COMPUTATIONAL MEDICINE, MINOR

The Institute for Computational Medicine (ICM) offers an undergraduate minor in Computational Medicine, the first educational program in CM, reflecting Johns Hopkins University’s leadership in this field. Like the ICM, the undergraduate minor in Computational Medicine is integrative and multidisciplinary. The ICM Core Faculty who serve as advisors to the undergraduate minor hold primary and joint appointments in multiple Johns Hopkins University departments and schools including Biomedical Engineering, Computer Science, Electrical and Computer Engineering, Mechanical Engineering, Applied Mathematics and Statistics (WSE); Neurosurgery, Emergency Medicine, Medicine, and the Divisions of Cardiology and Health Sciences Informatics (SOM); and Health Policy and Management (BSPH).

With a minor in CM, undergraduates gain a solid grounding in the development and application of computational methods in key areas of medicine. Specifically, undergraduates will understand how mathematical models can be constructed from biophysical laws or experimental data, and how predictions from these models facilitate diagnosis and treatment of a disease. Undergraduates will become conversant with a wide variety of statistical, deterministic and stochastic modeling methods, skills that are essential to the advancement of modern medicine, and are prized both in academic research and industrial research.

Declaring the Minor

Students interested in the minor should contact Alecia Flynn, Sr. Academic Coordinator, at aflynn12@jhu.edu to receive guidance about the program and be assigned a minor advisor.

Specific questions regarding the minor requirements and courses can be directed to Dr. Joshua Vogelstein (jovo@jhu.edu), Director of Undergraduate Studies for the CM minor.

Program Requirements

Minor Prerequisites

Before attempting the minor, undergraduates will have taken the following courses. For a course to count towards the minor, a minimum grade of C- is required:

1. Calculus I
2. Calculus II
3. Probability and Statistics: either a single course covering both (e.g. Probability & Statistics for the Physical Sciences & Engineering (EN.553.310) or Probability and Statistics for the Biological Sciences and Engineering (EN.553.311)) or a course devoted to each (e.g., Introduction to Probability (EN.553.420) and Introduction to Statistics (EN.553.430)) – this may be taken concurrent with core courses Introduction to Computational Medicine: Imaging (EN.580.431) and Introduction to Computational Medicine: The Physiome (EN.580.433).
4. At least one (1) additional course in mathematics or applied mathematics (at least 3 credits)
5. At least one (1) computer programming course (at least 3 credits)
6. At least one (1) biological sciences course at the 200 level or higher (at least 3 credits). AP Biology credits do not satisfy this requirement.

A list of approved courses for each prerequisite can be found here (https://icm.jhu.edu/academics/undergraduate-programs/undergraduate-minor/).

Core Courses

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN.580.431</td>
<td>Introduction to Computational Medicine: Imaging</td>
<td>1</td>
</tr>
<tr>
<td>EN.580.433</td>
<td>Introduction to Computational Medicine: The Physiome</td>
<td>2</td>
</tr>
<tr>
<td>Select one of the following:</td>
<td></td>
<td>3-4</td>
</tr>
<tr>
<td>EN.580.464</td>
<td>Advanced Data Science for Biomedical Engineering</td>
<td>2</td>
</tr>
<tr>
<td>EN.580.488</td>
<td>Foundations of Computational Biology and Bioinformatics</td>
<td>3</td>
</tr>
<tr>
<td>EN.580.430</td>
<td>Systems Pharmacology and Personalized Medicine</td>
<td>4</td>
</tr>
<tr>
<td>EN.601.448</td>
<td>Computational Genomics: Data Analysis</td>
<td>5</td>
</tr>
<tr>
<td>EN.553.450</td>
<td>Computational Molecular Medicine</td>
<td>6</td>
</tr>
</tbody>
</table>

Total Credits 7-8

1. EN.580.431 Introduction to Computational Medicine: Imaging and EN.580.433 Introduction to Computational Medicine: The Physiome cover computational anatomy and physiology.
2. EN.580.464 Advanced Data Science for Biomedical Engineering covers introductory R, data cleaning, reproducible research, basic statistical inference, machine learning, and artificial intelligence.
3. EN.580.488 Foundations of Computational Biology and Bioinformatics introduces probabilistic modeling and information theory applied to biological sequence analysis.
4. EN.580.430 Systems Pharmacology and Personalized Medicine covers applications of pharmacokinetics and pharmacodynamics to simulating the effects of drugs across a population of diseased individuals.
5. EN.601.448 Computational Genomics: Data Analysis covers computational analysis of genomic data with a focus on statistical methods and machine learning.
6. EN.553.450 Computational Molecular Medicine covers measuring associations, testing multiple hypotheses, and learning predictors, Markov chains and graphical models.

