graduate special topics course in current and emerging developments in information systems and technology. Note: This is an MS/IST course. No credit for Graduate CS programs. This course is repeatable for credit.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.
CIS 5221. Introduction to Mobile Application Development. 3 Credit Hours.
This course will introduce students to concepts in application development for mobile devices. Students will learn how to address challenges in hardware and user interfaces by incorporating software design and user-interaction design principles. Additionally, students will learn about mobile-centric concerns such as software and data distribution models, leveraging third party software, and managing data locally and remotely. Students should have prior experience in building applications that involve Object Oriented Development principles, such as inheritance, interfaces, encapsulation, and polymorphism. Additionally it would be good to have had a major role in working on a non-trivial software development project, such as a transactional system with CRUD (create, read, update, delete) operations, or a systems level program.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5274. Software Quality Assurance and Testing. 3 Credit Hours.
Software quality assurance consists of a means of monitoring the software engineering processes and methods used to ensure quality. The overarching goal of this class is to develop practical skills to help achieve software quality. The main objectives of this class are to understand the quality assurance process and to learn how to use testing techniques to achieve software quality. Students will learn 1) fundamental concepts in software testing, including software testing objectives, process, criteria, strategies, and methods; 2) various software testing techniques, including automated testing techniques, to support various levels of software testing: unit, integration, regression, and systems testing; 3) techniques and skills on how to use modern software testing tools to support software testing projects; 4) how to plan a test project, design test cases and data, conduct testing operations, manage software problems and defects, and generate a testing report; and 5) basic techniques in usability, performance, and security testing. Note: Students may not receive credit for both CIS 3374 and CIS 5274. This is an MS/IST course. No credit for Graduate CS programs.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5221. Introduction to Mobile Application Development. 3 Credit Hours.
CIS 5304. Network Technologies. 3 Credit Hours.
Focuses on the design, construction and use of modern networks and inter-networks, including Internet, intranet, firewalls, VPN, e-mail, and wireless technologies. Prepares students to successfully create and operate modern secure networks. Key concepts and technologies include LAN design and construction, Internet architecture, internetworking (with an emphasis on the Internet), WAN connectivity, firewalls, Application Layer protocols, virtual private networks, wireless and network operation in real-world environments. Note: This is an MS/IST course. No credit for Graduate CS programs.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5306. Software Engineering. 3 Credit Hours.
A project-based course focusing on current methodologies employed in software design and development. The core material covers the key components of software engineering, including requirements analysis, specification development, detailed design, program development, quality control (verification and validation), configuration management, testing, and post-development maintenance. Emerging software development techniques - security engineering, service-oriented architecture (SOA), and aspect-oriented development are also introduced. Note: This is an MS/IST course. No credit for Graduate CS programs.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5405. Introduction to Digital Forensics. 3 Credit Hours.
This course is a broad introduction to the field of Digital Forensics. It covers various fundamental topics necessary for digital forensics investigation. The course begins with foundations of electronic evidence including cyber-crime laws, the 4th amendment, compliance and requirements, collection and handling, analysis, and reporting. The course also covers fundamentals of file systems with specific details pertaining to Microsoft FAT file systems. Students will learn two important forensic techniques - file recovery and file carving - among other things. Finally, forensic artifacts relevant to Windows Systems and Networks are discussed with relevant lab activities and students are also introduced to Antiforensics. Hands-on lab activities familiarize students with several relevant investigation techniques and the use of open source forensics tools. Students who have completed an equivalent course at Temple or another institution will take an elective as recommended by the program advisor.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C in CIS 5017.

