SCHOOL OF MEDICINE

BIOMEDICAL INFORMATICS

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

Participating Faculty and Staff by Department:

Research opportunities are not limited to faculty and departments listed.

Biochemistry: Douglas L. Brutlag (Professor, emeritus), Rhiju Das (Assistant Professor), Ronald Davis (Professor), James Ferrell (Professor), Julie Theriot (Associate Professor)

Bioengineering: Russ B. Altman (Professor), Kwabena Boahen (Associate Professor), Markus Covert (Assistant Professor), Scott Delp (Professor), Charles A. Taylor (Associate Professor)

Biology: Markus Feldman (Professor), Dmitri Petrov (Associate Professor)

Chemistry: Vijay Pande (Associate Professor)

Chemical and Systems Biology: Joshua Elias (Assistant Professor), James Ferrell (Professor)

Computer Science: Serafim Batzoglou (Associate Professor), Gill Bejerano (Assistant Professor), David Dill (Professor), Leo Guibas (Professor), Daphne Koller (Associate Professor), Jean-Claude Latombe (Professor), Chris Manning (Associate Professor), Terry Winograd (Professor)

Developmental Biology: Gill Bejerano (Assistant Professor), Stuart Kim (Professor), Harley McAdams (Professor, Research)

Genetics: Russ B. Altman (Professor), Mike Cherry (Associate Professor, Research), Stanley N. Cohen (Professor), Ronald Davis (Professor), Stuart Kim (Professor), Teri E. Klein (Senior Research Scientist), Gavin Sherlock (Assistant Professor), Michael P. Snyder (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)

Medicine: Russ B. Altman (Professor), Jayanta Bhattacharya (Assistant Professor), Atul Butte (Assistant Professor), Robert W. Carlson (Professor), Betty Cheng (Associate Director), Amar K. Das (Assistant Professor), Lawrence M. Fagan (Co-Director), Alan M. Garber (Professor), Mary Goldstein (Professor), Peter D. Karp (Consulting Assistant 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), Samson Tu (Senior Research Scientist), P.J. Utz (Associate Professor), Michael G. Walker ((Consulting Associate Professor)

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

Pediatrics: Atul Butte (Assistant Professor)

Psychiatry and Behavioral Sciences: Amar K. Das (Assistant Professor), Vinod Menon (Associate Professor)

Radiation Oncology: Lei Xing (Professor)

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

Structural Biology: Michael Levitt (Professor)

Statistics: Trevor J. Hastie (Professor), Susan Holmes (Professor), Art Owen (Professor), Robert Tibshirani (Professor), Michael G. Walker (Consulting Associate Professor), Nancy Zhang (Assistant Professor)

Surgery: Thomas Krummel (Professor), Charles A. Taylor (Associate Professor, Research)

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Courses offered by the Program in Biomedical Informatics are listed under the subject code BIOMEDIN on the *Stanford Bulletin's* ExploreCourses web site.

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 IN BIOMEDICAL INFORMATICS

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, 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 Biomedical Informatics 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 must be justified in writing and approved by the student's Biomedical Informatics academic adviser and the chair of the Biomedical Informatics Executive 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 AND PROGRAM REQUIREMENTS IN BIOMEDICAL INFORMATICS

CORE CURRICULUM IN BIOMEDICAL INFORMATICS

Students are expected to participate regularly in the Biomedical Informatics Student Seminar (BIOMEDIN 201) and a research Colloquium, such as BIOMEDIN 200 or BIOMEDIN 205. In addition, all students are expected to fulfill requirements in the following five categories:

1. *Core Biomedical Informatics* (17 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 210, 211, 212, 214, and 217, all of which

should be taken during the first and second year in the program.

