BIOPHYSICS

http://biophysics.jhu.edu/

The Department of Biophysics offers programs leading to the B.A., M.A., and Ph.D. degrees. Biophysics is appropriate for students who wish to develop and integrate their interests in the physical and biological sciences.

Research interests in the Department cover experimental and computational, molecular and cellular structure, function, and biology, membrane biology, and biomolecular energetics. The teaching and research activities of the faculty bring its students in contact with biophysical scientists throughout the university. Regardless of their choice of research area, students are exposed to a wide range of problems of biological interest. For more information, and for the most up-to-date list of course offerings and requirements, consult the department web page at biophysics.jhu.edu.

Research Activities of Primary Faculty

Mucosal Protection and Reproductive Health (Dr. Cone)

The Mucosal Protection Laboratory is developing methods women can use for protection against both pregnancy and sexually transmitted diseases, including AIDS. Basic research projects include investigating the ability of mucosal antibodies and vaginal acidity (lactic acid) to inactivate viral and bacterial pathogens, and how normal vaginal lactobacilli suppress the array of anaerobic bacteria that causes BV (bacterial vaginosis). BV is the most common vaginal infection (one in three women at any given time) and women with this little-recognized infection are at markedly increased risk of sexually transmitted infections, miscarriage, and premature birth. Research and development of microbicides for preventing BV and sexually transmitted diseases is being sponsored by NIH in collaboration with ReProtect, Inc., through a research agreement with Johns Hopkins University. Research on nanoparticles for enhanced delivery of drugs to mucosal surfaces is being done in collaboration with Dr. Justin Hanes, Director of Nanomedicine at the Johns Hopkins School of Medicine.

Protein Engineering and pH Sensing (Dr. Garcia-Moreno)

To understand how biological macromolecules work, or to design and engineer new ones, it is necessary to understand in detail the relationship between structure and energetics. We study this problem in our lab by analysis of the connection between structure, thermodynamic stability, and dynamics of proteins with a combination of computational and experimental methods. The approach depends heavily on the application of NMR spectroscopy, X-ray crystallography, and equilibrium thermodynamics. The experiments contribute the physical insight needed to guide the development of computational methods for structure-based energy calculations, as well as the data required to benchmark these methods. We are focused on problems of protein electrostatics because electrostatic energy is the most useful metric for correlating structure with function in all the most important energy transduction processes in biological systems. We focus on the engineering of proteins with pH sensing

Protein Folding (Dr. Rose)

A globular protein will spontaneously self-assemble its components into a highly organized three-
dimensional structure under appropriate physiological conditions in a process called protein folding. Our principal goal is to understand protein folding, using an approach involving simulation, modeling, and analysis. In the classical model of folding, an unfolded protein visits an astronomical number of possible conformations. In contrast, we recently reevaluated this popular model and found that the unfolded state is far less heterogeneous than previously thought. This realization has prompted us to pursue a novel strategy to predict folding.

Biophysics of RNA (Dr. Woodson)

The control of cell growth and type depends on the ability of RNA to fold into complex three-dimensional structures. RNA catalysts are good models for studying the physical principles of RNA folding, and the assembly of protein-RNA complexes such as the ribosome. Changes in RNA three-dimensional structure are monitored by fluorescence spectroscopy, “X-ray footprinting,” and neutron scattering. Bacterial and yeast expression systems are used to study intracellular folding of RNA.

Protein Folding, Notch Signaling (Dr. Barrick)

The folding of proteins into their complex native structures is critical for proper function in biological systems. This spontaneous process of self-assembly is directed by physical chemistry, although the rules are not understood. We are using repeat-proteins, linear proteins with simple architectures, to dissect the energy distribution, sequence-stability relationship, and kinetic routes for folding. In addition, we are studying the molecular mechanisms of Notch signaling, a eukaryotic transmembrane signal transduction pathway. The transmission of information across the membranes of cells is essential for cell differentiation and homeostasis; signaling errors result in disease states including cancer. We are focusing on interactions between proteins involved in Notch signaling using modern biophysical methods. Thermodynamics of association and allosteric effects are determined by spectroscopic, ultracentrifugation, and calorimetric methods. Atomic structure information is being obtained by NMR spectroscopy. The ultimate goal is to determine the thermodynamic partition function for a signal transduction system and interpret it in terms of atomic structure.

NMR Spectroscopy (Dr. Lecomte)

Many proteins require stable association with an organic compound for proper functioning. One example of such “cofactor” is the heme group, a versatile iron-containing molecule capable of catalyzing a broad range of chemical reactions. The reactivity of the heme group is precisely controlled by interactions with contacting amino acids. Structural fluctuations within the protein are also essential to the fine-tuning of the chemistry. We are studying how the primary structure of cytochromes and hemoglobins codes for heme binding and the motions that facilitate function. The method of choice is nuclear magnetic resonance spectroscopy, which we use to obtain detailed structural and dynamic representations of proteins with and without bound heme. The ultimate goal is to understand the evolution of chemical properties in heme proteins and how to alter them.

Structural and Energetic Principles of Membrane Proteins (Dr. K. Fleming)

Membrane proteins must fold to unique native conformations and must interact in specific ways to form complexes essential for life. Currently, the chemical principles underlying these processes are poorly understood. Thermodynamic and kinetic studies on membrane proteins with diverse folds and oligomeric states are carried out with the goal of discovering the physical basis of stability and specificity for membrane proteins. Our research results in a quantitative understanding of sequence-structure-function relationships that can ultimately be used to describe membrane protein populations in both normal and disease states, to design novel membrane proteins, and to develop therapeutics that modulate membrane protein functions in desirable ways.

Chromatin Remodeling (Dr. Bowman)

Chromatin, the physical packaging of eukaryotic chromosomes, plays a major role in determining the patterns of gene silencing and expression across the genome. Chromatin remodelers are multicomponent protein machines that establish and maintain various chromatin environments through the assembly, movement, and eviction of nucleosomes. At present, the molecular mechanisms by which chromatin remodelers alter chromatin structure are not understood. Our long-term goal is to gain a molecular understanding of the remodeling process and in particular how remodeling is coupled to the transcriptional machinery. Our strategy is to couple structure determination with functional studies to determine how different components of a chromatin remodeler cooperate and interact with the nucleosome substrate.

