Biomedical Informatics

Courses offered by the Program in Biomedical Informatics are listed under the subject code BIOMEDIN on the [Stanford Bulletin's ExploreCourses website](http://explorecourses.stanford.edu/). 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.

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. 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.

The University requirements for the M.S. degree are described in the "Graduate Degrees [Stanford University](http://exploredegrees.stanford.edu/graduatedegrees)" 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 program (HCP) model, 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 Degrees" section 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.


University Coterminal Requirements

Coterminal master’s degree candidates are expected to complete all master’s degree requirements as described in this bulletin. University requirements for the coterminal master’s degree are described in the "Coterminal Master’s Program [Stanford University](http://exploredegrees.stanford.edu/cotermdegrees)" section. University requirements for the master’s degree are described in the "Graduate Degrees [Stanford University](http://exploredegrees.stanford.edu/graduatedegrees/#masterstext)" section of this bulletin.

After accepting admission to this coterminal master’s degree program, students may request transfer of courses from the undergraduate to the graduate career to satisfy requirements for the master’s degree. Transfer of courses to the graduate career requires review and approval of both the undergraduate and graduate programs on a case by case basis.

In this master’s program, courses taken three quarters prior to the first graduate quarter, or later, are eligible for consideration for transfer to the graduate career. No courses taken prior to the first quarter of the sophomore year may be used to meet master’s degree requirements.

Course transfers are not possible after the bachelor’s degree has been conferred.
The University requires that the graduate adviser be assigned in the student’s first graduate quarter even though the undergraduate career may still be open. The University also requires that the Master’s Degree Program Proposal be completed by the student and approved by the department by the end of the student’s first graduate quarter.

**Core Curriculum and Program Requirements in Biomedical Informatics**

### Core Curriculum in Biomedical Informatics

Students are expected to participate regularly in BIOMEDIN 201 Biomedical Informatics Student Seminar and a research colloquium. In addition, all students are expected to fulfill requirements in the following five categories:

1. **Core Biomedical Informatics (17 units)**
   - Students are expected to complete the core offerings in biomedical informatics:
     - a. BIOMEDIN 212 Introduction to Biomedical Informatics Research Methodology
     - b. and 4 of the following:
       - BIOMEDIN 210 Modeling Biomedical Systems: Ontology, Terminology, Problem Solving 3
       - BIOMEDIN 214 Representations and Algorithms for Computational Molecular Biology 3-4
       - BIOMEDIN 215 Data Driven Medicine 3
       - BIOMEDIN 217 Translational Bioinformatics 4
       - BIOMEDIN 260 Computational Methods for Biomedical Image Analysis and Interpretation 3-4
     - c. Any remaining units must be graduate level courses listed under BIOMEDIN.
     - d. Note that BIOMEDIN 211 is no longer offered, however that course may be used by students who completed it to fulfill a core BMI requirement.

2. **Computer Science, Statistics, Mathematics & Engineering (18 units)**
   - Students are expected to create a program of study with a mixture of graduate-level courses in computer science, statistics or other technical informatics-related disciplines that allows them to achieve in-depth mastery of these areas. The programs of study may focus on aspects of these disciplines including (but not limited to): machine learning, artificial intelligence, data mining, image analysis, human-computer interaction, systems engineering, scientific and numerical computing or graphics. In general, this course of study should include no more than 9 units in courses 100-199, and the rest should be 200 or above (unless specifically approved by adviser). CS courses 106A and 106B cannot be counted for this requirement, and all courses should be formal classroom-based courses, unless approved by the executive committee. Up to 6 units of this portion of the core curriculum may be taken on a pass/fail basis, but at least half of the units in this portion of the curriculum must be taken for a grade. Students may petition for quantitative courses in the Medical School or Humanities and Sciences to be counted in this section of the curriculum.