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 prior to matriculation students have 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 161, a class in artificial intelligence or learning (for example, CS 121, CS 228, CS 229, STATS 315A, STATS 315B), and a course that requires significant programming and knowledge of machine architectures (for example, CS 108). For those who have taken such courses previously, replacement units may be taken from any other course in CS selected by the student and approved by the academic adviser. A course in databases is especially recommended. With the exception of CS 108 and 121, all other CS 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 from 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 220, STATS 116, or MS&E 221. For the statistics requirements, students should take STATS 141 or STATS 212, 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). Also recommended is a course in the psychology of human problem solving. Specific courses should be chosen in consultation with the student's academic adviser.
4. *Biomedical Domain Knowledge* (6 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 BIO 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 are encouraged to take IMMUNOL 230 (formerly BIOMEDIN 207).
5. *Social and Ethical Issues* (4 units): candidates are expected to be familiar with issues regarding ethics, public policy, financing, organizational behavior, management, and pertinent legal topics. Students are required to take MED 255, The Responsible Conduct of Research, or the equivalent. Students may choose at least 3 units from suitable courses, including 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, 801 and 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. Masters candidates who are able to attend classes on campus should sign up at least once for BIOMEDIN 201, Student Seminar, plus a Research Colloquium in their field of research, such as BIOMEDIN 200 or BIOMEDIN 205. Regardless of their registration status, students should participate in the Student Seminar and Research Colloquium every quarter.
3. Electives: additional courses to bring the total to 45 or more units as necessary.
4. Masters candidates should sign up for BIOMEDIN 801 for their project units.

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

MASTER OF SCIENCE IN BIOMEDICAL INFORMATICS (ACADEMIC)

This degree is designed for individuals who wish to undertake in-depth study of biomedical informatics with research on a full-time basis. 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 IN BIOMEDICAL INFORMATICS (PROFESSIONAL/HONORS COOPERATIVE PROGRAM)

This degree is designed primarily 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 for 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 IN BIOMEDICAL INFORMATICS (COTERMINAL)

The coterminal degree program allows Stanford University 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 available only 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/pdf/ CotermApRules.pdf

DOCTOR OF PHILOSOPHY IN BIOMEDICAL INFORMATICS

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 Executive Committee:

1. A student plans and completes a coherent program of study including the core curriculum and additional requirements as for the master's program. In addition, doctoral candidates are expected to take at least nine more units of advanced courses to bring the total to 54 units. Recommended classes include: Computer Sciences courses 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. 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. 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 and an overall GPA of 3.0 for the required courses. 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 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 for the written dissertation and must orally defend the proposal before 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. After application for Terminal Graduate Registration (TGR) status, the Ph.D. candidate should register each quarter for BIOMEDIN 802 so their research effort may be counted toward the degree.
6. 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.
7. 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.
8. At the completion of training, while still matriculated and shortly prior to deposit of the dissertation, the student gives a final talk describing his or her results. No official additional oral examination is required upon completion of the written dissertation. The oral defense of the dissertation proposal satisfies the University oral examination requirement.
9. The student is expected to demonstrate an ability to present scholarly material and research in a lecture at a formal seminar.
10. 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.
11. 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.

BIOMEDICAL INFORMATICS (BIOMEDIN)

UNDERGRADUATE COURSES IN BIOMEDICAL INFORMATICS

BIOMEDIN 109Q. Genomics: A Technical and Cultural Revolution
(S,Sem) (Same as GENE 109Q) Stanford Introductory Seminar. Preference to sophomores. 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. Economics of Health and Medical Care
(Same as BIOMEDIN 256, ECON 126, HRP 256) 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. Prerequisites: ECON 50 and ECON 102A or equivalent statistics. Recommended: ECON 51.
5 units, Aut (Bhattacharya, J)

GRADUATE COURSES IN BIOMEDICAL INFORMATICS

BIOMEDIN 200. Biomedical Informatics Colloquium
Series of colloquia offered by program faculty, students, and occasional guest lecturers. May be repeated three times for credit.
1 unit, Aut (Musen, M), Win (Musen, M), 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. May be repeated three times for credit.
1 unit, Aut (Musen, M), Win (Musen, M), Spr (Musen, M)

BIOMEDIN 204. Pharmacogenomics
Via Internet. Genetically determined responses to drugs; applications focusing on the PharmGKB database, a publicly available Internet tool to aid researchers in understanding how genetic variation among individuals contributes to differences in reactions to drugs. Topics include: introduction to pharmacogenomics and pharmacology; the genome and genetics; human polymorphisms, frequencies, significance, and populations; informatics in pharmacogenomics; genotype to phenotype and phenotype to genotype approaches; drug discovery and validation; genomic variation discovery and genotyping; adverse drug reactions and interactions; pathways of drug metabolism; and cancer pharmacogenomics. Prerequisites: two of BIOSCI 41, 42, 43, and 44X,Y or consent of instructor.
1 unit, Aut (Cheng, B; Fagan, L), Win (Cheng, B; Fagan, L), Spr (Staff), Sum (Cheng, B; Fagan, L)