Physical Systems Biology (Dr. Roberts)

The laboratory is devoted to understanding and modeling the behavior of cells as complex systems. We are using tools from the general area of biological physics: potential- and probability-based computational modeling along with limited applications of single-cell, single-molecule experimental techniques (split roughly 80% theoretical/computational and 20% experimental). We term this approach “Physical Systems Biology” and it lies at the interface of biology, computer science, and physics. While this approach absolutely requires in-depth characterization of particular components, an equally critical step is then stepping back to consolidate the knowledge gained into a model of the entire cellular system. Incorporating many varied types of biological data into a genuine in silico model for the cell is the long-range goal of the laboratory.

Theoretical Biophysics (Dr. Johnson)

Protein interaction networks capture the cooperation required by proteins to carry out complex functions in the cell. The ability of proteins to assemble to form transient or permanent complexes and transmit signals or nutrients depends on their concentrations, their binding partners, and their spatial and temporal dynamics in the cell. Using computation and theory, we are building models to accurately simulate these multi-protein assembly processes, such as those occurring in endocytosis, that are critical to cell survival. We complement these detailed simulations with coarse-grained models to extend to larger protein interaction networks and characterize the role of network topology on protein binding specificity and dynamics.

Single Molecule Biophysics (Dr. Ha)

Our research is focused on pushing the limits of single-molecule detection methods to study complex biological systems. We develop state-of-the-art biophysical techniques (e.g., multicolor fluorescence, super-resolution imaging, combined force and fluorescence spectroscopy, vesicular encapsulation, single-molecule pull-down) and apply them to study diverse protein–nucleic acid and protein-protein complexes, and mechanical perturbation and response of these systems both in vitro and in vivo.

Quantitative analysis of gene expression in single molecule and single cell (Dr. Myong)

Our research is focused on dissecting biological pathways that control and modulate gene expression profiles that are pertinent to human diseases. We develop single molecule and single cell platforms to examine potential rate-limiting steps that contribute to modulating transcription and translation. In particular, we investigate RNA interference pathway and G-quadruplex DNA mediated promoter activity. In collaboration, we are also studying telomeric DNA processing and chromatin remodeling. Together, we seek to shed light on molecular orchestration and mechanism that govern the Central Dogma of Biology.

Facilities

The department shares state-of-the-art equipment for X-ray diffraction analysis, NMR spectroscopy, solution biophysical studies, and numerically intensive computer simulations with other biophysics units and departments within the University. In addition, the Department houses a full complement of equipment for molecular biological and biochemical work, and for various kinds of spectroscopy.

Bachelor of Arts in Biophysics

The undergraduate major in biophysics is intended for the student interested in advanced study of biophysics or the related fields of biochemistry, quantitative or computational biology, quantitative or computational biology, molecular biology, physiology, pharmacology, and neurobiology. The biophysics major fulfills all typical science premedical requirements with the exception of Organic Chemistry Lab (AS.030.225 Introductory Organic Chemistry Laboratory or AS.030.227 Chemical Chirality: An Introduction in Organic Chem. Lab, Techniques). The student majoring in biophysics, with the advice of a member of the department, chooses a program of study that will include foundation courses in biology, chemistry, and physics followed by advanced studies in modern biophysics, and independent research. The biophysics major requires that students earn a grade of “C” or greater for all courses required in the major. A student who earns a grade of “C-“ or below must repeat the course and earn a better grade.

For additional information on academic requirements and department events for majors, check the undergraduate website (http://biophysics.jhu.edu/undergraduate_program.html).

Requirements for the B.A. Degree

(See also Requirements for a Bachelor’s Degree (http://e-catalog.jhu.edu/undergrad-students/academic-policies/requirements-for-a-bachelors-degree).)

Major requirements are:

Chemistry		
AS.030.101 & AS.030.105	Introductory Chemistry I and Introductory Chemistry Laboratory I	4
AS.030.102 & AS.030.106	Introductory Chemistry II and Introductory Chemistry Laboratory II	4
or AS.030.103	Applied Chemical Equilibrium and Reactivity w/lab	
AS.030.205	Introductory Organic Chemistry I	4
AS.030.206	Organic Chemistry II	4
or AS.030.212	Honors Organic Chemistry II with Applications in Biological and Materials Chemistry	
Physics		
AS.171.101	General Physics:Physical Science Major I	4
or AS.171.103	General Physics I for Biological Science Majors	
or AS.171.105	Classical Mechanics I	
or AS.171.107	General Physics for Physical Sciences Majors (AL)	
AS.173.111	General Physics Laboratory I	
or AS.173.11	Classical Mechanics Laboratory	

AS.171.102	General Physics: Physical Science Major II	4
or AS.171.104	General Physics/Biology Majors II	
or AS.171.106	Electricity and Magnetism I	
or AS.171.108	General Physics for Physical Science Majors (AL)	
AS.173.112	General Physics Laboratory II	1
or AS.173.116	Electricity and Magnetism Laboratory	
Mathematics		
AS.110.108	Calculus I	4
AS.110.109	Calculus II (For Physical Sciences and Engineering)	4
or AS.110.113	Honors Single Variable Calculus	
AS.110.202	Calculus III	4
or AS.110.211	Honors Multivariable Calculus	
One additional Math elective is required. See "Math List" below.		4
Biophysics		
AS.250.205	Introduction to Computing	3
AS.250.315	Biochemistry I	4
AS.250.372	Biophysical Chemistry	4
AS.250.381	Spectroscopy and Its Application in Biophysical Reactions	3
AS.250.383	Molecular Biophysics Laboratory (Writing Intensive)	3
Research (6 credits required)		
AS.250.521	Research Problems	3
or AS.250.522	Research Problems	
or AS.250.574	Research Problems	
or AS.250.514	Research in Protein Design and Evolution	
*All students will be expected to present their research in poster or oral format at the Biophysics Department Research Symposium in April. In most cases, students will present in their senior year.		
Major Electives		
Three Courses from List #1		9-12
Three Courses from List #2		9-12
One Course from the Advanced Seminar List		3

