

BIOMEDICAL INFORMATICS

Courses offered by the Program in Biomedical Informatics are listed under the subject code BIOMEDIN on the (<http://explorecourses.stanford.edu/CourseSearch/search/?view=catalog&catalog=&page=0&q=BIOMEDIN&filter-catalognumber=BIOMEDIN=on>) Stanford Bulletin's (<http://explorecourses.stanford.edu/CourseSearch/search/?view=catalog&catalog=&page=0&q=BIOMEDIN&filter-catalognumber=BIOMEDIN=on>) ExploreCourses web site (<http://explorecourses.stanford.edu/CourseSearch/search/?view=catalog&catalog=&page=0&q=BIOMEDIN&filter-catalognumber=BIOMEDIN=on>).

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 GRE is not required for admission.

The University requirements for the M.S. degree are described in the "Graduate Degrees (<http://exploreddegrees.stanford.edu/graduatedegrees/>)" section of this bulletin.

Advising

Upon entering the program, each student is assigned an academic adviser to help with course selection and monitor progress towards program milestones and degree requirements. Each research-track (academic) M.S. and Ph.D. student conducts research under the primary mentorship of a faculty supervisor, who guides their scholarly and professional development. Further details about the adviser roles and responsibilities are found in the BMI Student Handbook (<http://med.stanford.edu/bmi/biomedical-informatics-students/handbook.html>) and on the Advising tab (p. 5) in this section of the Stanford 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 full-time and is enrolled in the M.S. on a part-time basis. Students who live locally may attend their courses on campus. Students have 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://exploreddegrees.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/coterminal-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 full-time. 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-coterminal-biomedical-informatics.html>) page.

1. Submit the University Coterminal Online Application (<https://applyweb.com/stanterm/>).
2. Submit your academic resume or curriculum vitae.
3. 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.

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://exploreddegrees.stanford.edu/cotermdegrees/>)" section. University requirements for the master's degree are described in the "Graduate Degrees (<http://exploreddegrees.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 advisor 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 (37 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 (15 or more units)

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

- BIOMEDIN 212 Introduction to Biomedical Informatics Research Methodology
- and four of the courses listed below. Additional core course requirements are listed under the M.S. degree program.

		Units
BIOMEDIN 210	Modeling Biomedical Systems	3
BIOMEDIN 214	Representations and Algorithms for Computational Molecular Biology	3-4
BIOMEDIN 215	Data Science for Medicine	3
BIOMEDIN 217	Translational Bioinformatics	4
BIOMEDIN 260	Computational Methods for Biomedical Image Analysis and Interpretation	3-4

• 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:

- CS 161 Design and Analysis of Algorithms
- STATS 200 Introduction to Statistical Inference

- STATS 315A Modern Applied Statistics: Learning or CS 229 Machine Learning
- No more than 9 units in courses numbered 100-199, and the rest should be 200 or above.
- CS 106A Programming Methodology and CS 106B Programming Abstractions cannot be counted for this requirement.
- All courses should be formal classroom-based courses, not research units.
- 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
BIODS 240	Race, Data Algorithms, and Health	1
BIOE 122	BioSecurity and Pandemic Resilience	4-5
BIOE 131	Ethics in Bioengineering	3
BIOE 450	Advances in Biotechnology	3
BIOMEDIN 254	Quality & Safety in U.S. Healthcare	3
BIOMEDIN 256	Economics of Health and Medical Care	5
BIOMEDIN 432	Analysis of Costs, Risks, and Benefits of Health Care	4
BIOS 224	Big Topics in Stem Cell Ethics	2
BIOS 258	Ethics, Science, and Society	1
CS 181	Computers, Ethics, and Public Policy	4
CS 181W	Computers, Ethics, and Public Policy	4
CSB 272	Responsible conduct, rigor, and reproducibility in research	1
EMED 122	BioSecurity and Pandemic Resilience	4-5
EMED 222	BioSecurity and Pandemic Resilience	4-5
GENE 210	Genomics and Personalized Medicine	3
HRP 209	Health Law: The FDA	2-3
HRP 211	Law and Biosciences: Neuroscience	3
HRP 221	Law and the Biosciences: Genetics	3
HRP 254	Quality & Safety in U.S. Healthcare	3
HRP 256	Economics of Health and Medical Care	5
HRP 285	Global Leaders and Innovators in Human and Planetary Health	1-2
HRP 392	Analysis of Costs, Risks, and Benefits of Health Care	4
HUMBIO 174	Foundations of Bioethics	3
INDE 212	Medical Humanities and the Arts	2
ME 208	Patent Law and Strategy for Innovators and Entrepreneurs	2-3
MED 228	Physicians and Social Responsibility	1
MED 242	Physicians and Human Rights	1
MED 255	The Responsible Conduct of Research	1
MED 255C	The Responsible Conduct of Research for Clinical and Community Researchers	1
MED 285	Global Leaders and Innovators in Human and Planetary Health	1-2