3. **Social and Ethical Issues (4 units)**
   - Students are expected to be familiar with issues regarding ethical, legal, social, organizational and behavioral aspects of the impact of biomedical informatics technologies on society in general. They should select courses broadly from University offerings to explore one or more of these aspects more deeply. Choose courses that fulfill this requirement by entering bmi::ethics in the Explore Courses search box. Students are required to take MED 255 The Responsible Conduct of Research, or the equivalent.

<table>
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<th>Units</th>
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<tbody>
<tr>
<td>BIOE 131 Ethics in Bioengineering 3</td>
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<tr>
<td>BIOE 450 Advances in Biotechnology 3</td>
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<tr>
<td>BIOMEDIN 256 Economics of Health and Medical Care 5</td>
</tr>
<tr>
<td>BIOMEDIN 432 Analysis of Costs, Risks, and Benefits of Health Care 4</td>
</tr>
<tr>
<td>BIOS 224 Big Topics in Stem Cell Ethics 2</td>
</tr>
<tr>
<td>CS 181 Computers, Ethics, and Public Policy 4</td>
</tr>
<tr>
<td>CS 181W Computers, Ethics, and Public Policy 4</td>
</tr>
<tr>
<td>GENE 210 Genomics and Personalized Medicine 3</td>
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<tr>
<td>HRP 209 Health Law: The FDA 2-3</td>
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<tr>
<td>HRP 210 Health Law and Policy 3</td>
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<tr>
<td>HRP 211 Law and the Biosciences: Neuroscience 3</td>
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<tr>
<td>HRP 221 Law and the Biosciences: Genetics 3</td>
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<tr>
<td>HRP 256 Economics of Health and Medical Care 5</td>
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<tr>
<td>HRP 392 Analysis of Costs, Risks, and Benefits of Health Care 4</td>
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<tr>
<td>HUMBIO 174 Foundations of Bioethics 3</td>
</tr>
<tr>
<td>INDE 212 Medical Humanities and the Arts 2</td>
</tr>
<tr>
<td>LAW 654 Law and Biosciences Workshop 1</td>
</tr>
<tr>
<td>ME 208 Patent Law and Strategy for Innovators and Entrepreneurs 2-3</td>
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<tr>
<td>MED 242 Physicians and Human Rights 1</td>
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<tr>
<td>MED 255 The Responsible Conduct of Research 1</td>
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<tr>
<td>MED 255C The Responsible Conduct of Research for Clinical and Community Researchers 1</td>
</tr>
<tr>
<td>MSE 256 Technology Assessment and Regulation of Medical Devices 3</td>
</tr>
<tr>
<td>MSE 278 Patent Law and Strategy for Innovators and Entrepreneurs 2-3</td>
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<tr>
<td>PEDS 251A Medical Ethics I 2</td>
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<tr>
<td>PEDS 251B Medical Ethics II 2</td>
</tr>
<tr>
<td>PUBLPOL 222 Biosecurity and Bioterrorism Response 2-5</td>
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<tr>
<td>SURG 222 Biosecurity and Bioterrorism Response 2-5</td>
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4. **Unrestricted Electives (6 units)**
   - Students may fulfill this requirement with any Stanford course, including courses taken to satisfy core curriculum prerequisites.

5. **For PhD Students only**
   - Domain Biology/Medicine, Pedagogy, Electives (9 units): In order to reach a total of 54 units of core curriculum, PhD students should take an additional 9 units; this should include 6 units of biology or medicine classes relevant to their research interests, 2 units of BIOMEDIN 290 Biomedical Informatics Teaching Methods and one additional unit of unrestricted elective.
   - 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 chosen and the previous training of the student.
The following courses may be taken for satisfactory/no credit (S/NC):