Math List (Select one from this list as required Math Elective)

AS.110.201	Linear Algebra	4
AS.110.212	Honors Linear Algebra	4
EN.553.211	Probability and Statistics for the Life Sciences	4
or EN.553.311	Probability and Statistics for the Biological Sciences and Engineering	
or EN.553.310	Probability & Statistics	
EN.553.291	Linear Algebra and Differential Equations	4
Any 300 level course or higher with approval of faculty advisor		

List #1 (Select 3 from this list as Major Electives)

AS.250.253	Protein Engineering and Biochemistry Lab	3
AS.250.316	Biochemistry II	3
AS.171.201	Special Relativity/Waves	4
or AS.171.309	Wave Phenomena with Biophysical Application	
AS.171.202	Modern Physics	4
or AS.171.310	Biological Physics	
EN.601.107	Introductory Programming in Java (*)	3
or EN.601.220	Intermediate Programming	
EN.601.226	Data Structures (*)	4
*Upper level computer science or bio-computing course can replace these courses with approval from advisor		

List #2 (Select 3 from this list as Major Electives)

AS.250.253	Protein Engineering and Biochemistry Lab	3
AS.250.265	Introduction to Bioinformatics	3
AS.250.302	Modeling the Living Cell	4
AS.250.313	Molecular and Cellular System Biology	4
AS.250.316	Biochemistry II	3
AS.250.320	Macromolecular Binding	3
AS.250.353	Computational Biology	3
AS.250.403	Bioenergetics: Origins, Evolution and Logic of Living Systems	3
AS.171.201	Special Relativity/Waves	4
or AS.171.309	Wave Phenomena with Biophysical Application	
AS.171.202	Modern Physics	4
or AS.171.310	Biological Physics	
Any course 300-level or higher in Biology, Chemistry, or Physics that is 3 credits or more.		3

Advanced Seminar List (Select one from this list as Advanced Seminar Requirement)

AS.250.401	Advanced Seminar in Structural and Physical Virology	3
AS.250.403	Bioenergetics: Origins, Evolution and Logic of Living Systems	3
AS.250.411	Advanced Seminar in Structural Biology of Chromatin	3
AS.250.421	Advanced Seminar in Membrane Protein Structure, Function & Pharmacology	3

Scheduling conflicts occasionally arise due to schedule changes in the departments of Physics, Biology, and Chemistry. Prospective biophysics majors should consult with the departmental undergraduate advisor to determine how the conflicts can be resolved.

Sample Programs for the B.A. in Biophysics

First Year

Fall		Credits	Spring		Credits
AS.030.101	Introductory Chemistry I	3	AS.030.102	Introductory Chemistry II	3
AS.030.105	Introductory Chemistry Laboratory I	1	AS.030.106	Introductory Chemistry Laboratory II	1
AS.110.108	Calculus I	4	AS.110.109	Calculus II (For Physical Sciences and Engineering)	4
AS.250.205	Introduction to Computing	3	AS.250.131	Freshman Seminar in Biophysics (optional)	1
		11			9

Second Year

Fall		Credits	Spring		Credits
AS.030.205	Introductory Organic Chemistry I	4	AS.030.206	Organic Chemistry II	4
AS.110.202	Calculus III	4	AS.171.104	General Physics/Biology Majors II	4
AS.171.103	General Physics I for Biological Science Majors	4	AS.173.112	General Physics Laboratory II	1
AS.173.111	General Physics Laboratory I	1	Required Math Elective		4
		13			13

Third Year

Fall		Credits	Spring		Credits
AS.250.253	Protein Engineering and Biochemistry Lab	3	AS.250.381	Spectroscopy and Its Application in Biophysical Reactions	3
AS.250.315	Biochemistry I	4	AS.250.522	Research Problems	3
AS.250.372	Biophysical Chemistry	4	Elective from List #1		3-4
AS.250.521	Research Problems	3	Elective from List #2		3-4
		14			12-14

Fourth Year

Fall		Credits	Spring		Credits
AS.250.521	Research Problems (optional)	3	AS.250.383	Molecular Biophysics Laboratory	3
Elective from List #1		3-4	Elective from List #1		3-4
Elective from List #2		3-4	Elective from List #2		3-4
Required Advanced Seminar Course		3			
		12-14			9-11

Total Credits: 93-99

A Note on Writing Courses

The Krieger School of Arts & Sciences requires 12 credits of writing-intensive coursework. Although many humanities and social science courses have a writing designation, a few courses within the major also fulfill the requirement. Current examples include:

AS.250.383 Molecular Biophysics Laboratory

AS.250.401 Advanced Seminar in Structural and Physical Virology

AS.250.403 Bioenergetics: Origins, Evolution and Logic of Living Systems

AS.250.411 Advanced Seminar in Structural Biology of Chromatin

AS.250.421 Advanced Seminar in Membrane Protein Structure, Function & Pharmacology

Fulfilling some of the writing requirement with one or more biophysics courses requires advanced planning because not all of these courses are offered every year.

Honors in Biophysics

The Jenkins Biophysics department offers outstanding students the opportunity to earn departmental honors in Biophysics. This honors distinction appears on the student's transcript upon graduation. If the honors requirements are approved prior to early April, an "Honors" distinction will additionally appear in the commencement program.

The requirements for departmental honors in biophysics are two-fold:

The student must maintain an overall GPA of 3.5 or greater
The student must write and receive approval of an Honors paper that is based on their 6 credits of required research.

Generally, the Honors paper must be submitted no later than March 1 of the senior year to meet the commencement deadline. Details on the format of the Honors paper can be found on the departmental website. Schedule a meeting with your Jenkins faculty adviser if you are interested in seeking departmental honors.

Ete Z. Szüts Undergraduate Research Travel Award

This award, named in honor of a Ph.D. graduate student from this department, will provide funds for up to 80 percent of the transportation costs of undergraduate research students in biophysics to attend a scholarly meeting. Recipients must be sponsored by a member of the departmental faculty who will be at the same meeting. Schedule a meeting with your Jenkins faculty adviser if you are interested in the Szuts Travel Award.

H. Keffer Hartline Award for Excellence in Undergraduate Research in Biophysics

This award honors a senior Biophysics Major for excellence in undergraduate research in Biophysics. Recipients are selected by Biophysics Faculty.