MS&E 256	Technology Assessment and Regulation of Medical Devices	3
MS&E 278	Patent Law and Strategy for Innovators and Entrepreneurs	2-3
NBIO 101	Social and Ethical Issues in the Neurosciences	2-4
PEDS 251A	Medical Ethics I	2
PEDS 251B	Medical Ethics II	2
PUBLPOL 122	BioSecurity and Pandemic Resilience	4-5
PUBLPOL 222	BioSecurity and Pandemic Resilience	4-5

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 37 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:

- Completion of the core curriculum with overall GPA of 3.0.
- Unrestricted Electives needed to complete 45 units. Students may fulfill this requirement with any Stanford graduate courses, including courses taken to satisfy program prerequisites.
- At least 23 units of courses must be at the level 200 or above.
- Students are expected to participate regularly in BIOMEDIN 201 Biomedical Informatics Student Seminar and a research colloquium.
- 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 290 Biomedical Informatics Teaching Methods .
- HCP professional masters students who are local are encouraged to participate in on-campus coursework and seminars.
- 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://exploreddegrees.stanford.edu/graduatedegrees/>)" section of this bulletin.

The Core Curriculum in Biomedical Informatics (37 units) is outlined below. The Ph.D. program requires an additional 15 units of coursework, to complete a total of 52 units.

Core Curriculum in Biomedical Informatics (37 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.

- BIOMEDIN 212 Introduction to Biomedical Informatics Research Methodology
- and two of the courses listed below.

		Units
BIOMEDIN 210	Modeling Biomedical Systems	3
BIOMEDIN 214	Representations and Algorithms for Computational Molecular Biology	3-4
BIOMEDIN 215	Data Science for Medicine	3
BIOMEDIN 217	Translational Bioinformatics	4
BIOMEDIN 260	Computational Methods for Biomedical Image Analysis and Interpretation	3-4

• Computer Science, Statistics, Mathematics & Engineering (24 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:

- CS 161 Design and Analysis of Algorithms
- STATS 200 Introduction to Statistical Inference
- STATS 315A Modern Applied Statistics: Learning or CS 229 Machine Learning
- No more than 9 units in courses numbered 100-199, and the rest should be 200 or above.
- CS 106A Programming Methodology and CS 106B Programming Abstractions cannot be counted for this requirement.
- All courses should be formal classroom-based courses, not research units.
- 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.

		Units
BIODS 240	Race, Data Algorithms, and Health	1
BIOE 122	BioSecurity and Pandemic Resilience	4-5
BIOE 131	Ethics in Bioengineering	3
BIOE 450	Advances in Biotechnology	3

