BIOMEDICAL INFORMATICS

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 complete additional course work to fulfill degree requirements and pursue their technical interests and goals as specified for each degree program.

The program can provide flexibility and can complement other opportunities in applied medical research at Stanford. Special arrangements may 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 (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 by the end of the second year. The first year involves acquiring the fundamental concepts and tools through course work and research project involvement. Academic M.S. 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. Although many classes necessary for the degree are available online, some requirements may be fulfilled through implementation of an alternative plan to be approved by the program. 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; if interested, 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. See the "Coterminal Degrees (http://exploredegrees.stanford.edu/cotermdegrees)" section of this bulletin for additional information. For University coterminal degree program rules and University application forms, see the Registrar's web site (https://registrar.stanford.edu/students/coterm-degree-programs/applying-coterm).

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; if interested, 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.

Application to the Coterminal Program

For complete information, see the program's Coterminal Master's Degree (http://bmi.stanford.edu/prospective-students/masters-degree-coterm-biomedical-informatics.html) page.

2. Submit the program's Coterminal Supplemental Application Form (http://bmi.stanford.edu/prospective-students/FilesProspectiveStudents/CotermSupplementApp.doc).
3. Submit your academic resume or curriculum vitae.
4. Submit a one-page Statement of Purpose describing how and why the BMI program is well matched to your interests.

Applicants to the coterminal M.S. programs are not required to submit GRE scores. GRE scores are recommended, especially if you have relatively little prior course work in quantitative and computational areas. The TOEFL is not required.

Advising

Upon acceptance into the program, students are assigned a BMI academic adviser. The student revises the program proposal at this time. Students should contact the BMI program office for advice about coterminal status between acceptance and the first appointment with the BMI academic adviser.

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 (http://exploredegrees.stanford.edu/cotermdegrees)" section. University requirements for the master's degree are described in the "Graduate Degrees (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 (31 units)**

Students are expected to participate regularly in BIOMEDIN 201 Biomedical Informatics Student Seminar and a research colloquium. Regardless of whether they are enrolled, they should attend all meetings throughout their graduate training, and attend a research colloquium appropriate to their interests. All students are expected to fulfill the following requirements:

- **Core Biomedical Informatics (9 or more units)**
  
  Students are expected to complete the core offerings in biomedical informatics. These courses should be taken for a grade.
  
  a. BIOMEDIN 212 Introduction to Biomedical Informatics Research Methodology
  
  b. and two of the following:

  - BIOMEDIN 210 Modeling Biomedical Systems: Ontology, Terminology, Problem Solving
  - BIOMEDIN 214 Representations and Algorithms for Computational Molecular Biology
  - BIOMEDIN 215 Data Driven Medicine
  - BIOMEDIN 217 Translational Bioinformatics
  - BIOMEDIN 260 Computational Methods for Biomedical Image Analysis and Interpretation

- **Computer Science, Statistics, Mathematics & Engineering (18 units)**

  Students are expected to create a program of study with graduate-level courses in computer science, statistics and other technical informatics-related disciplines to achieve in-depth mastery. The program of study may focus on aspects of these disciplines including machine learning, statistical modeling, artificial intelligence, data mining, image analysis, human-computer interaction and data visualization. A complete list of courses accepted for this requirement is on the BMI website. The following are required:

  a. CS 161 Design and Analysis of Algorithms
  
  b. STATS 200 Introduction to Statistical Inference
  
  c. STATS 315A Modern Applied Statistics: Learning is strongly recommended.
  
  d. No more than 9 units in courses numbered 100-199, and the rest should be 200 or above.
  
  e. CS 106A Programming Methodology and CS 106B Programming Abstractions cannot be counted for this requirement.
  
  f. All courses should be formal classroom-based courses, not research units.
  
  g. Up to 6 units of this portion of the core curriculum may be taken on a Satisfactory/No credit basis.

- **Social and Ethical Issues (4 units)**

  Students are expected to be familiar with issues regarding responsible conduct of research, reproducibility of research, and ethical, legal, social, organizational and behavioral aspects of the impact of biomedical informatics technologies on society. Courses that fulfill this requirement can be found by entering “bmi::ethics” in the Explore Courses search box. PhD students and Academic M.S. students should take MED 255 The Responsible Conduct of Research in their first year. These courses may be taken on a Satisfactory/No credit basis.