Detlev W. Bronk Award for Outstanding Scholarship in Biophysics

This award honors a senior Biophysics major for outstanding achievements in academics in Biophysics. Recipients are selected by Biophysics Faculty.

Master's Program

Fifth-Year Master's Degree

The T. C. Jenkins Department of Biophysics offers outstanding undergraduate biophysics majors the opportunity to advance their education through a combined, 5-year B.A., M.A. program. Candidates for this program must be current biophysics undergraduates with a departmental GPA of 3.5 or greater and a strong research history. All bachelor's requirements must be completed before matriculating into the Master's program.

Students in this program will be required to take courses such as:

AS.250.685	Proteins & Nucleic Acids	3
AS.250.689	Physical Chemistry of Biological Macromolecules	3
AS.250.690	Methods in Molecular Biophysics	3
Total Credits		9

These courses account for about half of the student's time. The remaining effort is spent on a substantial research project. A Master's thesis describing the research being carried out is also required.

Doctoral Programs

The Thomas C. Jenkins Department of Biophysics offers two Ph.D. programs (PMB and CMDB, see below). The annual application deadline is January 15.

Program in Molecular Biophysics

The Program in Molecular and Biophysics (PMB), which began in 1990, brings together Johns Hopkins faculty at the Homewood and Medical School campuses. Its goal is to prepare students to deal with interdisciplinary problems in molecular biophysics and structural biology. For more information, see PMB Web page at pmb.jhu.edu.

Admission

All applicants must have a B.S. or a B.A. degree. Applications from students in any branch of science are welcome; however, we are particularly eager to attract applicants with undergraduate majors in physics, chemistry, mathematics, or relevant areas of engineering. There are no required undergraduate courses. Instead, applications are examined for general strength of scientific background. The Graduate Record Examination, including a subject test, is required.

Please use the Johns Hopkins University online application, selecting biophysics under the School of Arts & Sciences. Supplementary materials (letters of recommendation, GRE scores, statement, etc.) should be sent directly to:

Program in Molecular Biophysics
Johns Hopkins University
101 Jenkins Hall
3400 N. Charles Street
Baltimore, MD 21218

Requirements for the Ph.D.

Programs are developed individually for each student, and due account is taken of previous training.

The following courses are required:		
EN.500.401	Research Laboratory Safety	1
AS.250.649	Introduction to Computing in Biology	
AS.250.685	Proteins & Nucleic Acids	
AS.250.689	Physical Chemistry of Biological Macromolecules	
AS.250.690	Methods in Molecular Biophysics	
At the School of Medicine: ME.100.705 Computer Modeling of Biological Macromolecules and ME.330.709 Organic Mechanisms in Biology		

Students must demonstrate strength in the following four areas: biological sciences, chemistry, mathematics, and physics. Typically, incoming students already have strength in at least two of these areas from undergraduate training. Deficiencies will be remedied through additional course work or self-study. Students must pass a proficiency exam in biological sciences at the end of their first year. In the mathematics and physics areas, students will be required to have calculus through the study of several variables, and one year of calculus-based physics, respectively. In the chemistry area, students are required to have basic chemistry, organic chemistry, and physical chemistry. In biological sciences, students are required to have knowledge of biochemistry and cell and molecular biology.

Additional academic requirements include completion of three 12-week laboratory rotations, a one-hour seminar on a current topic of biophysical research, and passing the Graduate Board Oral Preliminary Examination, to be given near the end of the second year.Responsible Conduct of Research instruction is required throughout the duration of graduate studies.

Completion of an original investigation and presentation of a dissertation are required. The dissertation must be accepted by the program and be considered worthy of publication by the referees. Students must then pass an oral examination on their dissertation and related topics.

The Program in Cell, Molecular Developmental Biology and Biophysics

The Program in Cell, Molecular Developmental Biology and Biophysics (CMDB) gives students a strong background in modern biology and physical biochemistry. This combination prepares students to study complex biological phenomena using quantitative physical methods. The training faculty reside in the T. C. Jenkins Department of Biophysics, the Biology Department, and the Carnegie Institutions Department of Embryology, all located on the Johns Hopkins Homewood campus. Students take core graduate courses in cell, molecular, and developmental biology, and in biophysics, and complete four eight-week rotations their first year. Other requirements include the Graduate Board Oral Preliminary Examination, given before the end of the second year, and successful defense of the dissertation.

For more information about CMDB, please check its website (**cmdb.jhu.edu**). Interested applicants can apply online via the program website or by U. S. mail to:

Ms. Joan Miller (joan@jhu.edu)
Graduate Admissions Coordinator
CMDB Program
Department of Biology
Johns Hopkins University
3400 N. Charles Street
Baltimore, MD 21218
410-516-5502

Financial Aid

Two National Institutes of Health training grants currently provide stipend and tuition support: one is for students who enroll in PMB and the other is for those who enter CMDB. Students supported by these training grants must be U.S. citizens or permanent residents. In addition, several research assistantships funded by grants and contracts awarded to faculty by outside agencies may be available to qualified students. University fellowships providing remission of tuition are also available. Graduate students in biophysics are eligible for and encouraged to apply for various nationally administered fellowships, such as National Science Foundation fellowships. Information on these and other support mechanisms can be obtained through the fellowship advisor at the applicant's college or from the National Research Council:

Attn: Fellowships
1000 Thomas Jefferson St.
Washington, D.C., 20007.

It is anticipated that financial support covering normal living costs and tuition will be made available to accepted students. Support for foreign students is extremely limited.

For current faculty and contact information go to http://biophysics.jhu.edu/faculty_and_research.html

Faculty

Faculty

Doug Barrick
Thomas C. Jenkins Professor: energetic and structural basis of Notch signal transduction, protein energetics, repeat protein folding.

Gregory Bowman
Associate Professor: biophysical and biochemical characterization of chromatin-remodeling proteins; X-ray crystallography.

Richard Cone
Professor: mucosal protective mechanisms, contraception and prevention of sexually transmitted diseases, cellular and molecular mechanics.