BIOMEDIN 254	Quality & Safety in U.S. Healthcare	3
BIOMEDIN 256	Economics of Health and Medical Care	5
BIOMEDIN 432	Analysis of Costs, Risks, and Benefits of Health Care	4
BIOS 224	Big Topics in Stem Cell Ethics	2
BIOS 258	Ethics, Science, and Society	1
CS 181	Computers, Ethics, and Public Policy	4
CS 181W	Computers, Ethics, and Public Policy	4
CSB 272	Responsible conduct, rigor, and reproducibility in research	1
EMED 122	BioSecurity and Pandemic Resilience	4-5
EMED 222	BioSecurity and Pandemic Resilience	4-5
GENE 210	Genomics and Personalized Medicine	3
HRP 209	Health Law: The FDA	2-3
HRP 211	Law and Biosciences: Neuroscience	3
HRP 221	Law and the Biosciences: Genetics	3
HRP 254	Quality & Safety in U.S. Healthcare	3
HRP 256	Economics of Health and Medical Care	5
HRP 285	Global Leaders and Innovators in Human and Planetary Health	1-2
HRP 392	Analysis of Costs, Risks, and Benefits of Health Care	4
HUMBIO 174	Foundations of Bioethics	3
INDE 212	Medical Humanities and the Arts	2
ME 208	Patent Law and Strategy for Innovators and Entrepreneurs	2-3
MED 228	Physicians and Social Responsibility	1
MED 242	Physicians and Human Rights	1
MED 255	The Responsible Conduct of Research	1
MED 255C	The Responsible Conduct of Research for Clinical and Community Researchers	1
MED 285	Global Leaders and Innovators in Human and Planetary Health	1-2
MS&E 256	Technology Assessment and Regulation of Medical Devices	3
MS&E 278	Patent Law and Strategy for Innovators and Entrepreneurs	2-3
NBIO 101	Social and Ethical Issues in the Neurosciences	2-4
PEDS 251A	Medical Ethics I	2
PEDS 251B	Medical Ethics II	2
PUBLPOL 122	BioSecurity and Pandemic Resilience	4-5
PUBLPOL 222	BioSecurity and Pandemic Resilience	4-5

Program Requirements for the Biomedical Informatics PhD:

1. Completion of the Core Curriculum (37 or more units) described above.
2. Domain biology or medicine (6 units). Students should take classes relevant to their application area interests.
3. The core curriculum and domain biology/medicine requirements should be completed by the end of the second year of graduate study.
4. Unrestricted electives (9 units). Students may fulfill this requirement with any Stanford graduate courses, including courses taken to satisfy program prerequisites.
5. A cumulative GPA of 3.0 or greater to remain in good academic standing.
6. In the first year, at least two research rotations are required.

7. 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 Biomedical Informatics Teaching Methods to obtain credit for each teaching assistantship.
8. 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.
9. During the third year of training, each doctoral student is required to give a thesis pre-proposal seminar that describes evolving research plans.
10. 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.
11. 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.
12. Each student must present and defend their dissertation work 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 their completed research are sufficient to be granted the doctoral degree. Further details about the Oral Examination, and the submission of the written dissertation are in the BMI Student Handbook, and in University policies cited therein.
13. The student is expected to demonstrate an ability to present scholarly material and research in a lecture at a formal seminar.
14. 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 adviser as suitable for submission to a refereed journal before the doctoral degree is conferred.
15. 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:

		Units
BIOMEDIN 210	Modeling Biomedical Systems	3
BIOMEDIN 212	Introduction to Biomedical Informatics Research Methodology	3
BIOMEDIN 214	Representations and Algorithms for Computational Molecular Biology	3-4
BIOMEDIN 215	Data Science for Medicine	3
BIOMEDIN 217	Translational Bioinformatics	4
BIOMEDIN 260	Computational Methods for Biomedical Image Analysis and Interpretation	3-4

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.

COVID-19 Policies

On July 30, the Academic Senate adopted grading policies effective for all undergraduate and graduate programs, excepting the professional Graduate School of Business, School of Law, and the School of Medicine M.D. Program. For a complete list of those and other academic policies relating to the pandemic, see the "COVID-19 and Academic Continuity (<http://exploreddegrees.stanford.edu/covid-19-policy-changes/#tempdepttemplatetabtext>)" section of this bulletin.

The Senate decided that all undergraduate and graduate courses offered for a letter grade must also offer students the option of taking the course for a "credit" or "no credit" grade and recommended that deans, departments, and programs consider adopting local policies to count courses taken for a "credit" or "satisfactory" grade toward the fulfillment of degree-program requirements and/or alter program requirements as appropriate.

Graduate Degree Requirements

Grading

The Biomedical Informatics program counts all courses taken in academic year 2020-21 with a grade of 'CR' (credit) or 'S' (satisfactory) towards satisfaction of graduate degree requirements that otherwise require a letter grade. Students are encouraged to enroll in the letter grade option for degree requirements whenever possible.

