

COMPUTATIONAL MEDICINE, MINOR

The Institute for Computational Medicine (ICM) (<https://icm.jhu.edu/>) 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

Interested students should contact Alecia Flynn, Sr. Academic Coordinator, to receive guidance on declaring the minor:

Phone: 410-516-6892
Email: aflynn12@jhu.edu

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 (courses graded as 'S/U' do not satisfy prerequisites):

1. Calculus I
2. Calculus II
3. Probability and Statistics: either a single course covering both (e.g. EN.553.310 Probability & Statistics for the Physical Sciences & Engineering **or** EN.553.311 Probability and Statistics for the Biological Sciences and Engineering) or a course devoted to each (e.g., EN.553.420 Introduction to Probability **and** EN.553.430 Introduction to Statistics) – this may be taken concurrent with core course EN.580.431 Introduction to Computational Medicine: Imaging
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). A list of approved courses can be found here (<https://icm.jhu.edu/academics/undergraduate-programs/undergraduate-minor/>).

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.

Core Courses

Code	Title	Credits
EN.580.431	Introduction to Computational Medicine: Imaging ¹	4
Select one of the following:		3-4
EN.580.464	Advanced Data Science for Biomedical Engineering ²	
EN.580.488	Foundations of Computational Biology and Bioinformatics ³	
EN.580.430	Systems Pharmacology and Personalized Medicine ⁴	
EN.601.448	Computational Genomics: Data Analysis ⁵	
EN.553.450	Computational Molecular Medicine ⁶	
Total Credits		7-8

- ¹ EN.580.431 Introduction to Computational Medicine: Imaging covers 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/1FAIpQLSdBzF2XW6bPTNRgyg9ZEkfYs3xfkcM3hphdU868yiDnAzaDoQ/viewform/>).

Elective Courses

Following satisfaction of the prerequisites, to complete the minor undergraduates must take at least 18 credits of CM courses. This includes two one-semester 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

(EN.580.580 Senior Design Project/EN.580.581 Senior Design Project) 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 all 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)	3
EN.520.432	Medical Imaging Systems (M)	3
EN.520.601	Introduction to Linear Systems Theory	3
EN.520.621	Introduction To Nonlinear Systems	3
EN.520.473	Magnetic Resonance in Medicine (MC)	3
Mechanical Engineering		
EN.530.343	Design and Analysis of Dynamical Systems	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.553.391	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.553.386	Scientific Computing: Differential Equations (C)	4
EN.553.492	Mathematical Biology (C)	3
Biomedical Engineering		
EN.580.420	Build-a-Genome (M)	4
EN.580.492	Build-a-Genome Mentor (M)	4

EN.580.430	Systems Pharmacology and Personalized Medicine (MC)	4
EN.580.435	Applied Bioelectrical Engineering I (M)	1.5
EN.580.462	Representations of Choice (MC)	3
EN.580.488	Foundations of Computational Biology and Bioinformatics (MC)	4
EN.580.491	Learning, Estimation and Control (C)	3
EN.580.480	Precision Care Medicine I (MC)	4
EN.580.481	Precision Care Medicine II (MC)	4
EN.580.446	Physical Epigenetics (M)	3
Computer Science		
EN.601.350	Genomic Data Science (MC)	3
EN.601.448	Computational Genomics: Data Analysis (MC)	3
EN.601.447	Computational Genomics: Sequences (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