BIOMEDIN 205. Biomedical Informatics for Medicine
Primarily for M.D. students; open to other graduate students. Emphasis is on practical applications of bioinformatics and medical informatics for medicine, health care, clinicians, and biomedical research, focused on work at Stanford. Topics may include: methods to analyze genetic conditions' integrative methods for microarray, proteomic, and genomic data to understand the etiology of disease, clinical information systems in local healthcare facilities, cellular and radiology imaging, and pharmacogenomics. Enrollment for 2 units includes weekly assignments. Non-MD students may enroll for 1 unit. May be repeated for credit. Prerequisite: background in biomedicine. Recommended: background in programming.
1-2 units, Aut (Butte, A; Liu, L), Spr (Butte, A)

BIOMEDIN 206. Informatics in Industry
Effective management, modeling, acquisition, and mining of biomedical information in healthcare and biotechnology companies and approaches to information management adopted by companies in this ecosystem. Guest speakers from pharmaceutical/biotechnology companies, clinics/hospitals, health communities/portals, instrumentation/software vendors. May be repeated for credit.
1 unit, Spr (Kotecha, N; Shah, N)

BIOMEDIN 207. Digital Medicine: Promise and Peril in the Age of Electronic Health Records
Topical discussions of the use of electronic health records in clinical care and clinical research. Lectures by faculty, students and guest speakers are augmented by site visits to local clinical institutions that have implemented electronic health records systems. Goal is exposure to practical challenges of system implementation and to research opportunities in clinical informatics.
1 unit, Sum (Das, A)

BIOMEDIN 210. Modeling Biomedical Systems: Ontology, Terminology, Problem Solving
(Same as CS 270) Methods for modeling biomedical systems and for making those models explicit in the context of building software systems. Emphasis is on intelligent systems for decision support and Semantic Web applications. Topics: knowledge representation, controlled terminologies, ontologies, reusable problem solvers, and knowledge acquisition. Recommended: exposure to object-oriented systems, basic biology.
3 units, Aut (Musen, M)

BIOMEDIN 211. Effective Design in Clinical Informatics Systems
(Same as CS 271) Methods of designing and engineering software systems in complex clinical environments. Case studies illustrate factors leading to success or failure of systems. Project assignments involve focused team-based design work. Topics: user and organizational requirements, data and knowledge modeling, component-based system design, system prototyping, and human-systems interaction. Prerequisite: BIOMEDIN 210 recommended, or database or object-oriented programming course.
3 units, Win (Das, A)

BIOMEDIN 212. Introduction to Biomedical Informatics Research Methodology
(Same as BIOE 212, 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: BIOMEDIN 210, 211, 214, 217 or consent of instructor.
3 units, Aut (Altman, R; Cheng, B; Klein, T)

BIOMEDIN 214. Representations and Algorithms for Computational Molecular Biology
(Same as BIOE 214, CS 274, GENE 214) Topics: introduction to bioinformatics and computational biology, algorithms for alignment of biological sequences and structures, computing with strings, phylogenetic tree construction, hidden Markov models, Gibbs Sampling, 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, microarray analysis, machine learning (clustering and classification), and natural language text processing. Prerequisites: programming skills; consent of instructor for 3 units.
3-4 units, Spr (Staff)

BIOMEDIN 216. Lectures on Representations and Algorithms for Molecular Biology
Lecture series for BIOMEDIN 214. Via internet. Prerequisite: familiarity with biology recommended:
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.
4 units, Win (Butte, A)

BIOMEDIN 218. Translational Bioinformatics
Same content as 217; for medical and graduate students who attend lectures and participate in limited assignments and final project. 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 at the level of CS 106A; familiarity with statistics and biology.
2 units, Win (Butte, A)

BIOMEDIN 219. Mathematical Models and Medical Decisions
Analytic methods for determining the optimal diagnostic and therapeutic decisions for the care of individual patients and for the design of policies affecting the care of patient populations. Topics: utility theory and probability modeling, empirical methods for estimating disease prevalence, probability models for periodic processes, binary decision-making techniques, Markov models of dynamic disease state problems, utility assessment techniques, parametric utility models, utility models for multidimensional outcomes, analysis of time-varying clinical outcomes, and the design of cost-contstrained clinical policies. 2 units requires completion of a case study project. Prerequisites: introduction to calculus and basic statistics.
1-2 units, Win (Staff)