Graduate Advising Expectations

The Program in Biomedical Informatics is committed to providing academic and research advising in support of graduate student scholarly and professional development. When most effective, this advising relationship entails collaborative and sustained engagement by both the adviser and the advisee. As a best practice, advising expectations should be periodically discussed and reviewed to ensure mutual

understanding. Both the adviser and the advisee are expected to maintain professionalism and integrity.

Graduate students are active contributors to the advising relationship, proactively seeking academic and professional guidance and taking responsibility for informing themselves of policies and degree requirements for their graduate program. The program's student services staff is also an important part of the student's advising team. They inform students and advisers about University and department requirements, procedures, and opportunities, and they maintain the official records of advising assignments and approvals.

Academic Adviser—Each new student in the Program in Biomedical Informatics is assigned an academic adviser (a member of the core or advising faculty or Executive Committee of the program). Academic advisers guide students in key areas such as selecting courses, discussing research rotations, developing of teaching pedagogy, navigating policies and degree requirements, and exploring academic opportunities and professional pathways. Usually, the academic adviser serves for the duration of the student's study; the BMI Student Handbook (<http://med.stanford.edu/bmi/biomedical-informatics-students/handbook.html>) describes a process for formal adviser changes. In addition, the program director is available during the academic year by email and during office hours.

Academic progress and student completion of program requirements and milestones are monitored by the program director and student services staff, and are discussed by faculty during periodic meetings devoted to assessing graduate student progress. A detailed description of the program's requirements, milestones, and advising expectations are listed in the Biomedical Informatics Training Program Student Handbook, found on the program web site (<http://med.stanford.edu/bmi/biomedical-informatics.html>), as well as in the section on the Biomedical Informatics Program in ExploreDegrees (p. 1).

Research Adviser—Each student in the academic M.S. and Ph.D. degree programs must also have a research adviser, chosen by mutual agreement at the end of their research rotations (typically by the end of their first year in the program). This research adviser is a member of the core or advising faculty for the BMI program. The research adviser may not be the same person as the academic adviser. Research advisers and the students should have a clear, shared understanding of the scientific objectives of the student's work, and how it fits into a research program that will lead to an M.S. degree or Ph.D. degree. They should focus on the development of methods that are novel, generally applicable, and well-grounded in the informatics literature. In select cases, the research adviser may be a member of the collaborating faculty, in which case the student must have a co-adviser from the BMI core or advising faculty. When there is a secondary or co-adviser, the primary adviser and co-adviser should have a clear understanding of their mentorship roles.

Each Ph.D. student is required to fill out an annual Individual Developmental Plan (IDP), usually in the Summer. The IDP is then discussed with the research adviser, as a way to facilitate: advising the student, both during and beyond the Ph.D.; establishing clear expectations on both sides with respect to degree progress and timely graduation; and emphasizing the importance of wellness in graduate school, together with access to University wellness resources.

Each Ph.D. candidate is required to establish a reading committee for the doctoral dissertation by late third year or early fourth year. Students should consult frequently with all members of the committee about the direction and progress of the dissertation research and are required to meet annually with their whole committee. The detailed process, including Stanford and BMI policies such as composition of the committee, process toward dissertation, defense, submission of the final dissertation, and readiness to graduate, are described in the BMI

Student Handbook (<http://med.stanford.edu/bmi/biomedical-informatics-students/handbook.html>).

Additionally, the program adheres to the University policies, guidelines, and responsibilities that apply to all faculty-student advising relationships. For a statement of University policy on graduate advising, see the "Graduate Advising (<https://exploreddegrees.stanford.edu/graduatedegrees/#advisingandcredentialstext>)" section of this bulletin.

