BIOMEDICAL INFORMATICS PROGRAM

Committee: Russ B. Altman *(Chair and Program Director)*; Mark A. Musen *(Co-Director)*; Betty Cheng, Lawrence M. Fagan *(Associate Directors)*; Atul Butte, Amar K. Das, Parvati Dev, Teri E. Klein, David Paik

Participating Faculty and Staff by Department:

Opportunities for research are not limited to the faculty and departments listed.

Anesthesia: David M. Gaba (Professor)

Biochemistry: Douglas L. Brutlag (Professor), Ron Davis (Professor), Julie Theriot (Assistant Professor)

Bioengineering: Scott L. Delp (Associate Professor)

Chemistry: Vijay Pande (Assistant Professor)

Civil and Environmental Engineering: Raymond E. Levitt (Professor)

Computer Science: Serafim Batzoglou (Assistant Professor), Leo Guibas (Professor), Daphne Koller (Associate Professor), Jean-Claude Latombe (Professor), Gio Wiederhold (Professor, Research, emeritus)

Developmental Biology: Stuart Kim (Professor)

Genetics: Russ B. Altman (Professor), Mike Cherry (Associate Professor, Research), Stanley N. Cohen (Professor), Teri E. Klein (Senior Research Scientist), Richard M. Myers (Professor), Gavin Sherlock (Assistant Professor)

Health Research and Policy: Mark A. Hlatky (Professor), Richard A. Olshen (Professor), Robert Tibshirani (Professor)

Management Science and Engineering: Margaret Brandeau (Professor), Ross D. Shachter (Associate Professor)

Mathematics: Samuel Karlin (Professor, emeritus)

Medicine: Russ B. Altman (Professor), Jay Bhattacharya (Assistant Professor), Terrance Blaschke (Professor), Atul Butte (Assistant Professor), Robert W. Carlson (Professor), Amar K. Das (Assistant Professor), Parvati Dev (Senior Research Scientist), Lawrence M. Fagan (Senior Research Scientist), Alan M. Garber (Professor), Mary Goldstein (Professor), Michael Higgins (Consulting Associate Professor), Peter D. Karp (Consulting Assistant Professor), David Katzenstein (Professor, Research), John Koza (Consulting Professor), Henry Lowe (Associate Professor, Research; Senior Associate Dean for Information Resources and Technology), Mark A. Musen (Professor), Douglas K. Owens (Associate Professor), Robert W. Shafer (Assistant Professor, Research), P.J. Utz (Associate Professor)

Microbiology and Immunology: Karla Kirkegaard (Professor), Garry Nolan (Associate Professor)

Obstetrics and Gynecology: W. LeRoy Heinrichs (Professor, emeritus)

Pathology: Arend Sidow (Assistant Professor)

Pediatrics: Atul Butte (Assistant Professor)

Psychiatry and Behavioral Sciences: Amar K. Das (Assistant Professor)

Radiation Oncology: Arthur L. Boyer (Professor), Lei Xing (Assistant Professor, Research)

Radiology: Sam Gambhir (Professor), Gary H. Glover (Professor), Sandy A. Napel (Professor), David Paik (Assistant Professor), Norbert J. Pelc (Professor), Geoffrey Rubin (Associate Professor)

Statistics: Trevor J. Hastie (Professor), Susan Holmes (Professor), Art Owen (Professor)

Structural Biology: Michael Levitt (Professor)

Surgery: Thomas Krummel (Professor), Charles Taylor (Assistant Professor, Research)

Program Offices: MSOB 215

Mail Code: 94305-5479

Phone: (650) 723-6979

Web Site: http://bmi.stanford.edu

Courses given in Biomedical Informatics Program have the subject code BIOMEDIN. For a complete list of subject codes, see Appendix.

The program in Biomedical Informatics emphasizes research to develop novel computational methods that can advance biomedicine. Students receive training in the investigation of new approaches to conceptual modeling and to development of new algorithms that address challenging problems in the biological sciences and clinical medicine. Students with a primary interest in developing new informatics methods and knowledge are best suited for this program. Students with a primary interest in the biological or medical application of existing informatics techniques may be better suited for training in the application areas themselves.