Distinguished Seminar Series

Students enrolled in the Computational Medicine Minor are required to attend 6 ICM Distinguished Seminars (https://icm.jhu.edu/seminar-series/) in person by graduation. Documentation of seminar attendance is two-fold. For each seminar attended students must:

1. sign-in at the seminar and
2. complete an online Seminar Attendance Form (https://docs.google.com/forms/d/e/1FAIpQLSdD6zF2XW6bPTNRgyg9ZEkfYS3xfkcMhphdU868yIDnAzaDoQ/viewform/).

Elective Courses

Following satisfaction of the prerequisites, to complete the minor undergraduates must take at least 18 credits of CM courses. This includes the core courses plus approved elective courses selected from those listed below. The following restrictions are noted:

...
1. No more than 3 of the 18 elective credits may consist of independent research in computational medicine or approved CM-related research. Eligibility of independent research as “M”, “C”, “MC”, or neither is at the adviser’s discretion. Note: The Senior Design Project Course (Senior Design Project (EN.580.580)/Senior Design Project (EN.580.581)) may count toward independent research, provided that the research falls within the field of computational medicine, as decided by the advisor;

2. The 18 credits will be at 300-level or above, and courses must be passed at a C- level or above;

3. At least 1 non-core/elective courses must be outside student’s home department;

4. At least 2 non-core/elective courses must have a substantial biology or medicine component, as identified in the list below with an (M) designation;

5. At least 1 non-core course must have a significant component of “applied programming” (distinct from a course on computer language or on programming such as Intermediate Computer Programming in Computer Science) to satisfy the computational component, as identified in the list of electives with an “C” designation;

6. All courses must be passed at a C- level or above;

7. A class may not be counted as both a prerequisite and an elective.

Students may suggest elective courses to be added to the list by completing a “Class Approval Request Form”. Requests should be made to Alecia Flynn (aflynn12@jhu.edu) and will be reviewed by the CM Minor Curriculum Committee.

### Code | Title | Credits
--- | --- | ---
**Electrical and Computer Engineering**
EN.520.315 | Intro. to Bio-Inspired Processing of Audio-Visual Signals | 3
EN.520.353 | Control Systems (C) | 4
EN.520.432 | Medical Imaging Systems (C) | 3
EN.520.473 | (MC) | 3
EN.520.601 | Introduction to Linear Systems Theory | 3
EN.520.621 | Introduction To Nonlinear Systems | 3
**Mechanical Engineering**
EN.530.343 | Design and Analysis of Dynamical Systems | 3
EN.530.616 | Introduction to Linear Systems Theory | 3
EN.530.676 | Locomotion Dynamics & Control (M) | 3
**Chemical and Biomolecular Engineering**
EN.540.400 | Project in Design: Pharmacokinetics (MC) | 3
EN.540.409 | Dynamic Modeling and Control (C) | 4
EN.540.414 | Computational Protein Structure Prediction and Design (C) | 3
EN.540.421 | Project in Design: Pharmacodynamics (MC) | 3
EN.540.638 | Advanced Topics in Pharmacokinetics and Pharmacodynamics I (C) | 3
**Applied Mathematics and Statistics**
EN.553.361 | Introduction to Optimization (C) | 4
EN.553.386 | Scientific Computing: Differential Equations (C) | 4
EN.553.391 | Dynamical Systems | 4
EN.553.420 | Introduction to Probability | 4
EN.553.426 | Introduction to Stochastic Processes | 4
EN.553.430 | Introduction to Statistics | 4
EN.553.436 | Introduction to Data Science (C) | 4
EN.553.492 | Mathematical Biology (C) | 3
**Biomedical Engineering**
EN.580.430 | Systems Pharmacology and Personalized Medicine (MC) | 4
EN.580.435 | Applied Bioelectrical Engineering I (M) | 1.5
EN.580.437 | Neuro Data Design I (C) | 4
EN.580.238 | Neuro Data Design II (C) | 3
EN.580.446 | Physical Epigenetics (M) | 3
EN.580.447 | Computational Stem Cell Biology (MC) | 3
EN.580.460 | Epigenetics at the Crossroads of Genes and the Environment (MC) | 1.5
EN.580.462 | Representations of Choice (MC) | 3
EN.580.488 | Foundations of Computational Biology and Bioinformatics (MC) | 4
EN.580.480 | Precision Care Medicine I (MC) | 4
EN.580.481 | Precision Care Medicine II (MC) | 4
EN.580.491 | Learning, Estimation and Control (C) | 3
**Computer Science**
EN.601.350 | Genomic Data Science (MC) | 3
EN.601.447 | Computational Genomics: Sequences (MC) | 3
EN.601.448 | Computational Genomics: Data Analysis (MC) | 3
EN.601.455 | Computer Integrated Surgery I (C) | 4
EN.601.461 | Computer Vision (C) | 3
EN.601.475 | Machine Learning (C) | 3
EN.601.476 | Machine Learning: Data to Models (C) | 3
EN.601.482 | Machine Learning: Deep Learning (C) | 4
EN.601.485 | Probabilistic Models of the Visual Cortex (C) | 3
EN.601.723 | Advanced Topics in Data-Intensive Computing (C) | 3