Bertrand Garcia-Moreno E.
Professor (Chair): experimental and computational studies of protein energetics and electrostatics.

Karen G. Fleming
Professor: energetics and folding of membrane proteins.

Taekjip Ha
Bloomberg Professor: single molecule biophysics, Fluorescence imaging and spectroscopy, mechanobiology

Margaret Johnson
Assistant Professor: computational and theoretical studies of protein-protein interactions; protein assembly and dynamics.

Juliette T. J. Lecomte
Professor: structure and dynamics of proteins in solution; NMR spectroscopy.

Sua Myong
Associate Professor: quantitative analysis of gene expression in single molecule and single cell

Elijah Roberts
Assistant Professor: development and application of in-silico cell models.

George Rose
Krieger-Eisenhower Professor, Research Professor, Professor Emeritus: modeling and simulation of protein folding and protein structure.

Sarah A. Woodson
Thomas C. Jenkins Professor: folding and assembly of RNA and RNA-protein complexes.

Research/Teaching Faculty

Ana Damjanovic
Associate Research Scientist: computational studies of protein structure, dynamics and function.

Carolyn Fitch
Senior Lecturer: computational and experimental studies on protein structure, function, and energetics.

Patrick Fleming
Senior Lecturer: computational studies of protein folding, structure and solvation.

Secondary Appointments, Biology

Ernesto Freire
Professor: biophysical chemistry, thermodynamics of macromolecular assemblies in membranes protein-lipid interactions, microcalorimetry.

Vincent J. Hilser
Professor: conformational fluctuations in function, disease, and evolution.

Christian Kaiser
Assistant Professor: Single-molecule biochemistry studies of the machines and processes in protein translation, translocation, and folding

Evangelos Moudrianakis
Professor: mechanisms of enzyme action, especially of chloroplast and mitochondrial coupling factors. Human chromosome structure and function, self- assembly of chromosomal components.

Robert Schleif
Professor: protein-DNA interactions and regulation of gene activity.

Secondary Appointments, Chemistry

Christopher Falzone
Teaching Professor: NMR spectroscopy of proteins.

Craig A. Townsend
Professor: organic and bioorganic chemistry, biosynthesis of natural products, stereochemical and mechanistic studies of enzyme action, application of spectroscopic techniques to the solutions of biological problems.

Secondary Appointments, Advanced Academic Programs

Alexandra Tan
Program Director, Advanced Academic Programs and Lecturer, Biophysics

Joint Appointments

Brian Camley
Assistant Professor (Physics & Astronomy): theoretical and computational studies of single and collective cell motility; soft matter in cell biology

P. C. Huang
Professor (Biochemistry and Molecular Biology): organization and regulation of stress inducible genes and their gene products.

Affiliations with the School of Medicine

L. Mario Amzel
Professor: X-ray diffraction studies of biological macromolecules; enzymes involved in oxidate reductions and phosphorylation; experimental and modeling studies of binding proteins.

James M. Berger
Professor: structural and mechanistic biochemistry of protein/nucleic acid machines and assemblies.

Dominique Frueh
Assistant Professor: NMR studies of protein dynamic modulations and conformations in active enzymatic systems.

Albert Lau

Assistant Professor: characterization of receptor-ligand interactions and macromolecular conformational transitions using computational and crystallographic approaches.

Jungsan Sohn
Assistant Professor: structure and function of biological stress sensors.

Herschel Wade
Assistant Professor: structural, functional, and energetic treatments of ligand-activated molecular switches.

Cynthia Wolberger
Professor: three-dimensional structure of protein-DNA complexes, X-ray crystallography.

Bin Wu
Assistant Professor: single molecule imaging, RNA biology, and gene expression

Jie Xiao
Assistant Professor: dynamics of molecular process at single molecule and single cell level.

For current course information and registration go to https://sis.jhu.edu/classes/

Courses

AS.250.106. Introduction to Biomedical Research and Careers I. 1.0 Credit.
Lecture Series designed for those curious about a career in life sciences, medicine and public health. A novel format combining presentation with didactic interviews gives a broad view of a range of research topics, experimental approaches and logistics, and practical applications as well as career paths. Emphasis is on the excitement of scientific explorations not an abundance of the technical facts and figures. Freshmen and non-science majors Co-listed with AS50.300 and AS.250.306
Instructor(s): P. Huang
Area: Natural Sciences.

AS.250.131. Freshman Seminar in Biophysics. 1.0 Credit.
Introduction of contemporary biophysics research topics through presentations, discussion and hands-on exercise. Freshmen and sophomores only. S/U grading only.
Instructor(s): K. Fleming; R. Cone
Area: Natural Sciences.

AS.250.205. Introduction to Computing. 3.0 Credits.
This course is useful for many disciplines not only the life sciences. It will introduce students to basic computing concepts and tools useful in many applications. Students learn to work in the Unix environment, to write shells scripts, and to make use of powerful Unix commands (e.g grep, awk, and sed). They will learn to program using the Python programming language, graphing software, and a package for numerical and statistical computing, such as Mathematica or MATLAB. At the end of the semester students will complete a project coupling all components of the semester together. Brief lectures followed by extensive hands-on computer laboratories with examples from many disciplines. No prerequisites .Course offered every semester.
Instructor(s): A. Damjanovic; M. Procopio
Area: Natural Sciences.

AS.250.253. Protein Engineering and Biochemistry Lab. 3.0 Credits.
Entry-level project laboratory. Protein engineering and biotechnology techniques used to modify proteins to give them new structural or physical properties. Students introduced to standard biochemistry laboratory practice and protein science; perform experiments in site-directed mutagenesis, protein purification and structural and physical characterization of biological macromolecules. No prerequisites. Preference given to freshmen and sophomores.
Prerequisites: Students must have completed Lab Safety training prior to registering for this class.
Instructor(s): C. Fitch; J. Sorenson
Area: Natural Sciences.

AS.250.265. Introduction to Bioinformatics. 3.0 Credits.
Lectures and computer labs introduce bioinformatics concepts, algorithms and databases. Computer based exercises cover sequence comparisons, database searching, gene expression analysis, and phylogenetic relationships. Emphasis on algorithms and a critical interpretation of information obtained. Instructor permission required. .
Instructor(s): P. Fleming
Area: Natural Sciences.