GRADUATE PROGRAMS

The Biomedical Informatics Program is interdepartmental and offers instruction and research opportunities leading to M.S. and Ph.D. degrees in Biomedical Informatics. All students are required to complete the core curriculum requirements outlined below, and also to elect additional courses to complement both their technical interests and their goals in applying informatics methods to clinical settings, biology, or imaging. Candidates must maintain a 3.0 GPA in each of the five core areas, and an overall GPA of 3.0. If the candidate's GPA does not meet the minimum requirement, the executive committee may require corrective courses of action. In addition, prior to being formally admitted to candidacy for the Ph.D. degree, the student must demonstrate knowledge of biomedical informatics fundamentals and a potential for research by passing a qualifying exam.

The core curriculum is common to all degrees offered by the program but is adapted or augmented depending on the interests and experience of the student. Deviations from the core curriculum outlined below must be justified in writing and approved by the student's Biomedical Informatics academic adviser and the chair of the Biomedical Informatics Committee. It should be noted, however, that the program is intended to provide flexibility and to complement other opportunities in applied medical research that exist at Stanford. Although most students are expected to comply with the basic program of study outlined here, special arrangements can be made for those with unusual needs or those simultaneously enrolled in other degree programs within the University. Similarly, students with prior relevant training may have the curriculum adjusted to eliminate requirements met as part of prior training.

CORE CURRICULUM

Students are expected to participate regularly in the Biomedical Informatics Student Seminar (201) and Colloquia (200), regardless of whether they register for credit in those courses. In addition, all students are expected to fulfill requirements in the following five categories:

1. *Core Biomedical Informatics* (15 units): students are expected to understand current applications of computers in biology and medicine and to develop a broad appreciation for research in the management of biomedical information. Required courses are: BIOMEDIN 200, 201, 210, 211, 212, and 214, all of which should be taken during the first and second year in the program. BIOMEDIN 200 and 201 are required courses but are not counted toward the core or elective units. Students must also take an additional 3 units of Biomedical Informatics course work (which may include crosslisted courses from other departments, but not including BIOMEDIN 200, 201, 299, 302, 303, or 305), selected in consultation with the academic adviser.
2. *Computer Science* (9 units): the student is expected to acquire a knowledge of the use of computers, computer organization, programming, and symbolic systems. It is assumed that students have had by matriculation computing experience at least equivalent to a course introducing the fundamentals of data structures and algorithms such as CS 103A,B, 103X, 106A,B, 106X, or other courses approved by academic adviser or executive committee. Students are required to take a minimum of 9 units of courses in the Department of Computer Science. If similar courses have not been taken previously, these units must include CS 121 or 221, 161, and a course that requires significant programming and knowledge of machine architectures (for example, CS 108, or the CS 193 series). For those who have taken such courses previously, replacement units may be taken from any other course in

Biomedical Informatics

CS selected by the student and approved by the academic adviser. A course in databases is especially recommended. With the exception of CS 108, all other courses applied to the degree requirements must be numbered 137 or higher.

3. *Probability, Statistics, and Decision Science* (9 units): students are required to take at least three courses that span the following five topics: basic probability theory, Bayesian statistics, decision analysis, machine learning, and experimental-design techniques. Prior courses in statistics at least equivalent to STATS 60 and calculus equivalent to MATH 42 are prerequisites. A prior course in linear algebra equivalent to MATH 103 or 113 is recommended. For the probability requirements, students may, for example, take MS&E 120, STATS 116, or MS&E 221. For the statistics requirements, students should take STATS 141, if they have not had an equivalent class prior to entry to the program. Otherwise, sequences (taken after STATS 116) may include STATS 200 followed by a course in stochastic modeling, machine learning or data mining, such as STATS 202 or 315A,B, or CS 228 or 229. Options for decision analysis include MS&E 152 or 252, or cost effectiveness analysis (BIOMEDIN 432). Specific courses should be chosen in consultation with the student's academic adviser. Also recommended is a course in the psychology of human problem solving.
4. *Biomedical Domain Knowledge* (9 units): students are expected to acquire an understanding of pertinent life sciences and how to analyze a domain of application interest. Prior courses in biology at least equivalent to BIOSCI 41 and 42 are prerequisites. All students must have completed a course in basic biochemistry, molecular biology, or genetics. Other areas of basic biology may be an acceptable alternative. Exposure to laboratory methods in biology is encouraged. All students without formal health care training must take IMMUNOL 230 (formerly BIOMEDIN 207). First year students are encouraged to enroll in IMMUNOL 230.
5. *Social and Ethical Issues* (3 units for M.S., 6 for Ph.D.): candidates are expected to be familiar with key issues regarding ethics, public policy, financing, organizational behavior, management, and pertinent legal topics. Students may select at least 3 units from suitable courses that include, for example, BIOMEDIN 432; CS 201; MS&E 284, 197; HRP 391, 392; or any other advanced course in policy and social issues proposed by the student and approved by the Biomedical Informatics academic adviser.