Program Director and Chair: Sylvia Plevritis

Director of Graduate Studies: Sylvia Plevritis

BMI Executive Committee: Sylvia Plevritis (Program Director and Chair), Steven Bagley (Interim Executive Director), Russ B. Altman, Manisha Desai, Ying Lu, Stephen Montgomery, Mark A. Musen, Daniel L. Rubin, Chiara Sabatti, Nigam Shah, Lu Tian, Robert Tibshirani, Dennis P. Wall

*Participating Faculty and Staff by Department**

Anesthesiology: Nima Aghaepour (Assistant Professor)

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

Bioengineering: Russ B. Altman (Professor), Kwabena Boahen (Professor), Markus Covert (Associate Professor), Scott Delp (Professor), Ingmar Riedel-Kruse (Consulting Assistant Professor), Vijay Pande (Adjunct Professor)

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

Biomedical Data Science: Russ B. Altman (Professor), Euan Ashley (Professor), Gill Bejerano (Associate Professor), Manisha Desai (Professor), Bradley Efron (Professor), Andrew Gentles (Assistant Professor), Olivier Gevaert (Assistant Professor), Trevor Hastie (Professor), Tina Hernandez-Boussard (Associate Professor), Iain Johnstone (Professor), Purvesh Khatri (Associate Professor), Teri Klein (Professor), Ying Lu (Professor), Mark A. Musen (Professor), Aaron Newman (Assistant Professor), Richard Olshen (Professor Emeritus), Julia Palacios (Assistant Professor), Sylvia Plevritis (Professor), Manuel Rivas (Assistant Professor), Daniel L. Rubin (Associate Professor), Chiara Sabatti (Professor), Julia Salzman (Assistant Professor), Nigam Shah (Associate Professor), Lu Tian (Professor), Robert Tibshirani (Professor), Dennis P. Wall (Associate Professor), Wing H Wong (Professor), James Zou (Assistant Professor)

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Chemistry: Vijay Pande (Professor)

Computer Science: Gill Bejerano (Associate Professor), David Dill (Professor Emeritus), 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)

Electrical Engineering: Kwabena Boahen (Professor)

Energy Resources Engineering: Margot Gerritsen (Professor)

Genetics: Russ B. Altman (Professor), Euan Ashley (Professor), Michael Bassik (Assistant Professor), Ami Bhatt (Assistant Professor), J. Michael

Cherry (Professor, Research), Stanley N. Cohen (Professor), Christina Curtis (Assistant Professor), Ronald Davis (Professor), William Greenleaf (Associate Professor), Karla Kirkegaard (Professor), Teri E. Klein (Senior Research Scientist), Anshul Kundaje (Assistant Professor), Jin Billy Li (Associate Professor), Stephen B. Montgomery (Assistant Professor), Jonathan Pritchard (Professor), Gavin Sherlock (Associate Professor), Arend Sidow (Professor), Michael P. Snyder (Professor), Hua Tang (Professor)

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

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

Mechanical Engineering: Scott Delp (Professor)

Medicine: Russ B. Altman (Professor), Euan Ashley (Professor), Mike Baiocchi (Assistant Professor), Sanjay Basu (Assistant Professor), Ami Bhatt (Assistant Professor), Jayanta Bhattacharya (Professor), Catherine Blish (Associate Professor), Carol Cain (Adjunct Assistant Professor), Jonathan Chen (Assistant Professor), Stanley Cohen (Professor), Christina Curtis (Assistant Professor), Manisha Desai (Professor), Michel Dumontier (Associate Professor), Andrew Gentles (Assistant Professor), Olivier Gevaert (Assistant Professor), Mary Goldstein (Professor), Summer Han (Assistant Professor), Tina Hernandez-Boussard (Associate Professor), Michael Higgins (Adjunct Associate Professor), Mark Hlatky (Professor), Hanlee P. Ji (Associate Professor), Purvesh Khatri (Associate Professor), Teri Klein (Professor), Lianne Kurina (Associate Professor, Teaching), Curtis Langlotz (Professor), Henry Lowe (Associate Professor), Mark A. Musen (Professor), Douglas K. Owens (Professor), Natalie Pageler (Clinical Associate Professor), David Relman (Professor), Daniel L. Rubin (Associate Professor), Robert W. Shafer (Professor, Research), Nigam Shah (Associate Professor), Samson Tu (Senior Research Engineer), P.J. Utz (Professor), Steven Bagley (Sr. Research Engineer), Eran Bendavid (Associate Professor), Zihuai He (Assistant Professor, Research)

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

Neurology: Zihuai He (Assistant Professor, Research)

Neurosurgery: Summer Han (Assistant Professor)

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

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

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

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

Psychology: Russell Poldrack (Professor)