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOMEDIN 200</td>
<td>Biomedical Informatics Colloquium</td>
<td>1</td>
</tr>
<tr>
<td>BIOMEDIN 201</td>
<td>Biomedical Informatics Student Seminar</td>
<td>1</td>
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<tr>
<td>BIOMEDIN 205</td>
<td>Precision Practice with Big Data</td>
<td>1</td>
</tr>
<tr>
<td>BIOMEDIN 206</td>
<td>Informatics in Industry</td>
<td>1</td>
</tr>
<tr>
<td>BIOMEDIN 207</td>
<td>Smart Health through Digital Medicine</td>
<td>1</td>
</tr>
<tr>
<td>BIOMEDIN 290</td>
<td>Biomedical Informatics Teaching Methods</td>
<td>1-6</td>
</tr>
<tr>
<td>BIOMEDIN 299</td>
<td>Directed Reading and Research</td>
<td>1-18</td>
</tr>
<tr>
<td>BIOMEDIN 801</td>
<td>TGR Master's Project</td>
<td>0</td>
</tr>
<tr>
<td>BIOMEDIN 802</td>
<td>TGR PhD Dissertation</td>
<td>0</td>
</tr>
<tr>
<td>MED 255</td>
<td>The Responsible Conduct of Research</td>
<td>1</td>
</tr>
</tbody>
</table>

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 using a formal annual process administered by the BMI executive committee, in which students demonstrate satisfaction of core curriculum prerequisites, and request permission to receive core curriculum credit for classes taken previously in areas of the core curriculum. Students design appropriate programs for their interests with the assistance and approval of their Biomedical Informatics academic adviser. At least 27 units of formal graded course work are expected for the core curriculum.

**Program Requirements for the Academic M.S., HCP Professional M.S., and Coterminal M.S. Degrees**

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

1. Completion of the core curriculum with overall GPA of 3.0.
2. Students are expected to participate regularly in BIOMEDIN 201 Biomedical Informatics Student Seminar and a research colloquium. HCP professional masters candidates who are able to attend classes on campus should also participate regularly.
3. Electives: additional courses to bring the total to 45 or more units taken at Stanford to fulfill the University's residency requirement.
4. Masters candidates should sign up for BIOMEDIN 801 TGR Master's Project for their project units after completing their 45-unit residency requirement.

**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. The Core Curriculum in Biomedical Informatics is outlined in the Master's section (p. 1).

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 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.

2. 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.

3. To remain in the Ph.D. program, each student must attain a grade point average (GPA) of 3.0 for the core curriculum. The student must fulfill these requirements and apply for admission to candidacy for the Ph.D. by the beginning of the third year. In addition, reasonable progress in the student's research activities is expected of all doctoral candidates.

4. During the third year of training, each doctoral student is required to give a propositional seminar that describes evolving research plans.

5. By the beginning of the fourth year, each student must orally present a written thesis proposal for the written dissertation and must orally defend the thesis proposal before a University oral examination 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.

6. After application for Terminal Graduate Registration (TGR) status and completion of 135 units, the Ph.D. candidate should register each quarter for BIOMEDIN 802 TGR PhD Dissertation so their research effort may be counted toward the degree.

7. 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.

8. 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 should be approved by the Biomedical Informatics Executive Committee, and all dissertation reading committees should include at least one BMI participating faculty member.

9. 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.

10. The student is expected to demonstrate an ability to present scholarly material and research in a lecture at a formal seminar.

11. 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.

12. 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. A fourth reader may be added at the discretion of the student and their adviser.

**Ph.D. Minor in Biomedical Informatics**

For a Ph.D. minor in Biomedical Informatics (BMI), a candidate must complete a minimum of 20 unduplicated units of biomedical informatics course work, including 12 units in BMI core courses from:
The candidate must complete the one-unit MED 255 The Responsible Conduct of Research or an approved substitute.

The remaining units must be courses that would count towards the BMI master's degree, taken from these areas:

- Computer Science, Probability, Statistics, Machine Learning, Mathematics, Engineering
- Biomedicine
- Other BMI courses from the list above

Students are expected to participate regularly in BIOMEDIN 201 (https://exploredegrees-nextyear.stanford.edu/schoolofmedicine/biomedicalinformatics) Biomedical Informatics Student Seminar.

Courses used for the BMI Ph.D. minor may not be double-counted to meet the requirements of a master's or Ph.D. degree.