AS.250.300. Introduction to Biomedical Research and Careers II. 1.0 Credit.
Lecture Series designed for those curious about a career in life sciences, medicine and public health. A novel format combining presentation with didactic interviews gives a broad view of a range of research topics, experimental approaches and logistics, and practical applications as well as career paths. Emphasis is on the excitement of scientific explorations not an abundance of the technical facts and figures. Sophomores, juniors and seniors. Science Majors; Co-listed with AS.250.106 and AS.250.306.
Instructor(s): P. Huang
Area: Natural Sciences.

AS.250.301. Laboratory in Molecular Evolution: Using ancestral. 3.0 Credits.
The availability of genomic sequences from a vast number of species has enabled the reconstruction of ancestral proteins. In this course we will reconstruct the genes of ancestral proteins and study the physical properties of proteins coded for by "extinct" genes. To examine the evolutionary mechanisms whereby modern proteins obtained their remarkable physical and functional properties, we will focus on understanding how the physical properties of proteins evolved hand-in-hand with changing environmental conditions such as pH, temperature, pressure, ionic strength, oxidative stress, etc.
Instructor(s): A. Robinson.

AS.250.302. Modeling the Living Cell. 4.0 Credits.
Introduction to physical and mathematical models used to represent biophysical systems and phenomena. Students will learn algorithms for implementing models computationally and perform basic implementations. We will discuss the types of approximations made to develop useful models of complex biological systems, and the comparison of model predictions with experiment.
Instructor(s): M. Johnson
Area: Natural Sciences.

AS.250.306. Introduction to Biomedical Research and Careers III. 1.0 Credit.
Lecture Series designed for those curious about a career in life sciences, medicine and public health. A novel format combining presentation with didactic interviews gives a broad view of a range of research topics, experimental approaches and logistics, and practical applications as well as career paths. Emphasis is on the excitement of scientific explorations not an abundance of the technical facts and figures. For those who have already taken AS.250.106 or AS.250.300. Co-listed with AS.250.106 & AS.250.300.
Instructor(s): P. Huang
Area: Natural Sciences.

AS.250.310. Exploring Protein Biophysics using Nuclear Magnetic Resonance (NMR) Spectroscopy. 3.0 Credits.
NMR is a spectroscopic technique which provides unique, atomic level insights into the inner workings of biomolecules in aqueous solution. A wide variety of biophysical properties can be studied by NMR. For example, we can use the technique to determine three dimensional structure of biological macromolecules such as proteins and nucleic acids, probe their dynamical properties in solution, study their interaction with other molecules and understand how physico-chemical properties (such electrostatics and redox chemistry) affects and modulates structure-function relationships. NMR exploits the exquisite sensitivity of magnetic properties of atomic nuclei to their local electronic (and therefore, chemical) environment. As a result, biophysical properties can be studied at atomic resolution. That is to say, we can deconstruct global properties of a molecule in terms of detailed, atomic level information. In addition, interactions between nuclei can be exploited to enhance the information content of NMR spectra via multi-dimensional (2D and 3D) spectroscopy. Since these properties can be studied in solution, NMR methods serve as an effective complement to X-Ray crystallography, which also provides detailed, atomic level information in the solid state. In this course, we will learn about the basics of NMR spectroscopy, acquire 1D and 2D NMR spectra and use various NMR experiments to characterize and probe biophysical properties of proteins at an atomic level. Juniors and Seniors Only.
Prerequisites: ((AS.030.101 AND AS.030.105) OR (AS.030.103 AND AS.030.204)) AND (AS.030.370 OR AS.250.372) AND (AS.020.305 OR AS.030.315 OR AS.250.315) AND AS.030.205
Instructor(s): A. Majumdar.

AS.250.313. Molecular and Cellular System Biology. 4.0 Credits.
This course covers the principles of biological networks, with an emphasis on computational analysis. Networks ranging from simple biochemical pathways to genome-scale metabolic, regulatory, and signaling networks will be studied. Topics include dynamic modeling of biochemical pathways, steady-state analysis of cellular metabolic networks, inference of gene regulatory networks using –omics data, and systems biology approaches to studying signal transduction. Recommended Course Background: Calculus (AS.110.106 and AS.110.107), Biochemistry (AS.250.315 or AS.020.305 or equivalent). Computational Biology (AS.250.353) or Introduction to Bioinformatics (AS.250.265) or prior exposure to programming.
Instructor(s): E. Roberts.

AS.250.314. Research in Protein Design and Evolution. 3.0 Credits.
Instructor(s): B. Garcia-Moreno; J. Lecomte
Writing Intensive.

AS.250.315. Biochemistry I. 4.0 Credits.
Foundation for advanced classes in Biophysics and other quantitative biological disciplines. Lecture and computer laboratory. This class is the first semester of a two semester course in biochemistry. Topics in Biochemistry I include chemical and physical properties of biomolecules and energetic principles of catabolic pathways. Computer labs include extensive use of molecular graphics and modelling of reaction kinetics and pathway flux. Co-listed with AS.030.315
Prerequisites: If you have completed AS.250.307 you may not register for AS.250.315.;Prerequisites: AS.030.206 OR AS.030.212
Instructor(s): P. Fleming
Area: Natural Sciences.

AS.250.316. Biochemistry II. 3.0 Credits.
Biochemical anabolism, nucleic acid structure, molecular basis of transcription, translation and regulation, signal transduction with an emphasis on physical concepts and chemical mechanisms. Format will include lectures and class discussion of readings from the literature.
Prerequisites: (AS.250.315 OR AS.030.315 OR AS.020.305) AND (AS.030.206 OR AS.030.212) or permission of the instructor.
Instructor(s): S. Rokita; S. Woodson.

AS.250.320. Macromolecular Binding. 3.0 Credits.
All biological processes require the interactions of macromolecules with each other or with ligands that activate or inhibit their activities in a controlled manner. This course will discuss theoretical principles, logic, approaches and practical considerations used to study these binding processes from a quantitative perspective. Topics will include thermodynamics, single and multiple binding equilibria, linkage relationships, cooperativity, allostery, and macromolecular assembly. Some biophysical methods used in the study of binding reactions will be discussed. Computer simulation and analysis of binding curves will be used to analyze binding data, and binding schemes and examples from the scientific literature will be reviewed and discussed. Recommended Course Background: AS.250.372 Biophysical Chemistry
Prerequisites: AS.250.315 OR AS.020.305
Instructor(s): K. Fleming
Writing Intensive.