The core curriculum generally entails a minimum of 45 units of course work for master's students and 54 units of course work for Ph.D. students, but can require substantially more or less depending upon the courses selected and the previous training of the student. All courses must be taken for a letter grade. Students may request an elective course be taken for a grade of credit/no credit by submitting a petition to the BMI executive committee. BIOMEDIN 299 and BIOMEDIN 802 may be taken for satisfactory/no credit (S/NC). The varying backgrounds of students are well recognized and no one is required to take courses in an area in which he or she has already been adequately trained; under such circumstances, students are permitted to skip courses or substitute more advanced work. Students design appropriate programs for their interests with the assistance and approval of their Biomedical Informatics academic adviser. At least 27 units of formal course work are expected.

PROGRAM REQUIREMENTS FOR THE ACADEMIC M.S., PROFESSIONAL M.S., AND COTERMINAL DEGREES

Students enrolled in any of the M.S degrees must complete the program requirements in order to graduate. Programs of at least 45 units that meet the following guidelines are normally approved:

1. Completion of the core curriculum.
2. A minimum of 6 additional units of courses in Computer Science numbered 135 or higher, courses in Management Science and Engineering or Statistics numbered 200 or higher, PSYCH 256 or 225, or relevant courses in other departments approved by the student's academic adviser.
3. Electives: additional courses to bring the total to 45 or more units.

The University requirements for the M.S. degree are described in the "Graduate Degrees" section of this bulletin.

MASTER OF SCIENCE (ACADEMIC)

This degree is designed for individuals who wish to undertake in-depth study of biomedical informatics with research, typically supported with fellowship funding. Normally, a student spends two years in the program and implements and documents a substantial project during the second year. The first year involves acquiring the fundamental concepts and tools through course work and research project involvement. All first- and second-year students are expected to devote 50 percent or more of their time participating in research projects. Research rotations are not required, but can be done with approval of the academic adviser or training program director. Graduates of this program are prepared to contribute creatively to basic or applied projects in biomedical informatics. This degree requires a written research paper to be approved by two faculty members.

MASTER OF SCIENCE (HONORS COOPERATIVE PROGRAM)

This degree is primarily designed for the working professional who already has advanced training in one discipline and wishes to acquire interdisciplinary skills. All classes necessary for the degree are available online. The professional M.S. is offered in conjunction with Stanford Center of Professional Development (SCPD), which establishes the rates of tuition and fees. The program uses the honors cooperative model (HCP), which assumes that the student is working in a corporate setting and is enrolled in the M.S. on a part-time basis. The student has up to five years to complete the program. Research projects are optional and the student must make arrangements with program faculty. Graduates of this program are prepared to contribute creatively to basic or applied projects in biomedical informatics.

MASTER OF SCIENCE (COTERMINAL)

The coterminal degree program allows undergraduates to study for a master's degree while completing their bachelor's degree(s) in the same or a different department. Please refer to the "Coterminal Bachelor's and Master's Degrees" section under "Undergraduate Degrees and Programs" in this bulletin for additional information.

The coterminal Master of Science program follows the same program requirements as the Master of Science (Professional), except for the requirement to be employed in a corporate setting. The coterminal degree is only available to current Stanford undergraduates. Coterminal students are enrolled full-time and courses are taken on campus. Research projects are optional and the student must make arrangements with program faculty. Graduates of this program are prepared to contribute creatively to basic or applied projects in biomedical informatics

For University coterminal degree program rules and University application forms, see http://registrar.stanford.edu/shared/publications.htm#Coterm.