All courses used for the BMI Ph.D. minor, except MED 255, must be taken for a letter grade and passed with an overall GPA of 3.0 or better.

Stanford students apply using the Application for Ph.D. Minor and must provide an unofficial Stanford transcript as well as a statement of purpose for adding the Ph.D. minor degree.

This degree offering became effective in Autumn Quarter 2010-11. Courses taken at Stanford prior to that date may be counted towards the BMI Ph.D. minor degree. A minor program advisor is assigned from the Biomedical Informatics Executive Committee or advising faculty.

Committee: Russ B. Altman (Chair and Program Director), Mark A. Musen (Co-Director), Steven C. Bagley (Executive Director), Manisha Desai, Michel Dumontier, Teri Klein, Daniel L. Rubin, Nimag Shah, Dennis P. Wall

Participating Faculty and Staff by Department*

Biochemistry: Douglas L. Brutlag (Professor Emeritus), Rhiju Das (Assistant Professor), Ronald Davis (Professor), James Ferrell (Professor), Julia Saltzman (Assistant Professor), Julie Theriot (Professor)

Bioengineering: Russ B. Altman (Professor), Kwabena Boahen (Associate Professor), Markus Covert (Assistant Professor), Ingmar Riedel-Kruse (Assistant Professor)

Biology: Hunter Fraser (Assistant Professor), Dmitri Petrov (Professor), Jonathan Pritchard (Professor)

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

Chemistry: Vijay Pande (Professor)

Computer Science: Serafin Batzoglou (Professor), Gill Bejerano (Assistant Professor), David Dill (Professor), Leonidas Guibas (Professor), Anshul Kundaje (Assistant Professor), Daphne Koller (Professor), Terry Winograd (Professor Emeritus)

Developmental Biology: Gill Bejerano (Assistant Professor)

Genetics: Russ B. Altman (Professor), Steven C. Bagley (Senior Research Engineer), Michael Bassik (Assistant Professor), Carlos Bustamante (Professor), Atul Butte (Associate Professor), J. Michael Cherry (Professor, Research), Stanley N. Cohen (Professor), Ronald Davis (Professor), William Greenleaf (Assistant Professor), Teri E. Klein (Senior Research Scientist), Anshul Kundaje (Assistant Professor), Jin Billy Li (Assistant Professor), Stephen B. Montgomery (Assistant Professor), Jonathan Pritchard (Professor), Gavin Sherlock (Professor), Ared Sidow (Professor), Michael P. Snyder (Professor), Hua Tang (Associate Professor)

Health Research and Policy: Trevor Hastie (Professor), Mark Hlatky (Professor), Richard A. Olslen (Professor), Chiara Sabatti (Associate Professor), Robert Tibshirani (Professor)

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

Medicine: Russ B. Altman (Professor), Euan Ashley (Assistant Professor), Jayanta Bhattacharya (Associate Professor), Catherine Blish (Assistant Professor), Carol Cain (Consulting Assistant Professor), Stanley Cohen (Professor), Manisha Desai (Associate Professor), Michel Dumontier (Associate Professor), Andrew Gentles (Assistant Professor), Olivier Gevaert (Assistant Professor), Mary Goldstein (Professor), Michael Higgins (Consulting Associate Professor), Mark Hlatky (Professor), Hanlee P. Ji (Assistant Professor), Purvesh Khatri (Assistant Professor), Henry Lowe (Associate Professor), Mark A. Musen (Professor), Douglas K. Owens (Professor), Daniel R. Rubin (Assistant Professor), Robert W. Shafer (Professor, Research), Nimag Shah (Assistant Professor), Samson Tu (Senior Research Scientist), P.J. Utz (Professor)

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

Operations, Information and Technology: Mohsen Bayati (Assistant Professor)

Pathology: Stephen B. Montgomery (Assistant Professor), Arend Sidow (Professor)

Pediatrics: Chris Longhurst (Clinical Associate Professor), Jonathan Palma (Clinical Assistant Professor), Dennis Wall (Associate Professor)