AS.250.335. Single Molecule & Cell Biophysics. 3.0 Credits.
This (elective) course offers an introduction to the field of single molecule and single cell biophysics to second and third year undergraduate students in biophysics. We will examine technologies such as single molecule fluorescence, force measurements and single cell fluorescence detections that enable high precision molecular visualizations in vitro and in cells. In addition, we will cover topics of genome engineering, cell mechanics and optogenetics toward the end of the semester. Each student is expected to read two articles assigned for each week and submit a written summary. All students will take turns presenting the assigned articles to class.
Instructor(s): S. Myong; T. Ha.

AS.250.345. Cellular and Molecular Physiology. 3.0 Credits.
How cells and molecules function as parts of whole organisms. Topics include speeds of diffusion, motor proteins, and animal motility; bacterial size, shape, and chemotaxis; sensory and neuronal mechanisms; osmosis; mucosal protective mechanisms; cellular and organismic circulation and respiration. Discussion section to be arranged 1 hour per week.
Instructor(s): R. Cone
Area: Natural Sciences.

AS.250.351. Reproductive Physiology. 2.0 Credits.
Focuses on reproductive physiology and biochemical and molecular regulation of the female and male reproductive tracts. Topics include the hypothalamus and pituitary, peptide and steroid hormone action, epididymis and male accessory sex organs, female reproductive tract, menstrual cycle, ovulation and gamete transport, fertilization and fertility enhancement, sexually transmitted diseases, and male and female contraceptive methods. Introductory lectures on each topic followed by research-oriented lectures and readings from current literature.
Instructor(s): B. Zirkin
Area: Natural Sciences.

AS.250.353. Computational Biology. 3.0 Credits.
This course introduces several computational approaches to the study of biological macromolecules. Students will learn to use computational tools to carry out and analyze molecular simulations and how to work in a UNIX networked environment. A major goal is to understand molecular systems as ensembles. No programming experience is required. A previous biochemistry course is strongly recommended.
Prerequisites: (AS.030.101 AND AS.030.102) or AS.030.103.
Instructor(s): P. Fleming
Area: Natural Sciences.

AS.250.372. Biophysical Chemistry. 4.0 Credits.
Course covers classical and statistical thermodynamics, spanning from simple to complex systems. Major topics include the first and second law, gases, liquids, chemical mixtures and reactions, conformational transitions in peptides and proteins, ligand binding, and allostery. Methods for thermodynamic analysis will be discussed, including calorimetry and spectroscopy. Students will develop and apply different thermodynamic potentials, learn about different types of ensembles and partition functions. Students will learn to use Mathematica and will use it for data fitting and for statistical and mathematical analysis. Background: Calculus, Organic Chemistry, and Introductory Physics.
Instructor(s): D. Barrick
Area: Natural Sciences.

AS.250.381. Spectroscopy and Its Application in Biophysical Reactions. 3.0 Credits.
Continues Biophysical Chemistry (AS.250.372). Fundamentals of quantum mechanics underlying various spectroscopies (absorbance, circular dichroism, fluorescence, NMR); application to characterization of enzymes and nucleic acids.
Instructor(s): J. Lecomte
Area: Natural Sciences.

AS.250.383. Molecular Biophysics Laboratory. 3.0 Credits.
An advanced inquiry based laboratory course covering experimental biophysical techniques to introduce fundamental physical principles governing the structure/function relationship of biological macromolecules. Students will investigate a “model protein”, staphylococcal nuclease, the “hydrogen atom” of biophysics. Using a vast library of variants, the effect of small changes in protein sequence will be explored. A variety of techniques will be used to probe the equilibrium thermodynamics and kinetics of this system; chromatography, spectroscopy (UV-Vis, fluorescence, circular dichroism, nuclear magnetic resonance), calorimetry, analytical centrifugation, X-ray crystallography and computational methods as needed for analysis. These methods coupled with perturbations to the molecular environment (ligands, co-solvents, and temperature) will help to elucidate protein function.
Prerequisites: Students must have completed Lab Safety training prior to registering for this class.;AS.250.372
Instructor(s): C. Fitch
Writing Intensive.

AS.250.401. Advanced Seminar in Structural and Physical Virology. 3.0 Credits.
Illustrated fundamental contributions from biophysics and quantitative and physico-chemical approaches to study of complex biological systems. Focus on the physical and structural basis of viral infectivity, emphasizing replication cycles and evolution and structural biology of human pathogens such as HIV and influenza. AS.250.372 - Introduction to Biophysical Chemistry useful. Recommended Course Background: AS.030.205 and (AS.020.305 or AS.250.307)
Instructor(s): B. Garcia-Moreno
Area: Natural Sciences
Writing Intensive.

AS.250.403. Bioenergetics: Origins, Evolution and Logic of Living Systems. 3.0 Credits.
The trait shared by all living systems is the capacity to perform energy transduction. This biophysics/biochemistry course examines the physico-chemical and structural basis of biological energy transduction.Emphasis is on understanding the molecular and cellular logic of the flow of energy in living systems. The course explores the connection between fundamental physical requirements for energy transduction and the organization, evolution and possibly even the origins of biological molecules, cells, and organisms. Implications for planet earth¹s energy balance and for the design of synthetic organisms and of artificial energy transducing machines will be discussed, time permitting. Recommended Course Background: One semester of Biochemistry. Recommended Course Background: One semester of Biochemistry
Instructor(s): B. Garcia-Moreno
Writing Intensive.

AS.250.411. Advanced Seminar in Structural Biology of Chromatin. 3.0 Credits.
Focus is on structural and physical aspects of DNA processes in cells, such as nucleosomal packaging, DNA helicases, RNA polymerase, and RNA inhibition machinery. Topics are meant to illustrate how the structural and chemical aspects of how proteins and nucleic acids are studied to understand current biological questions. Recommended Course Background: Biochemistry I (AS.250.315) and Biochemistry II (AS.250.316) or Biochemistry (AS.020.305) and Intro to Biophys Chem (AS.250.372)
Instructor(s): G. Bowman
Area: Natural Sciences
Writing Intensive.