**Units**

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<thead>
<tr>
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<tbody>
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<td>BIOMEDIN 256</td>
<td>Economics of Health and Medical Care</td>
<td>5</td>
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<tr>
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<tr>
<td>BIOS 224</td>
<td>Big Topics in Stem Cell Ethics</td>
<td>2</td>
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<tr>
<td>BIOS 258</td>
<td>Ethics, Science, and Society</td>
<td>1</td>
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<tr>
<td>CS 181</td>
<td>Computers, Ethics, and Public Policy</td>
<td>4</td>
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<td>GENE 210</td>
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<td>Health Law: The FDA</td>
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<td>HRP 211</td>
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<td>HRP 221</td>
<td>Law and the Biosciences: Genetics</td>
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<td>HRP 273</td>
<td>Essentials of Clinical Research at Stanford</td>
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<td>HRP 392</td>
<td>Analysis of Costs, Risks, and Benefits of Health Care</td>
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<tr>
<td>HUMBIO 174</td>
<td>Foundations of Bioethics</td>
<td>3</td>
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<td>INDE 212</td>
<td>Medical Humanities and the Arts</td>
<td>2</td>
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<tr>
<td>ME 208</td>
<td>Patent Law and Strategy for Innovators and Entrepreneurs</td>
<td>2-3</td>
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<tr>
<td>MED 242</td>
<td>Physicians and Human Rights</td>
<td>1</td>
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<tr>
<td>MED 255</td>
<td>The Responsible Conduct of Research</td>
<td>1</td>
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<tr>
<td>MED 255C</td>
<td>The Responsible Conduct of Research for Clinical and Community Researchers</td>
<td>1</td>
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<tr>
<td>MS&amp;E 256</td>
<td>Technology Assessment and Regulation of Medical Devices</td>
<td>3</td>
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<tr>
<td>MS&amp;E 278</td>
<td>Patent Law and Strategy for Innovators and Entrepreneurs</td>
<td>2-3</td>
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<tr>
<td>NBIO 101</td>
<td>Social and Ethical Issues in the Neurosciences</td>
<td>2-4</td>
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<tr>
<td>PEDS 251A</td>
<td>Medical Ethics I</td>
<td>2</td>
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<tr>
<td>PEDS 251B</td>
<td>Medical Ethics II</td>
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<tr>
<td>PUBLPOL 222</td>
<td>Biosecurity and Bioterrorism Response</td>
<td>2-5</td>
</tr>
</tbody>
</table>

**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.

- The core curriculum generally entails a minimum of 31 units of course work, but can require more or less depending upon the courses chosen and the previous training of the student.
• M.S. candidates should complete additional course work and program requirements as outlined below. 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. Students design appropriate programs for their interests with the assistance and approval of their Biomedical Informatics academic adviser.

• At least 21 units of formal letter-graded coursework are expected for all MS and PhD candidates.

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. Two additional BMI core offerings from among BIOMEDIN 210 Modeling Biomedical Systems: Ontology, Terminology, Problem Solving, BIOMEDIN 214 Representations and Algorithms for Computational Molecular Biology, BIOMEDIN 215 Data Driven Medicine, BIOMEDIN 217 Translational Bioinformatics and BIOMEDIN 260 Computational Methods for Biomedical Image Analysis and Interpretation (6-7 units) that were not taken to satisfy the core curriculum.
3. Unrestricted Electives needed to complete 45 units. Students may fulfill this requirement with any Stanford graduate courses, including courses taken to satisfy program prerequisites.
4. At least 23 units of courses must be at the level 200 or above.
5. A cumulative GPA of 3.0 or greater to remain in good academic standing.
6. Students are expected to participate regularly in BIOMEDIN 201 Biomedical Informatics Student Seminar and a research colloquium. HCp professional masters students who are able to attend classes on campus should participate regularly.
7. Academic M.S. students who are funded by the program are required to be a teaching assistant for one course; those students may register for 1-3 units of BIOMEDIN 201 Biomedical Informatics Teaching Methods.
8. HCP professional masters students who are local are encouraged to participate in on-campus coursework and seminars.
9. Masters students 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

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 University’s basic requirements for the doctorate (residence, dissertation, examination, and so on) are discussed in the “Graduate Degrees (http://exploredegrees.stanford.edu/graduatedegrees)” section of this bulletin.

The Core Curriculum in Biomedical Informatics (31 units) is outlined below. The Ph.D. program requires an additional 21 units of coursework, to complete a total of 52 units.