CIS 5410. Advanced Seminar in Information Science and Technology. 3 Credit Hours.
An advanced level graduate special topics course in current and emerging developments in the field of information systems and technology. Note: This is an MS/IST course. No credit for Graduate CS programs. This course is repeatable for credit.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

CIS 5415. Ethical Hacking and Intrusion Forensics. 3 Credit Hours.
This class will introduce students to the field of hacking with the primary focus being the difference between White-hat Hacking (a.k.a Ethical Hacking) and Black-hat Hacking. The course will enable students to understand how to use hacking techniques to perform a hack within legal confines. The course will focus on both technical and social aspects of security, ranging from cryptography and biometrics to risk mitigation and disaster recovery aspects of organizational security. Of specific focus will be the following broad concepts - Reconnaissance, Scanning, enumeration, and Sniffing and Evasion. Based on the ethical concepts built during the first half of the semester, students will learn the process involved with forensics investigations of intrusion attack.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C in CIS 5017 and CIS 5107.
CIS 5425. Audit and Compliance for Security and Digital Forensics. 3 Credit Hours.
Information Systems' audit and assurance professionals are faced with different requirements and different types of audit and assurance. This course will provide students with a basic understanding of enterprise IT security and the need for audit and compliance. Students will learn about IT Security Terminology, Governance, and the Security audit practice that has matured into given sets of frameworks, methodologies, approaches, and models with certain sets of underlying assumptions such as COBIT, SOX, DoD, FIPS 100/200, FISMA, NIST, HSPD, OMB. Students will be exposed to various governance standards and federal compliance requirements - ISO27000, SAS, GAAP. Students will also learn some fundamentals such as differences between policy, process and procedure and the purpose of policy, process and procedure. Students who have completed an equivalent course at Temple or another institution will take an elective as recommended by the program advisor.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5511. Programming Techniques. 3 Credit Hours.
Prerequisites: CIS 2168 and CIS 3223.
A more formalized view of data structures. Stacks, trees, tables, lists, multilinked structures, strings and files are considered. These are viewed in terms of their general usefulness in the construction of algorithms and in their efficient implementation. Both theoretical results and programming techniques will be stressed.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5512. Operating Systems. 3 Credit Hours.
Prerequisites: CIS 3207 and CIS 3223.
Basic principles of operating systems; multi-tasking systems; control and coordination of tasks; deadlocks; synchronization, mutual exclusion, sharing; memory management, virtual memories, segmentation, paging; protection; file systems; resource management; evaluation and prediction of performance; design and implementation of operating systems in high-level languages.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5513. Automata and Formal Languages. 3 Credit Hours.
Prerequisites: CIS 2166 and CIS 3242.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5515. Design and Analysis of Algorithms. 3 Credit Hours.
The course objective is to provide students with an understanding of the principles and techniques used in the design and analysis of efficient algorithms. The main topics cover Greedy Algorithms, Divide and Conquer, Dynamic Programming, Network Flow, and Approximation Algorithms. Theoretical results related to NP-completeness will also be discussed.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C in CIS 5511.