Radiation Oncology: Ruijiang Li (Assistant Professor), Lei Xing (Professor)

Radiology: Sam (Sanjiv) Gambhir (Professor), Curtis Langlotz (Professor), Matt Lungren (Assistant Professor), Parag Mallick (Associate Professor, Research), Sandy A. Napel (Professor), David Paik (Adjunct Assistant Professor), Sylvia Plevritis (Professor/ Program Director), Daniel L. Rubin (Professor), Greg Zaharchuk (Professor)

Statistics: Bradley Efron (Professor), Trevor J. Hastie (Professor), Susan Holmes (Professor), Iain Johnstone (Professor), Art Owen (Professor),

Julia Palacios (Assistant Professor), Chiara Sabatti (Professor), Robert Tibshirani (Professor), Wing H Wong (Professor)

Structural Biology: Michael Levitt (Professor)

Surgery: Tina Hernandez-Boussard (Associate Professor), 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 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. Seminar: Health IT in Care Delivery systems. 1 Unit.

The practice of medicine is reacting quickly to the avalanche of information available from electronic health records and data directly submitted by patients and from the environment. 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, medical education, and the innovation pipeline for healthcare delivery organizations.

BIOMEDIN 208. Clinical Informatics Literature Review Seminar. 1 Unit.

Weekly seminar series in which seminal literature and current publications in the field of clinical informatics are reviewed and discussed. Organized by the Stanford Clinical Informatics fellowship program. Topics include electronic health record design, implementation, and evaluation; patient engagement; provider satisfaction; and hot topics in clinical informatics. Limited enrollment.

BIOMEDIN 210. Modeling Biomedical Systems. 3 Units.

At the core of informatics is the problem of creating computable models of biomedical phenomena. This course explores methods for modeling biomedical systems with an emphasis on contemporary semantic technology, including knowledge graphs. Topics: data modeling, knowledge representation, controlled terminologies, ontologies, reusable problem solvers, modeling problems in healthcare information technology and other aspects of informatics. Students acquire hands-on experience with several systems and tools. Prerequisites: CS106A. Basic familiarity with Python programming, biology, probability, and logic are assumed. 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 214 or 215 or 217 or 260. 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 Science for Medicine. 3 Units.

The widespread adoption of electronic health records (EHRs) has created a new source of big data namely, the record of routine clinical practice as a by-product of care. This graduate class will teach you how to use EHRs and other patient data to discover new clinical knowledge and improve healthcare. Upon completing this course, you should be able to: differentiate between and give examples of categories of research questions and the study designs used to address them, describe common healthcare data sources and their relative advantages and limitations, extract and transform various kinds of clinical data to create analysis-ready datasets, design and execute an analysis of a clinical dataset based on your familiarity with the workings, applicability, and limitations of common statistical methods, evaluate and criticize published research using your knowledge of 1-4 to generate new research ideas and separate hype from reality. Prerequisites: CS 106A or equivalent, STATS 60 or equivalent. Recommended: STATS 216, CS 145, STATS 305.

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. 3-4 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, GENE 217

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 compliment the lectures. Prerequisites: introduction to calculus and basic statistics.

BIOMEDIN 220. Artificial Intelligence in Healthcare. 3-4 Units.

Healthcare is one of the most exciting application domains of artificial intelligence, with transformative potential in areas ranging from medical image analysis to electronic health records-based prediction and precision medicine. This course will involve a deep dive into recent advances in AI in healthcare, focusing in particular on deep learning approaches for healthcare problems. We will start from foundations of neural networks, and then study cutting-edge deep learning models in the context of a variety of healthcare data including image, text, multimodal and time-series data. In the latter part of the course, we will cover advanced topics on open challenges of integrating AI in a societal application such as healthcare, including interpretability, robustness, privacy and fairness. The course aims to provide students from diverse backgrounds with both conceptual understanding and practical grounding of cutting-edge research on AI in healthcare. Prerequisites: Proficiency in Python or ability to self-learn; familiarity with machine learning and basic calculus, linear algebra, statistics; familiarity with deep learning highly recommended (e.g. prior experience training a deep learning model).