DOCTOR OF PHILOSOPHY

The University's basic requirements for the doctorate (residence, dissertation, examination, and so on) are discussed in the "Graduate Degrees" section of this bulletin.

Individuals wishing to prepare themselves for careers as independent researchers in biomedical informatics, with applications experience in bioinformatics, clinical informatics, or imaging informatics, should apply for admission to the doctoral program. The following are additional requirements imposed by the Biomedical Informatics Interdisciplinary Committee:

1. A student plans and completes a coherent program of study including the core curriculum and additional requirements for the master's program. In addition, doctoral candidates are expected to take at least three more advanced courses (see categories under item '2' of the master's program requirements) and must complete a total of 54 units. In the first year, two or three research rotations are encouraged. The master's requirements should be completed by the end of the second year in the program (six quarters of study, excluding summers). Doctoral students are generally advanced to Ph.D. candidacy after passing the qualifying exam, which takes place during the end of the second year of training or early in the third year. A student's

academic adviser has primary responsibility for the adequacy of the program, which is regularly reviewed by the Biomedical Informatics executive committee.

2. To remain in the Ph.D. program, each student must attain a grade point average (GPA) of 3.0 (B) in each of the five core areas. The student must fulfill these requirements and apply for admission to candidacy for the Ph.D. by the end of six quarters of study (excluding summers). In addition, reasonable progress in the student's research activities is expected of all doctoral candidates.
3. During the third year of training, generally in the Winter Quarter, each doctoral student is required to give a preproposal seminar that describes evolving research plans and allows program faculty to assure that the student is making good progress toward the definition of a doctoral dissertation topic.
4. By the end of nine quarters (excluding summers), each student must orally present a written thesis proposal and an oral university defense of this proposal to a dissertation committee that generally includes at least one member of the Biomedical Informatics executive committee. The committee determines whether the student's general knowledge of the field and the details of the planned thesis are sufficient to justify proceeding with the dissertation.
5. As part of the training for the Ph.D., each student is required to be a teaching assistant for two courses approved by the Biomedical Informatics executive committee; one should be completed in the first two years of study.
6. The most important requirement for the Ph.D. degree is the dissertation. Prior to the oral dissertation proposal and defense, each student must secure the agreement of a member of the program faculty to act as dissertation adviser. The principal adviser need not be an active member of the Biomedical Informatics program faculty, but all committees should include at least one participating BMI faculty member.
7. No official additional oral examination is required upon completion of the dissertation. The oral defense of the dissertation proposal satisfies the University oral examination requirement. At the completion of training, the student should give a final talk describing their results.
8. The student is expected to demonstrate an ability to present scholarly material and research in a lecture at a formal seminar.
9. The student is expected to demonstrate an ability to present scholarly material in concise written form. Each student is required to write a paper suitable for publication, usually discussing his or her doctoral research project. This paper must be approved by the student's academic adviser as suitable for submission to a refereed journal before the doctoral degree is conferred.
10. The dissertation must be accepted by a reading committee composed of the principal dissertation adviser, a member of the program faculty, and a third faculty member chosen from anywhere within the University.

COURSES

BIOMEDIN 109Q. Genomics: A Technical and Cultural Revolution—(Same as GENE 109Q.) Stanford Introductory Seminar. For nonscience majors. Concepts of genomics, high-throughput methods of data collection, and computational approaches to analysis of data. The social, ethical, and economic implications of genomic science. Students may focus on computational or social aspects of genomics.

3 units, Win (Altman, R)

BIOMEDIN 156/256. Economics of Health and Medical Care—(Same as ECON 126.) Graduate students with research interests should take ECON 248. Institutional, theoretical, and empirical analysis of the problems of health and medical care. Topics: institutions in the health sector; measurement and valuation of health; nonmedical determinants of health; medical technology and technology assessment; demand for medical care and medical insurance; physicians, hospitals, and managed care; international comparisons. Prerequisite: ECON 50 and ECON 102A or equivalent statistics, or consent of instructor. Recommended: ECON 51.