CIS 5516. Principles of Data Management. 3 Credit Hours.
Prerequisites: CIS 5511 (or 8511).
This course covers fundamental concepts in constructing database management systems, including relational query languages, such as SQL and relational algebra, file organizations, storage management, system architectures, query processing, query optimization, transaction management, recovery, and concurrency control. Additional topics may include distributed databases, NoSQL databases and data integration.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.
CIS 5517. Data-Intensive and Cloud Computing. 3 Credit Hours.
Prerequisites: CIS 2168 and (CIS 2166 or MATH 2101 or ENGR 2011 or MATH 3045).
This course will expose students to recently emerged and fast moving technology of big data and cloud computing. It will cover a spectrum of topics from core techniques in data management and analysis to highly-scalable data processing using parallel database systems. Students will be introduced to big data ecosystems such as Hadoop, Spark, Storm and MapReduce; cloud technologies such as Amazon EC2, Microsoft Azure and Google Cloud; data management tailored to cloud and big data such as No SQL, Google Big Table/Apache HBase, and introductory applications to Big Data and cloud environment. Students will work directly with a selected set of these platforms, compare and contrast their relative strengths and weaknesses, and characterize the problems they are designed to solve. Note: Students may not receive credit for both CIS 5517 and CIS 4517.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5523. Knowledge Discovery and Data Mining. 3 Credit Hours.
Prerequisites: MATH 2043 and (CIS 2166 or MATH 2101 or ENGR 2011) and (MATH 3031 or ECE 3522 or STAT 2103 or BIOL 3312) and (CIS 1051 or CIS 1057 or CIS 1068).
Basic concepts and techniques for the automated extraction of interesting patterns in large databases. Topics covered include: association-rule mining, sequence mining, web and text mining, data warehousing, information filtering, classification and clustering analysis, Bayesian and neural networks, classification and regression trees, hypotheses evaluation, feature extraction, dimensionality reduction, singular value decomposition, data compression and reconstruction, visualization of large data sets, fractals in databases, and indexing methods that support efficient data mining and queries by content. Special emphasis is given in multimedia, business, scientific, and medical databases. Note: Students may not receive credit for both CIS 5523 and CIS 4523.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5524. Analysis and Modeling of Social and Information Networks. 3 Credit Hours.
Prerequisites: MATH 2043 and (CIS 2166 or MATH 2101 or ENGR 2011) and (MATH 3031 or ECE 3522 or STAT 2103 or BIOL 3312) and (CIS 1051 or CIS 1057 or CIS 1068).
This course will include methods for analyzing and modeling the following aspects of social networks: the small-world network models, centralized and decentralized social network search algorithms, power-laws and preferential attachment, diffusion and information propagation in social networks, influence maximization in social networks, community detection in social networks, models of network cascades, models of evolving social networks, links and attributes prediction. Note: Students may not receive credit for both CIS 5524 and CIS 4524.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5525. Neural Computation. 3 Credit Hours.
Prerequisites: STAT 8003/8103 and undergraduate-level understanding of probability, statistics, and linear algebra.
Neural networks provide powerful techniques to model and control nonlinear and complex systems. The course is designed to provide an introduction to this interdisciplinary topic. The course is structured such that students from computer science, engineering, physics, mathematics, statistics, cognitive sciences, and other disciplines learn the main principles of this area as well as have an opportunity to explore promising research topics through hands-on experience with neural network simulators applied to classification and prediction problems ranging from biomedical sciences to finance and business.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5526. Machine Learning. 3 Credit Hours.
Prerequisites: MATH 2043 and (CIS 2166 or MATH 2101 or ENGR 2011) and (MATH 3031 or ECE 3522 or STAT 2103 or BIOL 3312) and (CIS 1051 or CIS 1057 or CIS 1068).
The goal of the field of machine learning is to build computer systems that learn from experience and are able to adapt to their environments. This introductory machine learning course will present modern machine learning algorithms for supervised and unsupervised learning. It will provide the basic intuition behind the algorithms as well as a more formal understanding of how and why they work. Students will learn how to apply machine learning algorithms on a range of real-life problems and how to evaluate their performance.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.
CIS 5527. Data Warehousing, Filtering and Mining. 3 Credit Hours.

Prerequisites: CIS 5511 (or CIS 8511) and an undergraduate course in databases.

The course is devoted to information system environments enabling efficient indexing and advanced analyses of current and historical data for strategic use in decision making. Data management will be discussed in the context of data warehouses/data marts; Internet databases; Geographic Information Systems, mobile databases, temporal and sequence databases. Constructs aimed at an efficient online analytic processing (OLAP) and those developed for nontrivial exploratory analysis of current and historical data will be discussed in detail. The theory will be complemented by hands-on applied studies of problems in such fields as financial engineering, e-commerce, geosciences, and bioinformatics.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5535. Probabilistic Graph Models. 3 Credit Hours.

Prerequisites: CIS 2033 and CIS 3223.

Probabilistic graphical models are very important machine learning tools for knowledge representation and reasoning under uncertainty. They have been widely used in machine learning and related fields, such as computer vision, natural language processing, data mining, bioinformatics and even computer network research. This course aims to make a comprehensive introduction over the most important theories, algorithms, and applications of probabilistic graphical models, and facilitate the advanced research within the computer & information sciences department and related disciplines outside.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5538. Text Mining and Language Processing. 3 Credit Hours.

Prerequisites: CIS 2033.