AS.250.421. Advanced Seminar in Membrane Protein Structure, Function & Pharmacology. 3.0 Credits.
Topics are meant to illustrate the physical basis of membranes and membrane proteins towards understanding their functions and pharmacological importance including aspects of drug design as it relates to membranes. Contemporary issues in the field will be covered using primary literature articles, structural manipulations in pymol, and computational binding simulations. Recommended Course Background: AS.030.205, AS.250.307, and AS.250.372
Instructor(s): K. Fleming
Writing Intensive.

AS.250.514. Research in Protein Design and Evolution. 3.0 Credits.
Instructor(s): B. Garcia-Moreno; J. Lecomte
Writing Intensive.

AS.250.519. Independent Study. 3.0 Credits.
Instructor(s): K. Fleming; S. Myong
Writing Intensive.

AS.250.520. Independent Study. 0.0 - 3.0 Credits.
Instructor(s): B. Garcia-Moreno; D. Barrick; R. Cone
Writing Intensive.

AS.250.521. Research Problems. 3.0 Credits.
Instructor(s): Staff.

AS.250.522. Research Problems. 0.0 - 3.0 Credits.
Instructor(s): Staff.

AS.250.531. Laboratory - Biophysics. 3.0 Credits.
Introduction to Independent research in Biophysics emphasizing basic laboratory techniques. Individual study arranged with faculty mentor. Permission from Faculty Sponsor.
Instructor(s): Staff.

AS.250.574. Research Problems. 2.0 Credits.
Instructor(s): K. Fleming; S. Woodson.

AS.250.595. Internship. 1.0 Credit.
Instructor(s): K. Fleming; R. Huang.

AS.250.596. Laboratory - Biophysics. 3.0 Credits.
Instructor(s): D. Barrick; R. Cone; S. Myong; S. Woodson.

AS.250.597. Research. 3.0 Credits.
Instructor(s): Staff.

AS.250.599. Independent Study. 3.0 Credits.
Instructor(s): D. Barrick.

AS.250.601. Biophysics Seminar.
Graduate students only. Students and invited speakers present current topics in the field.
Instructor(s): J. Lecomte.

AS.250.602. Biophysics Seminar.
Student and invited speakers present current biophysics topics. Permission required. Graduate student only.
Instructor(s): J. Lecomte.

AS.250.622. Statistics and Data Analysis.
Basics of statistics and data analysis
Instructor(s): D. Barrick.

AS.250.623. Molecular Dynamics.
Basics of molecular dynamics
Instructor(s): A. Damjanovic.

AS.250.624. NMR Spectroscopy.
Basics of NMR spectroscopy
Instructor(s): A. Majumdar.

AS.250.625. Single Molecule Measurements.
Basic Principles of Single Molecule Measurements
Instructor(s): T. Ha.

AS.250.641. Seminar on Mucosal Protection.
Graduate level seminar on physiology, immunology, and epidemiology of mucosal protection. Permission required.
Instructor(s): R. Cone.

AS.250.649. Introduction to Computing in Biology.
Four week, intensive introductory course on the use of computers for applications in biology. The course will cover fundamentals of UNIX, PYTHON and Mathematica. Brief daily lectures followed by extensive hands-on experience in the computer laboratory. Examples from the world of biology are used to teach a large variety of concepts and computational techniques useful to examine a broad range of topics in biology.
Instructor(s): G. Bowman.

AS.250.674. Semi-Annual Thesis.
Departmental Majors Only.
Instructor(s): B. Garcia-Moreno.

AS.250.685. Proteins & Nucleic Acids.
The structure of proteins, DNA and RNA, and their functions in living systems. Students are required to participate in class discussions based on readings from the primary scientific literature. Co-requisite: AS 250.649 Introduction to Computing in Biology, or knowledge of Python programming. Instructor permission for undergraduates.
Instructor(s): G. Bowman; S. Woodson.

AS.250.689. Physical Chemistry of Biological Macromolecules.
Introduction to the principles of thermodynamics and kinetics as applied to the study of the relationship between structure, energy dynamics, and biological function of proteins and nucleic acids. Topics include of classical, chemical, and statistical thermodynamics, kinetics, theory of ligand binding, and conformational equilibria.
Instructor(s): B. Garcia-Moreno.

AS.250.690. Methods in Molecular Biophysics.
Introduction to methods employed in study of energetics, structure and function of biological macromolecules. Topics include optical spectroscopy, transport methods, NMR, X-ray crystallography. Theoretical understanding and knowledge through problem solving and literature discussion emphasized.
Prerequisites: AS.250.685 AND AS.250.689
Instructor(s): J. Lecomte.

AS.250.801. Dissertation Research.
Instructor(s): Staff.

AS.250.802. Dissertation Research.
Instructor(s): B. Garcia-Moreno.

Cross Listed Courses

Biology

AS.020.674. Graduate Biophysical Chemistry.
This course will provide an overview of protein and nucleic acid structure, fundamentals of thermodynamics and kinetics, ligand binding, folding and stability of macromolecules, and the principles of biophysical methods such as fluorescence spectroscopy, NMR, and X-ray crystallography. Biology PhD students only. Monday Discussion Session is optional. Recommended Course Background: AS.020.305, AS.020.306
Instructor(s): E. Freire; E. Roberts.

Biomedical Engineering

EN.580.446. Physical Epigenetics. 3.0 Credits.
Epigenetics describes information heritable during cell division other than DNA sequence per se. Recent advances show the critical role of epigenetics in controlling gene expression, embryonic development, and common human diseases such as cancer. This course will introduce fundamental epigenetic principles with a focus on mechanisms, modeling, and physical principles, relationship to genetics, and application to understanding human disease mechanisms. Recommended Course Background: EN.580.221 Molecules and Cells or equivalent (molecular and cell biology), college level calculus and calculus-based general physics.
Instructor(s): A. Feinberg; T. Ha
Area: Engineering, Natural Sciences.