BIOMEDIN 228. Computational Genomic Biology
(Same as BIOC 228) Application of computational genomics methods to biological problems. Topics include: assembly of genomic sequences; genome databases; comparative genomics; gene discovery; gene expression analyses including gene clustering by expression, transcription factor binding site discovery, metabolic pathway discovery, functional genomics, and gene and genome ontologies; and medical diagnostics using SNPs and gene expression. Recent papers from the literature and hands-on use of the methods. Prerequisites: introductory course in computational molecular biology or genomics such as BIOC 218, BIOMEDIN 214 or GENE 211.
3 units, not given this year

BIOMEDIN 231. Computational Molecular Biology
(Same as BIOC 218) For molecular biologists and computer scientists. Representation and analysis of genomes, sequences, and proteins. Strengths and limitations of existing methods. Course work performed on web or using downloadable applications. See http://biochem218.stanford.edu/. Prerequisites: introductory molecular biology course at level of BIOSCI 41 or consent of instructor. Autumn and spring offerings are via internet only.
3 units, Aut (Brutlag, D), Win (Brutlag, D), Spr (Brutlag, D)

BIOMEDIN 233. Intermediate Biostatistics: Analysis of Discrete Data
(Same as HRP 261, STATS 261) Methods for analyzing data from case-control and cross-sectional studies: the 2x2 table, chi-square test, Fisher's exact test, odds ratios, Mantel-Haenzel methods, stratification, tests for matched data, logistic regression, conditional logistic regression. Emphasis is on data analysis in SAS. Special topics: cross-fold validation and bootstrap inference.
3 units, Win (Sainani, K)

BIOMEDIN 251. Outcomes Analysis
(Same as HRP 252) 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 256. Economics of Health and Medical Care
(Same as BIOMEDIN 156, ECON 126, HRP 256) 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. Prerequisites: ECON 50 and ECON 102A or equivalent statistics. Recommended: ECON 51.
5 units, Aut (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 273A. A Computational Tour of the Human Genome
(Same as CS 273A, DBIO 273A) Biology through an exploration of Human Genome. Key genomic and genetic concepts from an informatics perspective. Biomedical advances resulting from the Genomics revolution. Topics: genome sequencing: technologies, assembly, personalized sequencing. Functional landscape: genes, gene regulation, repeats, RNA genes. Genome evolution: comparative genomics, ultraconservation, co-option. Additional topics: population genetics, personalized genomics, and ancient DNA. Course starts with primer in Biology and text processing languages. Ends with guest lectures from forefront of genomic research.
3 units, Aut (Batzoglou, S; Bejerano, G)

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

BIOMEDIN 366. Computational Biology
(Same as STATS 166, STATS 366) Methods to understand sequence alignments and phylogenetic trees built from molecular data, and general genetic data. Phylogenetic trees, median networks, microarray analysis, Bayesian statistics. Binary labeled trees as combinatorial objects, graphs, and networks. Distances between trees. Multivariate methods (PCA, CA, multidimensional scaling). Combining data, nonparametric inference. Algorithms used: branch and bound, dynamic programming, Markov chain approach to combinatorial optimization (simulated annealing, Markov chain Monte Carlo, approximate counting, exact tests). Software such as Matlab, Phylip, Seq-gen, Arlequin, Puzzle, Splitstree, XGobi.
2-3 units, Spr (Zhang, N)

BIOMEDIN 370. Medical Scholars Research
Provides an opportunity for student and faculty interaction, as well as academic credit and financial support, to medical students who undertake original research. Enrollment is limited to students with approved projects.
4-18 units, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)

BIOMEDIN 374. Algorithms in Biology (same as CS 374)
(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, Spr (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 (Musen, M), Win (Staff), Spr (Musen, M), Sum (Musen, M)

BIOMEDIN 390B. Curricular Practical Training
BIOMEDIN 390A, B, and C may each be taken only once.
1 unit, Aut (Musen, M), Win (Staff), Spr (Musen, M), Sum (Musen, M)

BIOMEDIN 390C. Curricular Practical Training
BIOMEDIN 390A, B, and C may each be taken only once.
1 unit, Aut (Musen, M), Win (Staff), Spr (Musen, M), Sum (Musen, M)

BIOMEDIN 432. Analysis of Costs, Risks, and Benefits of Health Care

(Same as HRP 392) (Same as MGTECON 332) For graduate students. How to do cost/benefit analysis when the output is difficult or impossible to measure. How do M.B.A. analytic tools apply in health services? Literature on the principles of cost/benefit analysis applied to health care. Critical review of actual studies. Emphasis is on the art of practical application.

4 units, Aut (Garber, A; Owens, D)