This course will cover a broad overview of problems and techniques in text mining and natural language processing. It will also provide in-depth coverage of the latest natural language processing research in selected topics. The in-depth part of the course will focus on the latest research in unsupervised information extraction. This part of the course will cover such techniques as pointwise mutual information, pattern-matching, bootstrapping, Hidden Markov Models, Conditional Random Fields, and language modeling techniques, among others.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5543. Computer Vision. 3 Credit Hours.

Prerequisites: CIS 2033 and CIS 3219 and CIS 3223.

The objective of the course is to introduce the theory and application of computer vision. The theoretic part introduces the analysis of visual patterns and the generative models behind them. The application part uses real world tasks to help students to learn practical computer vision technologies. The course covers the following topics: image formation (camera model, color space, illumination model, etc.), low level vision processing (edge detection, intensity based segmentation, etc.), popular research tools in computer vision, visual matching and registration, visual recognition, image and category classification, scene understanding, object detection, visual tracking, activity and action analysis, and selected advanced topics. In addition to course lectures, the course uses homework assignments, in-class discussions and course projects.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5590. Topics in Computer Science. 3 Credit Hours.

Prerequisites: Special authorization required.

Current topics and issues in Computer Sciences are covered. This course is repeatable for credit.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

CIS 5603. Artificial Intelligence. 3 Credit Hours.

Artificial intelligence encompasses the algorithms and representations used to design computers and agents for problem-solving and learning. This course covers the classic and modern methods that support technology such as game-playing agents, autonomous vehicles, and virtual assistants. The topics covered include: search, reasoning, knowledge representation, and learning. The course is intended to prepare graduate students for further study in machine learning, data mining, robotics, and computer vision.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.
CIS 5617. Computer Networking and Communication. 3 Credit Hours.
Prerequisites: CIS 5511 (or 8511) and CIS 5512 (or 8512).
Introduction to the design and analysis of computer networks and communications systems, including the Physical, Data Link, Network, Transport and Application layers. The Internet (TCP/IP) model will be emphasized and compared and contrasted with other current technologies. Major themes include the distinction between service and protocol, performance metrics, analysis techniques, and fundamental performance tradeoffs.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5618. Energy Management in Data Centers and Beyond. 3 Credit Hours.
Students are expected to have a background in data structures and algorithms as well as computer architecture and operating systems. Comprehensive coverage of energy management in data centers: essential concepts in data center architecture, including the computing core, data center network, and storage systems; energy management in computing elements, caches, “in-the-box” interconnects, primary memory, storage systems, and data center network; data center level issues including power, thermal, and cooling management at data center level and interaction of data centers with smart grid. Other issues covered include design of energy efficient software, virtualization and energy management of VMs, energy issues in cloud computing, and modeling of energy-performance interplay.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5635. Security in Cyber-Physical Systems. 3 Credit Hours.
Prerequisites: CIS 3207 and CIS 3223.
Cyber-Physical Systems (CPS) augment physical systems with monitoring, communication and control capabilities to enhance their efficiency, flexibility, safety, and resilience. The course will start with an overview of these opportunities and challenges and then gradually explore a few physical systems including their monitoring, communications, control, safety, and security requirements, as well as potential attack vectors and solutions.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5636. Ad Hoc Networks. 3 Credit Hours.
Prerequisites: CIS 3223, and CIS 4319 or 4329.
A comprehensive approach to fundamentals of ad hoc networks including media access protocols, routing protocols, implementation and communication performance analysis.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5637. Network & Information Security. 3 Credit Hours.
Prerequisites: CIS 3329 or CIS 4319 or CIS 5003.
This course introduces fundamental knowledge of cryptography and its applications to network and information security.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5639. Wireless Network and Communication. 3 Credit Hours.
Prerequisites: CIS 3207 and CIS 3223.
This course introduces the fundamental design and performance issues of wireless networks and communications.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.
CIS 5642. Computer Architecture. 3 Credit Hours.
Prerequisites: CIS 2168 and CIS 3207.
Since 1951, there have been thousands of new computers using a wide range of technologies and having widely varying capabilities. Dramatic changes
that have occurred in just over 50 years. After adjusting for inflation, price/performance has improved by almost 100 billion in 55 years, or about 58% per
year. Another way to say it is we’ve seen a factor of 10,000 improvement in cost and a factor of 10,000,000 improvement in performance. This course
covers the recent developments in modern computer architectures and the emerging design methods for high performance computing.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5643. Emerging Storage Systems and Technologies. 3 Credit Hours.
Prerequisite: CIS 3207.
Storage systems are of increasing importance because of ever-growing volume, velocity, and heterogeneity of data produced by a wide variety of
computer systems. This course will provide a comprehensive coverage of storage and file systems that underlie bigdata systems with respect to both
technological and application related challenges.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5644. Distributed Systems. 3 Credit Hours.
Prerequisites: CIS 2166 and CIS 2168 and CIS 5512 (or 8512).
We consider a distributed computer system that consists of multiple autonomous processors that do not share primary memory but cooperate by
sending messages over a communication network. Discussion of special problems related to distributed control such as election and mutual exclusion,
routing, data management Byzantine agreement, and deadlock handling.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 5701. Introduction to Teaching Computer Science Principles. 3 Credit Hours.
This course provides students with a foundation in the concepts and computational thinking practices central to the discipline of computer science. The
content in this course is organized around ideas that are foundational to the study of computer science: creativity, abstraction, data and information,
algorithms, programming, and the global impact of computing. By the end of the course, students will be able to apply creative processes and
computational thinking skills to develop a computer program in order to solve a problem. In addition, students will engage in pedagogical content related
to equitable and inclusive teaching of computer science principles in secondary education. This course assumes no prior knowledge of computing. It is
designed to support K12 teachers who are new to the computer science discipline and want to integrate computational thinking and computer science
principles into their classroom teaching activities. This course cannot be taken for credit towards any other graduate programs offered by CIS.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C in MATH 1021.