Core Curriculum in Biomedical Informatics (31 units)

Students are expected to participate regularly in BIOMEDIN 201 Biomedical Informatics Student Seminar and a research colloquium. Regardless of whether they are enrolled, they should attend all meetings throughout their graduate training, and attend a research colloquium appropriate to their interests. All students are expected to fulfill the following requirements:

• Core Biomedical Informatics Courses (9 or more units)

Students are expected to complete the core offerings in biomedical informatics. These courses should be taken for a grade.

a. BIOMEDIN 212 Introduction to Biomedical Informatics Research Methodology

b. and two of the following:

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<td>BIOMEDIN 260</td>
<td>Computational Methods for Biomedical Image Analysis and Interpretation</td>
<td>3-4</td>
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• Computer Science, Statistics, Mathematics & Engineering (18 units)

Ph.D. students are expected to create a program of study with graduate-level courses in computer science, statistics and other technical informatics-related disciplines to achieve in-depth mastery. The program of study may focus on aspects of these disciplines including machine learning, statistical modeling, artificial intelligence, data mining, image analysis, human-computer interaction and data visualization. A complete list of courses accepted for this requirement is on the BMI website. The following are required:

a. CS 161 Design and Analysis of Algorithms
b. STATS 200 Introduction to Statistical Inference
c. STATS 315A Modern Applied Statistics: Learning is strongly recommended.
d. No more than 9 units in courses numbered 100-199, and the rest should be 200 or above.
e. CS 106A Programming Methodology and CS 106B Programming Abstractions cannot be counted for this requirement.
f. All courses should be formal classroom-based courses, not research units.
g. Up to 6 units of this portion of the core curriculum may be taken on a Satisfactory/No credit basis.

• Social and Ethical Issues (4 units)

Students are expected to be familiar with issues regarding responsible conduct of research, reproducibility of research, and ethical, legal, social, organizational and behavioral aspects of the impact of biomedical informatics technologies on society. Courses that fulfill this requirement can be found by entering “bmi::ethics” in the Explore Courses search box. PhD students should take MED 255 The Responsible Conduct of Research in their first year. These courses may be taken on a Satisfactory/No credit basis.

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</table>
Program Requirements for the Biomedical Informatics PhD:

1. Completion of the Core Curriculum (31 or more units) described above.
2. Additional technical electives (6 units) drawn from the courses in Computer Science, Mathematics, Statistics, and Engineering as specified for the Core Curriculum above.
3. Domain biology or medicine (6 units). Students should take classes relevant to their application area interests.
4. The above three requirements should be completed by the end of the second year of graduate study.
5. Unrestricted electives (9 units). Students may fulfill this requirement with any Stanford graduate courses, including courses taken to satisfy program prerequisites.
6. A cumulative GPA of 3.0 or greater to remain in good academic standing.
7. In the first year, at least two research rotations are required.
8. Each student is required to be a teaching assistant for two courses as assigned by the Biomedical Informatics Executive Committee; one should be completed in the first two years of study. Students may register for up to 3 units of BIOMEDIN 290 to obtain credit for teaching assistantships.
9. Doctoral students are generally advanced to Ph.D. candidacy after passing the qualifying exam, which takes place by 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. The student must fulfill these requirements and apply for admission to candidacy for the Ph.D. by the beginning of the third year.
10. During the third year of training, each doctoral student is required to give a thesis pre-proposal seminar that describes evolving research plans.
11. The most important requirement for the Ph.D. degree is the dissertation. Each student must secure the agreement of a member of the BMI advising faculty to act as the doctoral dissertation adviser or co-adviser.
12. 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 that their research effort may be counted toward the degree.

13. Before the end 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 includes at least one member of the BMI Advising Faculty. 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.
14. 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 final research 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.
15. The student is expected to demonstrate an ability to present scholarly material and research in a lecture at a formal seminar.
16. 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 advisor as suitable for submission to a refereed journal before the doctoral degree is conferred.
17. The dissertation must be accepted by a doctoral dissertation reading committee composed of the principal dissertation adviser and two other readers. A fourth reader may be added at the discretion of the student and the principal 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:

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<td>Modeling Biomedical Systems: Ontology, Terminology, Problem Solving</td>
<td>3</td>
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<tr>
<td>BIOMEDIN 212</td>
<td>Introduction to Biomedical Informatics Research Methodology</td>
<td>3</td>
</tr>
<tr>
<td>BIOMEDIN 214</td>
<td>Representations and Algorithms for Computational Molecular Biology</td>
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<td>BIOMEDIN 215</td>
<td>Data Driven Medicine</td>
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<td>BIOMEDIN 217</td>
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<td>BIOMEDIN 260</td>
<td>Computational Methods for Biomedical Image Analysis and Interpretation</td>
<td>3-4</td>
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</tbody>
</table>

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 (p. 1) 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.
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.

**Application Process**

Stanford Ph.D. students apply using the Application for Ph.D. Minor (https://stanford.app.box.com/v/app-phd-minor) form and must provide an unofficial Stanford transcript as well as a statement of purpose for adding the Ph.D. minor degree. Submit the form and accompanying materials to the Biomedical Informatics program.