Same as: BIODS 220, CS 271

BIOMEDIN 221. Machine Learning Approaches for Data Fusion in Biomedicine. 2 Units.

Vast amounts of biomedical data are now routinely available for patients, ranging from genomic data, to radiographic images and electronic health records. AI and machine learning are increasingly used to enable pattern discover to link such data for improvements in patient diagnosis, prognosis and tailoring treatment response. Yet, few studies focus on how to link different types of biomedical data in synergistic ways, and to develop data fusion approaches for improved biomedical decision support. This course will describe approaches for multi-omics, multi-modal and multi-scale data fusion of biomedical data in the context of biomedical decision support. Prerequisites: CS106A or equivalent, Stats 60 or equivalent.

BIOMEDIN 222. Cloud Computing for Biology and Healthcare. 3 Units.

Big Data is radically transforming healthcare. To provide real-time personalized healthcare, we need hardware and software solutions that can efficiently store and process large-scale biomedical datasets. In this class, students will learn the concepts of cloud computing and parallel systems' architecture. This class prepares students to understand how to design parallel programs for computationally intensive medical applications and how to run these applications on computing frameworks such as Cloud Computing and High Performance Computing (HPC) systems. Prerequisites: familiarity with programming in Python and R. Same as: CS 273C, GENE 222

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 226. Digital Health Practicum in a Health Care Delivery System. 2-3 Units.

Practical experience implementing clinical informatics solutions with a focus on digital health in one of the largest healthcare delivery systems in the United States. Individual meetings with senior clinical informatics leaders to discuss elements of successful projects. Implementation opportunities include supporting the use of electronic health records, engagement of patients and providers via a personal health record, use of informatics to support patient service centers, and improvement of patient access to clinical data. Consent of course instructors required at least one quarter prior to student enrollment in course.

BIOMEDIN 233. Intermediate Biostatistics: Analysis of Discrete Data. 3 Units.

(Formerly HRP 261) Methods for analyzing data from case-control and cross-sectional studies: the 2x2 table, chi-square test, Fisher's exact test, odds ratios, Mantel-Haenzel methods, stratification, tests for matched data, logistic regression, conditional logistic regression. Emphasis is on data analysis in SAS or R. Special topics: cross-fold validation and bootstrap inference.

Same as: EPI 261, STATS 261

BIOMEDIN 240. Race, Data Algorithms, and Health. 1 Unit.

This course studies the interplay between race, data and algorithms in healthcare. The particular viewpoint we want to take is to understand the role of data, data analysis and algorithms in supporting equitable delivery of health care to members of all races. Topics as "representative data", "machine bias", "algorithmic fairness" are going to be central to the discussion. However, we want to stress the uniqueness of the "medicine/health care" viewpoint. For example, while in contexts as loan applications, it is normative that race information (or its proxies) not to be included among the variables used for decision, in healthcare, information on race is routinely collected in the attempt to provide "best" care. One of the goals of the class will be to understand what are the differences between biological populations and social environments that a doctor needs to be aware of as opposed to overly emphasized or imaginary ones. This will provide a context to understand the challenges that data collection and analysis faces to support equitable care. Same as: BIODS 240

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, STATS 345

BIOMEDIN 246. Seminar in Healthcare Quality and Safety. 1 Unit.

Primarily for medical students in the Quality and Safety Scholarly Concentration. Almost everyone will be a patient at some point in their lives. It is estimated that over 98,000 patients die in US hospitals each year due to medical errors and recent articles suggest that medical errors are the third leading cause of death in the US. Patient safety is the foundation of high-quality health care, which has become a critical issue in health policy discussions. This course will provide an overview of the quality & patient safety movement, the array of measurement techniques and issues, and perspectives of quality improvement efforts under the current policy landscape. Lunch will be provided for enrolled students.

Same as: HRP 246

BIOMEDIN 248. Clinical Trial Design in the Age of Precision Medicine and Health. 3 Units.

Overview of requirements, designs, and statistical foundations for traditional Phase I, II, and III clinical trials for medical product approval and Phase IV postmarketing studies for safety evaluation. As these methods cost too much and take too much time in the era of precision medicine and precision health, this course then introduces innovative designs that have been developed for affordable clinical trials, which can be completed within reasonable time constraints and which have been encouraged by regulatory agencies. Prerequisites: Working knowledge of statistics and R.