CIS 5702. Teaching Advanced Computer Science Principles. 3 Credit Hours.
Creating computer programs that solve problems is facilitated by the use of abstractions. Building on the computational thinking concepts and practices
learned in the previous course, this course will extend students’ knowledge of computational thinking, problem solving, and programming abstractions.
Students will extend their knowledge and practice the use of simple algorithms as part of a computer program. In addition, students will extend their
knowledge of basic types used to represent data in programming languages, including primitive data types, strings, classes, arrays, and streams.
Students will also be introduced to more advanced programming language concepts (e.g., parameter passing techniques) and basic object-oriented
programming abstractions (e.g., classes, objects, inheritance, and polymorphism). Searching and sorting algorithms will be covered, with a focus on
exposing students to different algorithm design strategies (iterative vs. recursive). Finally, students will apply pedagogical principles related to equitable
and inclusive teaching of computer science principles in secondary education to begin developing a portfolio of teaching materials that they can use in
their own classrooms. This course cannot be taken for credit towards any other graduate programs offered by CIS.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C in CIS 5701.
CIS 5703. Teaching Networked Computing Systems. 3 Credit Hours.
This course provides an introduction to computer networks with a strong focus on the Internet. Topics introduced include the layered network architecture, types of connectivity, addressing, packet switching, routing, reliable data transmission, and network security. The course will include discussions regarding Internet security, privacy, modern networked applications, and social implications and ethics. It will also build on knowledge of algorithms and data structures, introducing queues, graphs, trees, and related algorithms used in the function of network protocols and the Internet. In addition, students will engage in pedagogical content related to equitable and inclusive teaching of networked computer systems concepts in secondary education.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C in CIS 5702.

CIS 5704. Teaching the Use of Data, Algorithms, and Creativity for Problem Solving. 3 Credit Hours.
In this course, students will advance their understanding of computer science principles through the development of a creative computational artifact that can be demonstrated and used for teaching purposes in secondary education classrooms. Through this experience, students will develop knowledge about how to represent and store data as well as how to appropriately select and apply algorithms to solve problems. Students will also explore user interaction and user experience design choices and their impact on populations of users. An essential learning objective is to understand the impact of the choice of data type and algorithm on the quality attributes of programs. Searching and sorting algorithms will be covered, with a focus on exposing students to different algorithm design strategies (iterative vs. recursive). In addition, students will develop, compile, present, and evaluate portfolios of pedagogical content related to equitable and inclusive teaching of computer science in secondary education, with a focus on strategies to increase student engagement and broaden participation of underrepresented groups in computing. This course cannot be taken for credit towards any other graduate programs offered by CIS.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites: Minimum grade of C in CIS 5702.