5 units, Aut (Bhattacharya, J)

BIOMEDIN 200. Biomedical Informatics Colloquium—Series of colloquia offered by program faculty, students, and occasional guest lecturers. Credit available only to students in a Biomedical Informatics degree program. May be taken no more than three times for credit.

1 unit, Aut, Win, Spr (Musen, M)

BIOMEDIN 201. Biomedical Informatics Student Seminar—Participants report on recent articles from the Biomedical Informatics literature or their research projects. Goal is to teach presentation skills. Credit available only to students in a Biomedical Informatics degree program. May be repeated three times for credit.

1 unit, Aut, Win, Spr (Musen, M)

BIOMEDIN 202. Introductory Biomedical Informatics—Online. Current research problems and computational approaches to them. Topics include medical security and privacy, electronic medical records, controlled terminologies and biomedical ontologies, electronic retrieval, technology-assisted learning environments, medical decision making and support, sequence analysis, phylogenetics, biological networks and pathways, microarray analysis, natural language processing, and protein structural analysis and prediction. Graduate students in Biomedical Informatics may not take this class for credit.

1 unit, Aut, Win, Spr, Sum (Altman, R; Cheng, B; Fagan, L)

BIOMEDIN 210. Introduction to Biomedical Informatics: Fundamental Methods—(Same as CS 270.) Issues in the modeling, design, and implementation of computational systems for use in biomedicine. Topics: basic knowledge representation, controlled terminologies in medicine and biological science, fundamental algorithms, information dissemination and retrieval, knowledge acquisition, and ontologies. Emphasis is on the principles of modeling data and knowledge in biomedicine and on translation of resulting models into useful automated systems. Recommended: principles of object-oriented systems.

3 units, Aut (Musen, M)

BIOMEDIN 211. Introduction to Biomedical Informatics: System Design—(Same as CS 271.) Focus is on undertaking design and implementation of computational and information systems for life scientists and healthcare providers. Case studies illustrate what design factors lead to success or failure in building systems in complex biomedical environments. Topics: requirements analysis, workflow and organizational factors, functional specification, knowledge modeling, data heterogeneity, component-based architectures, human-computer interaction, and system evaluation. Prerequisite: 210, or consent of instructor.

3 units, Win (Das, A)

BIOMEDIN 212. Introduction to Biomedical Informatics Research Methodology—(Same as CS 272, GENE 212.) Hands-on software building. Student teams conceive, design, specify, implement, evaluate, and report on a software project in the domain of biomedicine. Creating written proposals, peer review, providing status reports, and preparing final reports. Guest lectures from professional biomedical informatics systems builders on issues related to the process of project management. Software engineering basics. Prerequisites: 210, 211 or 214, or consent of instructor.

3 units, Aut (Altman, R; Cheng, B; Klein, T)

BIOMEDIN 214. Representations and Algorithms for Computational Molecular Biology—(Same as CS 274, GENE 214.) Topics: algorithms for alignment of biological sequences and structures, computing with strings, phylogenetic tree construction, hidden Markov models, computing with networks of genes, basic structural computations on proteins, protein structure prediction, protein threading techniques, homology modeling, molecular dynamics and energy minimization, statistical analysis of 3D biological data, integration of data sources, knowledge representation and controlled terminologies for molecular biology, graphical display of biological data, and machine learning (clustering & classification), and natural language text processing. Consent of instructor required for 3 units. Prerequisites: programming skills, interest in biology.