Psychiatry and Behavioral Sciences: Vinod Menon (Professor, Research)

Radiation Oncology: Lei Xing (Professor)

Radiology: Sam (Sanjiv) Gambhir (Professor), Parag Mallick (Assistant Professor, Research), Sandy A. Napel (Professor), David Paik (Consulting Assistant Professor), Sylvia Plevritis (Professor), Daniel L. Rubin (Associate Professor)

Statistics: Trevor J. Hastie (Professor), Susan Holmes (Professor), Art Owen (Professor), Chiara Sabatti (Associate Professor), Robert Tibshirani (Professor)

Structural Biology: Michael Levitt (Professor)

Surgery: Thomas Krumel (Professor)

* Research opportunities are not limited to faculty and departments listed.

Courses

**BIOMEDIN 156. Economics of Health and Medical Care. 5 Units.**

Institutional, theoretical, and empirical analysis of the problems of health and medical care. Topics: demand for medical care and medical insurance; institutions in the health sector; economics of information applied to the market for health insurance and for health care; measurement and valuation of health; competition in health care delivery. Graduate students with research interests should take ECON 249. Prerequisites: ECON 50 and either ECON 102A or STATS 116 or the equivalent. Recommended: ECON 51.

Same as: BIOMEDIN 256, ECON 126, HRP 256

**BIOMEDIN 200. Biomedical Informatics Colloquium. 1 Unit.**

Series of colloquia offered by program faculty, students, and occasional guest lecturers. May be repeated three times for credit.
BIOMEDIN 201. Biomedical Informatics Student Seminar. 1 Unit.
Participants report on recent articles from the Biomedical Informatics literature or their research projects. Goals are to teach critical reading of scientific papers and presentation skills. May be repeated three times for credit.

BIOMEDIN 205. Precision Practice with Big Data. 1 Unit.
Primarily for M.D. students; open to other graduate students. Provides an overview of how to leverage large amounts of clinical, molecular, and imaging data within hospitals and in cyberspace--big data--to practice medicine more effectively. Lectures by physicians, researchers, and industry leaders survey how the major methods of informatics can help physicians leverage big data to profile disease, to personalize treatment to patients, to predict treatment response, to discover new knowledge, and to challenge established medical dogma and the current paradigm of clinical decision-making based solely on published knowledge and individual physician experience. May be repeated for credit. Prerequisite: background in biomedicine. Background in computer science can be helpful but not required.

BIOMEDIN 206. Informatics in Industry. 1 Unit.
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.

BIOMEDIN 207. Smart Health through Digital Medicine. 1 Unit.
The widespread use of Health IT, such as electronic health records, and of health applications on the part of patients and consumers, will radically alter the practice of medicine in the coming decades. This seminar, comprised of guest lectures from healthcare professionals in industry and academia, will highlight the practical challenges and successes of health IT design and transformed care delivery programs. The goal of the course is to provide an understanding of how technology designs can advance the delivery and quality of healthcare. In addition to attending lectures, students will be asked to think through a health IT solution to a care delivery problem in a short report.

BIOMEDIN 208. Clinical Informatics Literature Review Seminar. 1 Unit.
Focus is on reading and discussing seminal papers in clinical and health informatics. Topics include biomedical informatics methods, systems design, implementation and evaluation. Limited enrollment.

BIOMEDIN 210. Modeling Biomedical Systems: Ontology, Terminology, Problem Solving. 3 Units.
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. Same as: CS 270

BIOMEDIN 212. Introduction to Biomedical Informatics Research Methodology. 3 Units.
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. Because the team projects start in the first week of class, attendance that week is strongly recommended. Prerequisites: BIOMEDIN 210 or 211 or 214 or 217 or consent of instructor. Same as: BIOE 212, CS 272, GENE 212

BIOMEDIN 214. Representations and Algorithms for Computational Molecular Biology. 3-4 Units.
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. Same as: BIOE 214, CS 274, GEN E 214