CIS 9182. Independent Study. 1 to 6 Credit Hour.
Independent research supervised by a Computer and Information Sciences faculty member. NOTE: Only six credits of independent study can be counted towards any MS degree.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

CIS 9190. Seminars in Computer and Information Science. 1 Credit Hour.
Throughout the semester, various guest lecturers will discuss their area of research. Students are required to attend at least five lectures and submit five short papers on the topics presented. This course counts in the same category as independent study when it comes to program requirements (MS and/or PhD degree). This course is recommended for PhD students who have passed the qualifying exam, to broaden their research interests. This course is recommended for MS students who are interested in CIS research and want to take 10 credits per semester.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
College Restrictions: Must be enrolled in one of the following Colleges: Science & Technology.

Repeatability: This course may be repeated for additional credit.

CIS 9282. Independent Study. 1 to 6 Credit Hour.
Independent research supervised by a Computer and Information Sciences faculty member. NOTE: Only six credits of independent study can be counted towards any MS degree.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

CIS 9590. Seminar in Advanced Topics in Computer Science. 3 Credit Hours.
Prerequisites: Permission of instructor.
Topics to be decided individually.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.
CIS 9601. Computer Graphics and Image Processing. 3 Credit Hours.
Prerequisites: CIS 5511 or 8511.
An analysis of techniques used in computer manipulation of two- and three-dimensional images. Although elements of computer graphics are covered (e.g., two- and three-dimensional transforms), the main focus is on image processing techniques. We will also gain insight into basic techniques in computer vision. Topics covered include image filters, image segmentation, similarity of images, object detection, object recognition, and shape representation and similarity. Nowadays it is an easy task to transfer visual input of a camera to a computer's memory. However, image and video understanding belong still to unsolved problems of computer science. The main objective of the course is to convey basic intuitions behind the unsolved and solved problems and to introduce some of the techniques that provided solutions to some of the problems.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 9602. User Interface Design and Systems Integration. 3 Credit Hours.
Prerequisites: CIS 5511 or 8511.
This course focuses on the principles of usability engineering to design effective interfaces and as the basis for integrating existing systems to form new systems. The course builds on knowledge of networking, databases, and programming. The course outline is partly based on the recommendations of the ACM Special Interest Group on Computer-Human Interaction for an introductory graduate course on user interface design.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 9618. Web Applications Development. 3 Credit Hours.
Prerequisites: CIS 5511 (or 8511) and CIS 5512 (or 8512).
This course takes a technology-based approach to software engineering of networked application systems design and programming. It draws on new Microsoft .NET technology, together with former object-oriented design and programming, for its theoretical, architectural, and system design foundations. The course bridges software engineering principles in their most abstract and conceptual sense, with programming technique in its most concrete and pragmatic sense. It demonstrates how to optimize productivity of the software engineer, integrate the best that open technologies have to offer, and build large-scale systems that operate most efficiently on the internet. The course is divided into three parts: 1) theory that flows from .NET and object-oriented methodologies, including Application System Architectures, Design Methodologies, Quality Assurance, Scalability, and Security; 2) development of a working skill set in two .NET languages: ASP.NET and VB.NET and its major development tool, VS.NET; and 3) design and programming of a small but complete web-deployed application.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 9651. Artificial Intelligence, Heuristic Models, and Education. 3 Credit Hours.
Prerequisites: CIS 5603 or 8603.
Introduction to how artificial intelligence and heuristic models are used to build better computer-based educational systems. Current as well as past models are explored (e.g. PROUST, GUIDON, SOAR, etc.). Key issues to be examined include student models, interfaces, pedagogical expertise, domain expertise, and collaborative learning systems.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 9665. Advanced Topics in Data Base Systems. 3 Credit Hours.
Prerequisites: CIS 5516 or 9616.
Survey of recent developments in database systems with an emphasis on object-oriented databases (OODB’s). Prototype and operational OODB systems will be analyzed. Applications of OODB’s to computer-aided software engineering (CASE) environments, integrated application development environments, and geographical information systems.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.
CIS 9666. Advanced Networks and Client-Server Computing. 3 Credit Hours.
Prerequisites: CIS 5617 or 9617.
Computer networks, network technology, protocols, routing algorithms, reliability and design issues. Data transmission and transmission media, data communications fundamentals, transmission efficiency, wide-area networks, local area networks, wireless networks, TCP/IP and other protocol architectures, client/server computing, network management, and network security.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 9668. Design and Development of E-Commerce Systems. 3 Credit Hours.
Prerequisites: CIS 9618.
This course teaches the technical aspects of developing a commercial website, including the business-to-consumer and business-to-business models. This process combines a number of integrated technologies: Web page and style sheet design; dynamic web pages that access data from relational and XML databases; server side transaction processing; client/server and distributed processing; principles of internet security, scalability, and database reliability; and .NET programming. Students develop a site as a course project using custom coding using .NET and Microsoft's web site development system Commerce Server 2000. Other tools to be used are Dreamweaver or FrontPage for web design, VS for .NET program development, and the Microsoft Enterprise Manager for the management of SQL Server databases.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 9669. Distributed and Parallel Computer Systems. 3 Credit Hours.
Prerequisites: CIS 5617 or 9617.
Intended for students interested in the advances of scalable parallel computing systems. The main goal is to apply distributed and parallel computing theories to practical scalable parallel application development and new parallel programming tool construction.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CIS 9991. Master's Research Projects. 1 to 6 Credit Hour.
Short-term, limited research project or laboratory project in the field. This course is not the capstone project course, nor can it be used for thesis based research. The course is for master's students only, including PSM, MA or MS. This class will not confer full-time program status unless nine credits are taken.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