3-4 units, Spr (Altman, R)

BIOMEDIN 216. Lectures on Representations and Algorithms for Molecular Biology—Lecture series for BIOMEDIN 214. Recommended: familiarity with biology.
1 unit, Spr (Altman, R)

BIOMEDIN 217. Translational Bioinformatics—(Same as CS 275.) Analytic, storage, and interpretive methods to optimize the transformation of genetic, genomic, and biological data into diagnostics and therapeutics for medicine. Topics: access and utility of publicly available data sources; types of genome-scale measurements in molecular biology and genomic medicine; analysis of microarray data; analysis of polymorphisms, proteomics, and protein interactions; linking genome-scale data to clinical data and phenotypes; and new questions in biomedicine using bioinformatics. Case studies. Prerequisites: programming ability at the level of CS 106A and familiarity with statistics and biology.
3-4 units, Win (Butte, A)

BIOMEDIN 233. Intermediate Biostatistics: Analysis of Discrete Data—(Same as HRP 261, STATS 261.) The 2x2 table. Chi-square test. Fisher's exact test. Odds ratios. Sampling plans; case control and cohort studies. Series of 2x2 tables. Mantel Hantzel. Other tests. k x m tables. Matched data logistic models. Conditional logistic analysis, application to case-control data. Log-linear models. Generalized estimating equations for longitudinal data. Cell phones and car crashes: the crossover design. Special topics: generalized additive models, classification trees, bootstrap inference.
3 units, Win (Staff)

BIOMEDIN 234. Biomedical Genomics—How genomics is influencing medical research and health-care delivery, illuminating the genomic discoveries being translated into diagnostic and therapeutic medical applications. Themes: the relevance of human genome project and functional genomics to inherited and acquired diseases, and the role of public databases and computational methods for solving problems in biology. Human genetic variation, SNPs, comparative genomics, computer models of biological processes, microbial genomics, pharmacogenomics, structure-based drug design, gene therapy. Case studies demonstrate the use of information technologies for converting molecular biological data into knowledge that can improve patient care and accelerate the discovery of new therapeutics.
3 units, Win (Shafer, R)

BIOMEDIN 240. Causal Models in Biomedical Informatics—Computational formalisms for encoding causal models in biological and biomedical domains from recent work on modeling genetic networks; also models that arise in medical applications. Readings include papers that describe causal models within a specific representational framework. Associated methods for reasoning over knowledge structures in that paradigm and for inducing such models from data. Goal is to understand how to represent, reason about, and discover biological knowledge in each framework, along with the strengths and weaknesses of that formalism.
3 units, not given this year

BIOMEDIN 251. Outcomes Analysis—Introduction to methods of conducting empirical studies which use large existing medical, survey, and other databases to ask both clinical and policy questions. Econometric and statistical models used to conduct medical outcomes research. How research is conducted on medical and health economics questions when a randomized trial is impossible. Problem sets emphasize hands-on data analysis and application of methods, including re-analyses of well-known studies. Prerequisites: one or more courses in probability, and statistics or biostatistics.
3 units, Spr (Bhattacharya, J)

BIOMEDIN 262. Computational Genomics—(Same as CS 262.) Applications of computer science to genomics, and concepts in genomics from a computer science point of view. Topics: dynamic programming, sequence alignments, hidden Markov models, Gibbs sampling, and probabilistic context-free grammars. Applications of these tools to sequence analysis: comparative genomics, DNA sequencing and assembly, genomic annotation of repeats, genes, and regulatory sequences, microarrays and gene expression, phylogeny and molecular evolution, and RNA structure. Prerequisites: 161 or familiarity with basic algorithmic concepts. Recommended: basic knowledge of genetics.
3 units, Win (Batzoglou, S)

BIOMEDIN 273. Algorithms for Structure and Motion in Biology—(Same as CS 273.) Algorithms motivated by challenges in predicting molecule properties in silico. Topics: geometric and kinematic models of biomolecules (proteins, ligands), conformation spaces, obtention of structure from experimental data, finding sequence and structural similarities, molecular surfaces and shape analysis, energy calculation, detection of steric clashes and proximity computation, conformation sampling, threading, and study folding and binding motions.
3 units, not given this year

BIOMEDIN 299. Directed Reading and Research—For students wishing to receive credit for directed reading or research time. Prerequisite: consent of instructor.
1-18 units, Aut, Win, Spr, Sum (Staff)

BIOMEDIN 303. Statistics for Research—Statistical methods commonly used in research. Emphasis is on when and how to use the methods rather than on proofs. How to describe data and detect unusual values, compare treatment effects, interpret p-values, detect and quantify trends, detect and measure association and correlation, determine the sample size and power for an experiment, and choose statistical tests and software. Topics include descriptive statistics (mean, median, standard deviation, standard error), probability, paired and unpaired t-tests, analysis of variance, correlation, regression, chi-square, discriminant analysis, and power and sample size. Statistical analysis software including Excel and Statistica.
1 unit, Spr (Staff), alternate years, not given next year