BIOMEDIN 215. Data Driven Medicine. 3 Units.
With the spread of electronic health records and increasingly low cost assays for patient molecular data, powerful data repositories with tremendous potential for biomedical research, clinical care and personalized medicine are being built. But these databases are large and difficult for any one specialist to analyze. To find the hidden associations within the full set of data, we introduce methods for data-mining at the internet scale, the handling of large-scale electronic medical records data for machine learning, methods in natural language processing and text-mining applied to medical records, methods for using ontologies for the annotation and indexing of unstructured content as well as semantic web technologies. Prerequisites: CS 106A; familiarity with statistics and biology. Highly recommended: STATS 216. Recommended: one of CS 246, STATS 305, or CS 229.

Lecture component of BIOMEDIN 214. One unit for medical and graduate students who attend lectures only; may be taken for 2 units with participation in limited assignments and final project. Lectures also available via internet. Prerequisite: familiarity with biology recommended.

BIOMEDIN 217. Translational Bioinformatics. 4 Units.
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. Same as: CS 275

BIOMEDIN 218. Translational Bioinformatics Lectures. 2 Units.
Same content as BIOMEDIN 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 ability at the level of CS 106A; familiarity with statistics and biology.
BIOMEDIN 219. Mathematical Models and Medical Decisions. 2 Units.
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-constrained clinical policies. Extensive problem sets
compliment course materials. Prerequisites: introduction to calculus and
basic statistics.

BIOMEDIN 224. Principles of Pharmacogenomics. 3 Units.
This course is an introduction to pharmacogenomics, including the relevant
pharmacology, genomics, experimental methods (sequencing, expression,
genotyping), data analysis methods and bioinformatics. The course reviews
key gene classes (e.g., cytochromes, transporters) and key drugs (e.g.,
warfarin, clopidogrel, statins, cancer drugs) in the field. Resources for
pharmacogenomics (e.g., PharmGKB, Drugbank, NCBI resources) are
reviewed, as well as issues implementing pharmacogenomics testing in the
clinical setting. Reading of key papers, including student presentations of
this work; problem sets; final project selected with approval of instructor.
Prerequisites: two of BIO 41, 42, 43, 44X, 44Y or consent of instructor.
Same as: GENE 224

BIOMEDIN 225. Data Driven Medicine: Lectures. 2 Units.
Lectures for BIOMEDIN 215. With the spread of electronic health records and
increasingly low cost assays for patient molecular data, powerful data
repositories with tremendous potential for biomedical research, clinical
care and personalized medicine are being built. But these databases are
large and difficult for any one specialist to analyze. To find the hidden associations
within the full set of data, we introduce methods for data-mining at the
internet scale, the handling of large-scale electronic medical records data for
machine learning, methods in natural language processing and text-mining
applied to medical records, methods for using ontologies for the annotation
and indexing of unstructured content as well as semantic web technologies.
Prerequisites: familiarity with statistics (STATS 202) and biology.

3 Units.
Methods for analyzing data from case-control and cross-sectional studies:
the 2x2 table, chi-square test, Fisher's exact test, odds ratios, Mantel-
Haenel 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.
Same as: HRP 261, STATS 261

BIOMEDIN 245. Statistical and Machine Learning Methods for
Genomics. 3 Units.
Introduction to statistical and computational methods for genomics. Sample
topics include: expectation maximization, hidden Markov model, Markov
chain Monte Carlo, ensemble learning, probabilistic graphical models,
kernel methods and other modern machine learning paradigms. Rationales
and techniques illustrated with existing implementations used in population
genetics, disease association, and functional regulatory genomics studies.
Instruction includes lectures and discussion of readings from primary
literature. Homework and projects require implementing some of the
algorithms and using existing toolkits for analysis of genomic datasets.
Same as: BIO 268, CS 373, GENE 245, STATS 345

BIOMEDIN 251. Outcomes Analysis. 4 Units.
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.
Same as: HRP 252, MED 252