**Advising**

A minor program adviser is assigned from the Biomedical Informatics Executive Committee or advising faculty upon admission to the program.

**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, Nigam Shah, Dennis P. Wall

**Participating Faculty and Staff by Department**

**Biochemistry:** Douglas Brutlag (Professor Emeritus), Rhiiju Das (Associate Professor), Ronald Davis (Professor), James Ferrell (Professor), Julia Salzman (Assistant Professor), Julie Theriot (Professor)

**Biomechanical Systems:** Russ B. Altman (Professor), Kwabena Boateng (Professor), Scott Delp (Professor), Markus Covert (Associate Professor), Ingrid Riedel-Kruse (Assistant Professor)

**Biological Data Science:** Carlos Bustamante (Professor), Richard Olshen (Professor), Chiara Sabatti (Associate Professor), Robert Tibshirani (Professor), Dennis P. Wall (Associate Professor)

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

**Chemistry:** Vijay Pande (Professor)

**Computer Science:** Serafim Batzoglou (Professor), Gill Bejerano (Associate Professor), David Dill (Professor), Ronald Dror (Associate Professor), Leonidas Guibas (Professor), Anshul Kundaje (Assistant Professor), Terry Winograd (Professor Emeritus)

**Dermatology:** Paul Khavari (Professor)

**Developmental Biology:** Gill Bejerano (Associate Professor)

**Energy Resources Engineering:** Margot Gerritsen (Associate Professor)

**Genetics:** Russ B. Altman (Professor), Euan Ashley (Associate Professor), Steven C. Bagley (Senior Research Engineer), Michael Bassik (Assistant Professor), Ami Bhatt (Assistant Professor), Carlos Bustamante (Professor), J. Michael Cherry (Professor, Research), Stanley N. Cohen (Professor, Christina Curtis (Assistant Professor), Ronald Davis (Professor), William Greenleaf (Assistant Professor), Karla Kirkegaard (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), Arent Sidow (Professor), Michael P. Snyder (Professor), Hua Tang (Associate Professor)

**Health Research and Policy:** Trevor Hastie (Professor), Mark Hlatky (Professor)

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

**Medicine:** Russ B. Altman (Professor), Euan Ashley (Associate Professor), Ami Bhatt (Assistant Professor), Jayanta Bhattacharya (Associate Professor), Catherine Blish (Assistant Professor), Carol Cain (Consulting Assistant Professor), Stanley Cohen (Professor), Christina Curtis (Associate Professor), Manisha Desai (Associate Professor), Michel Dumontier (Associate Professor), Andrew Gentles (Senior Research Engineer), Olivier Gevaert (Assistant Professor), Mary Goldstein (Professor), Michael Higgins (Consulting Associate Professor), Mark Hlatky (Professor), Hanlee P. Ji (Associate Professor), Purvesh Khatri (Assistant Professor), Lianne Kurina (Associate Professor, Teaching), Curtis Langlotz (Professor), Henry Low (Associate Professor), Mark A. Musen (Professor), Douglas K. Owens (Professor), Natalie Pageler (Clinical Associate Professor), David Relman (Professor), Robert W. Shafer (Professor, Research), Nigam Shah (Associate Professor), Samson Tu (Senior Research Scientist), P.J. Utz (Professor)

**Mechanical Engineering:** Scott Delp (Professor)

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

**Operations, Information, and Technology:** Mohsen Bayati (Associate Professor)

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

**Pediatrics:** Natalie Pageler (Clinical Associate Professor), Jonathan Palma (Clinical Assistant Professor), Dennis P. Wall (Associate Professor)

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

**Psychology:** Russell Poldrack (Professor)

**Radiation Oncology:** Lei Xing (Professor)

**Radiology:** Sam (Sanjiv) Gambhir (Professor), Curtis Langlotz (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—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. Digital Medicine: How health IT is changing the practice of medicine. 1 Unit. The widespread use of health IT, such as electronic health records, and of health applications by patients, will radically alter the practice of medicine in the coming decades. This seminar, comprised of guest lectures from industry and academia, will highlight the practical challenges and successes of how health IT has transformed care delivery programs. The seminar will cover current efforts in clinical decision support, patient-centered design, integration with community care, Big Data, and the innovation pipeline for healthcare delivery organizations.