CIS 9994. Preliminary Examination Preparation. 1 to 6 Credit Hour.
This course is required for students who are preparing for the preliminary or candidacy examination. Students should enroll after coursework is completed or when preparing for the candidacy exam until the time that the preliminary or candidacy examination is completed. This course will confer full-time status at the minimum credit hour registration limit of one credit. All students must complete a minimum of one credit of this course. Students must complete a total of 6 credit hours of 9994, 9998 and 9999.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

CIS 9995. Capstone Project. 1 to 6 Credit Hour.
Capstone project for master's students including students in PSM, MA or MS. This class will provide full-time status. Students in PSM programs need to register for at least one credit of this course to fulfill program requirements. Additional credits may be required for specific programs. This course will confer full-time status at the minimum credit hour registration limit of one credit.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.
CIS 9996. Master's Thesis Research. 1 to 6 Credit Hour.
Course for master's thesis research. Only intended for students in thesis bearing master's programs. A minimum of one credit is required. This course will confer full-time status at the minimum credit hour registration limit of one credit.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

CIS 9998. Pre-Dissertation Research / Elevation to Candidacy. 1 to 6 Credit Hour.
This course is intended for students who are performing research prior to candidacy. Students can register for this course after required courses are completed. This course will confer full-time status at the minimum credit hour registration limit of one credit. Students must be registered for this course during the semester that they are to be elevated to candidacy examination. Students must complete a total of 6 credit hours of 9994, 9998 and 9999.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

CIS 9999. Dissertation Research. 1 to 6 Credit Hour.
The course is for Ph.D. students who have been elevated to candidacy. During the course of their candidacy students must complete a minimum of two credits of dissertation research. This course will confer full-time status at the minimum credit hour registration limit of one credit. Students must complete a total of 6 credit hours of 9994, 9998 and 9999.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Student Attribute Restrictions: Must be enrolled in one of the following Student Attributes: Dissertation Writing Student.

Repeatability: This course may be repeated for additional credit.