BIOMEDIN 256. Economics of Health and Medical Care. 5 Units.
Institutional, theoretical, and empirical analysis of the problems of health
and medical care. Topics: demand for medical care and medical insurance;
institutions in the health sector; economics of information applied to the
market for health insurance and for health care; measurement and valuation
of health; competition in health care delivery. Graduate students with
research interests should take ECON 249. Prerequisites: ECON 50 and
either ECON 102A or STATS 116 or the equivalent. Recommended: ECON 51.
Same as: BIOMEDIN 156, ECON 126, HRP 256

BIOMEDIN 260. Computational Methods for Biomedical Image
Analysis and Interpretation. 3-4 Units.
The latest biological and medical imaging modalities and their applications
in research and medicine. Focus is on computational analytic and
interpreative approaches to optimize extraction and use of biological and
clinical imaging data for diagnostic and therapeutic translational medical applications. Topics include major image databases, fundamental
methods in image processing and quantitative extraction of image features,
structured recording of image information including semantic features and
ontologies, indexing, search and content-based image retrieval. Case
studies include linking image data to genomic, phenotypic and clinical
data, developing representations of image phenotypes for use in medical
decision support and research applications and the role that biomedical
imaging informatics plays in new questions in biomedical science. Includes
a project. Enrollment for 3 units requires instructor consent. Prerequisites:
programming ability at the level of CS 106A, familiarity with statistics,
biological modeling. Knowledge of Matlab highly recommended.
Same as: RAD 260

BIOMEDIN 262. Computational Genomics. 3 Units.
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.
Same as: CS 262

BIOMEDIN 273A. A Computational Tour of the Human Genome. 3 Units.
Introduction to computational biology through an informatic exploration
of the human genome. Topics include: genome sequencing (technologies,
assembly, personalized sequencing); functional landscape (genes, gene
regulation, repeats, RNA genes, epigenetics); genome evolution
(comparative genomics, ultraconservation, co-option). Additional topics
may include population genetics, personalized genomics, and ancient
DNA. Course includes primers on molecular biology, the UCSC Genome
Browser, and text processing languages. Guest lectures from genomic
researchers. No prerequisites. See http://cs273a.stanford.edu/
Same as: CS 273A, DBIO 273A
BIOMEDIN 279. Computational Biology: Structure and Organization of Biomolecules and Cells. 3 Units.
Computational approaches to understanding the three-dimensional spatial organization of biological systems and how that organization evolves over time. The course will cover cutting-edge research in both physics-based simulations and computational analysis of experimental data, at scales ranging from individual molecules to multiple cells. Prerequisites: elementary programming background (106A or equivalent) and an introductory course in biology or biochemistry.
Same as: BIOPHYS 279, CME 279, CS 279

BIOMEDIN 290. Biomedical Informatics Teaching Methods. 1-6 Unit.
Hands-on training in biomedical informatics pedagogy. Practical experience in pedagogical approaches, variously including didactic, inquiry, project, team, case, field, and/or problem-based approaches. Students create course content, including lectures, exercises, and assessments, and evaluate learning activities and outcomes. Prerequisite: instructor consent.

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

BIOMEDIN 370. Medical Scholars Research. 4-18 Units.
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.

BIOMEDIN 371. Computational Biology in Four Dimensions. 3 Units.
Computational approaches to understanding the three-dimensional spatial organization of biological systems and how that organization evolves over time. The course will cover cutting-edge research in both physics-based simulation and computational analysis of experimental data, at scales ranging from individual molecules to entire cells. Prerequisite: CS 106A or equivalent, and an introductory course in biology or biochemistry. Recommended: some experience in mathematical modeling (does not need to be a formal course).
Same as: BIOPHYS 371, CME 371, CS 371

BIOMEDIN 374. Algorithms in Biology. 2-3 Units.
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.
Same as: CS 374

BIOMEDIN 390A. Curricular Practical Training. 1 Unit.
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.

BIOMEDIN 390B. Curricular Practical Training. 1 Unit.
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.