BIOMEDIN 366. Advanced Bioinformatics—(Same as STATS 166/366.) Emphasis is on analysis of genomic scale data sets with multivariate methods. Comparative genomics: whole genome phylogeny, genome alignment, identification of constrained elements, genomic motif finding, ENCODE project. Functional genomics: interaction networks, random networks, data integration, tests for functional enrichment, network alignment, deterministic and stochastic genetic circuits, data-driven circuit reconstruction. Population genomics: principles of molecular evolution, tests for selection, HapMap, structural variation. Recommended: familiarity with R, Perl, Unix, basic bioinformatics (sequence alignment and protein structure) at the level of BIOC 218 or BIOMEDIN 274.
2-3 units, Win (Srinivasan, B)

BIOMEDIN 374. Algorithms in Biology—(Same as CS 374.) Algorithms and computational models applied to molecular biology and genetics. Topics vary annually. Possible topics include biological sequence comparison, annotation of genes and other functional elements, molecular evolution, genome rearrangements, microarrays and gene regulation, protein folding and classification, molecular docking, RNA secondary structure, DNA computing, and self-assembly. May be repeated for credit. Prerequisites: 161, 262 or 274, or BIOCHEM 218, or equivalents.
2-3 units, Aut (Batzoglou, S)

BIOMEDIN 390A. Curricular Practical Training—Provides educational opportunities in biomedical informatics research. Qualified biomedical informatics students engage in internship work and integrate that work into their academic program. Students register during the quarter they are employed and must complete a research report outlining their work activity, problems investigated, key results, and any follow-up on projects they expect to perform. BIOMEDIN 390A, B, and C may each be taken only once.
1 unit, Aut, Win, Spr, Sum (Staff)

BIOMEDIN 390B. Curricular Practical Training—Provides educational opportunities in biomedical informatics research. Qualified biomedical informatics students engage in internship work and integrate that work into their academic program. Students register during the quarter they are employed and must complete a research report outlining their work activity, problems investigated, key results, and any follow-up on projects they expect to perform. BIOMEDIN 390A, B, and C may each be taken only once.
1 unit, Aut, Win, Spr, Sum (Staff)

BIOMEDIN 390C. Curricular Practical Training—Provides educational opportunities in biomedical informatics research. Qualified biomedical informatics students engage in internship work and integrate that work into their academic program. Students register during the quarter they are employed and must complete a research report outlining their work activity, problems investigated, key results, and any follow-up on projects they expect to perform. BIOMEDIN 390A, B, and C may each be taken only once.
1 unit, Aut, Win, Spr, Sum (Staff)

BIOMEDIN 432. Analysis of Costs, Risks, and Benefits of Health Care—(Same as MGTECON 332, HRP 392.) For graduate students. The principal evaluative techniques for health care, including utility assessment, cost-effectiveness analysis, cost-benefit analysis, and decision analysis. Emphasis is on the practical application of these techniques. Group project presented at end of quarter. Guest lectures by experts from the medical school, pharmaceutical industry, health care plans, and government.
4 units, Aut (Garber, A)

COGNATE COURSES

See respective department listings for course descriptions and General Education Requirements (GER) information. See degree requirements above or the program's student services office for applicability of these courses to a major or minor program.

BIOC 218. Computational Molecular Biology
3 units, Win (Brutlag, D)

CS 228. Probabilistic Models in Artificial Intelligence
3 units, Win (Koller, D)

CS 329. Topics in Artificial Intelligence
3 units, by arrangement

CS 348B. Computer Graphics: Image Synthesis Techniques
3-4 units, Spr (Hanrahan, P)

CS 379. Interdisciplinary Topics
3 units, Aut (Staff)

MS&E 355. Influence Diagrams and Probabilistics Networks
3 units, alternate years, not given this year

SYMBSYS 216. Biological Knowledge and Symbolic Biocomputing
3 units, not given this year