Same as: BIODS 248, BIODS 248P, STATS 248

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 254. Quality & Safety in U.S. Healthcare. 3 Units.

The course will provide an in-depth examination of the quality & patient safety movement in the US healthcare system, the array of quality measurement techniques and issues, and perspectives of quality and safety improvement efforts under the current policy landscape.

Same as: HRP 254

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 or Python highly recommended.

Same as: CS 235, RAD 260

BIOMEDIN 273A. The Human Genome Source Code. 3 Units.

A computational primer to "hacking" the most amazing operating system "disk" on the planet: your genome. Handling genomic data is deceptively easy. But that's muscle. You want to be the brain, too. Topics include genome sequencing (assembling source code from code fragments); the human genome functional landscape: variable assignments (genes), control-flow logic (gene regulation) and run-time stack (epigenomics); human disease and personalized genomics (as a hunt for bugs in the human code); genome editing (code injection) to cure the incurable; and the source code modifications behind amazing animal adaptations. The course will introduce ideas from computational genomics, machine learning and natural language processing. Course includes primers on molecular biology, and text processing languages. Prerequisites: CS106A or equivalent. No biological background assumed.

Same as: CS 273A, DBIO 273A

BIOMEDIN 273B. Deep Learning in Genomics and Biomedicine. 3 Units.

Recent breakthroughs in high-throughput genomic and biomedical 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 produced 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 CS 109, and basic machine learning such as CS 229. No prior knowledge of genomics is necessary.

Same as: BIODS 237, 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 304. Clinical Experience Seminar for Students in Biomedical Informatics. 1 Unit.

This seminar is intended to expose Biomedical Informatics graduate students to clinical environments where informatics is being applied. Students will shadow clinical care and interact with physicians and other allied health professionals throughout Stanford Healthcare and Stanford Children's Health during weekly sessions. Students will be asked to reflect on their experiences and discuss future applications to informatics projects. Preference will be given to senior students. Requires Course Director approval for enrollment - students should register 30 days prior to the first day of class for consideration. Prerequisites: School of Medicine HIPAA Training; Occupational Health clearance; SHC Compliance Attestation. All prerequisites must be submitted 2 weeks before the 1st day in order to ensure hospital compliance.

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 388. Stakeholder Competencies for Artificial Intelligence in Healthcare. 2-3 Units.

Advancements of machine learning and AI into all areas of medicine are now a reality and they hold the potential to transform healthcare and open up a world of incredible promise for everyone. But we will never realize the potential for these technologies unless all stakeholders have basic competencies in both healthcare and machine learning concepts and principles - this will allow successful, responsible development and deployment of these systems into the healthcare domain. The focus of this course is on the key concepts and principles rather than programming or engineering implementation. Those with backgrounds in healthcare, health policy, healthcare system leadership, pharmaceutical, and clinicians as well as those with data science backgrounds who are new to healthcare applications will be empowered with the knowledge to responsibly and ethically evaluate, critically review, and even use these technologies in healthcare. We will cover machine learning approaches, medical use cases in depth, unique metrics to healthcare, important challenges and pitfalls, and best practices for designing, building, and evaluating machine learning in healthcare applications.

Same as: BIODS 388

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.

For graduate students. How to do cost/benefit analysis when the output is difficult or impossible to measure. 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 472. Data science and AI for COVID-19. 2 Units.

This project class investigates and models COVID-19 using tools from data science and machine learning. We will introduce the relevant background for the biology and epidemiology of the COVID-19 virus. Then we will critically examine current models that are used to predict infection rates in the population as well as models used to support various public health interventions (e.g. herd immunity and social distancing). The core of this class will be projects aimed to create tools that can assist in the ongoing global health efforts. Potential projects include data visualization and education platforms, improved modeling and predictions, social network and NLP analysis of the propagation of COVID-19 information, and behavior-nudging tools. The class is aimed toward students with experience in data science and AI, and will include guest lectures by biomedical experts. Prerequisites: background in machine learning and statistics (CS229, STATS216 or equivalent). Some biological background is helpful but not required. Same as: BIODS 472, CS 472

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.