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 building model-based 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. Students learn about current trends in the development of advanced biomedical software systems and acquire hands-on experience with several systems and tools. Prerequisites: CS106A, basic familiarity with biology. Same as: CS 270

BIOMEDIN 212. Introduction to Biomedical Informatics Research Methodology. 3-5 Units. Capstone Biomedical Informatics (BMI) experience. 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. Issues related to research reproducibility. 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. Preference to BMI graduate students. Consent of instructor required. 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, 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. Prerequisite: CS 106B; recommended: CS161; consent of instructor for 3 units. Same as: BIOE 214, CS 274, GENE 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; STATS 216. Recommended: one of CS 246, STATS 305, or CS 22.

BIOMEDIN 216. Representations and Algorithms for Molecular Biology: Lectures. 1-2 Unit. 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. Computational methods for the translation of biomedical data into diagnostic, prognostic, and therapeutic applications in medicine. Topics: multi-scale omics data generation and analysis, utility and limitations of public biomedical resources, machine learning and data mining, issues and opportunities in drug discovery, and mobile/digital health solutions. Case studies and course project. Prerequisites: programming ability at the level of CS 106A and familiarity with biology and statistics. Same as: BIOE 217, 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. Computational methods for the translation of biomedical data into diagnostic, prognostic, and therapeutic applications in medicine. Topics: multi-scale omics data generation and analysis, utility and limitations of public biomedical resources, machine learning and data mining, issues and opportunities in drug discovery, and mobile/digital health solutions. Case studies.nPrerequisites: programming ability at the level of CS 106A and familiarity with biology and statistics.

BIOMEDIN 219. Mathematical Models and Medical Decisions. 3 Units. Analytic methods for determining optimal diagnostic and therapeutic decisions with applications to the care of individual patients and the design of policies applied to patient populations. Topics include: utility theory and probability modeling, empirical methods for disease prevalence estimation, 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 complement the lectures. 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 216) and biology.

BIOMEDIN 233. Intermediate Biostatistics: Analysis of Discrete Data. 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-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. 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 interpretive 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, basic biology. 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, algorithms on strings and sequences, graphical models for sequence analysis. Applications of these tools to comparative genomics, DNA sequencing and assembly, genomic annotation, functional genomics, phylogeny and molecular evolution, population genomics, cancer genomics. Prerequisites: 161 or familiarity with basic algorithmic concepts. Recommended: basic knowledge of genetics.

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 273B. Deep Learning in Genomics and Biomedicine. 3 Units.
Recent breakthroughs in high-throughput genomic and biomedica data are transforming biological sciences into "big data" disciplines. In parallel, progress in deep neural networks are revolutionizing fields such as image recognition, natural language processing and, more broadly, AI. This course explores the exciting intersection between these two advances. The course will start with an introduction to deep learning and overview the relevant background in genomics and high-throughput biotechnology, focusing on the available data and their relevance. It will then cover the ongoing developments in deep learning (supervised, unsupervised and generative models) with the focus on the applications of these methods to biomedical data, which are beginning to produce dramatic results. In addition to predictive modeling, the course emphasizes how to visualize and extract interpretable, biological insights from such models. Recent papers from the literature will be presented and discussed. Students will be introduced to and work with popular deep learning software frameworks. Students will work in groups on a final class project using real world datasets. Prerequisites: College calculus, linear algebra, basic probability and statistics such as CS109, and basic machine learning such as CS229. No prior knowledge of genomics is necessary. 
Same as: BIOE 273, CS 273B, GENE 236

BIOMEDIN 279. Computational Biology: Structure and Organization of Biomolecules and Cells. 3 Units.
Computational techniques for investigating and designing the three-dimensional structure and dynamics of biomolecules and cells. These computational methods play an increasingly important role in drug discovery, medicine, bioengineering, and molecular biology. Course topics include protein structure prediction, protein design, drug screening, molecular simulation, cellular-level simulation, image analysis for microscopy, and methods for solving structures from crystallography and electron microscopy data. Prerequisites: elementary programming background (CS 106A or equivalent) and an introductory course in biology or biochemistry. 
Same as: BIOE 279, 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.
Cutting-edge research on computational techniques for investigating and designing the three-dimensional structure and dynamics of biomolecules, cells, and everything in between. These techniques, which draw on approaches ranging from physics-based simulation to machine learning, play an increasingly important role in drug discovery, medicine, bioengineering, and molecular biology. Course is devoted primarily to reading, presentation, discussion, and critique of papers describing important recent research developments. 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.

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.

BIOMEDIN 390C. 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 432. Analysis of Costs, Risks, and Benefits of Health Care. 4 Units.
(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. 
Same as: HRP 392

BIOMEDIN 801. TGR Master's Project. 0 Units.
Project credit for masters students who have completed all course requirements and minimum of 45 Stanford units.

BIOMEDIN 802. TGR PhD Dissertation. 0 Units.