An interdepartmental program

# Biological Physics

Courses of Study:
Major (B.S.)

## Objectives

The undergraduate major in biological physics is designed to provide the quantitative skills and the background in chemistry and biology for students interested in the study of the physics of biological systems, especially on the molecular scale. This program provides a strong foundation in the physical sciences that underpin much of the modern revolution in biology. It should be of particular interest to students wishing to pursue careers in fundamental or applied research in biophysics, quantitative biology, and biotechnology.

For a related graduate program, please see the Biophysics and Structural Biology program elsewhere in this *Bulletin*.

## How to Become an Undergraduate Major

The major requires a large number of science courses, some of which are prerequisites for more advanced courses. Therefore it is important to start taking these courses in the first year. Students are advised to meet with the biological physics chair as soon as possible to plan their schedule. It is most advantageous to take physics and math in the first year, but starting with chemistry and math in the first year is also adequate.

The Seminar in Biological Physics (BIPH 11a,b) is recommended for first-year students, but can be taken in the second year. Students interested in the honors program, involving a senior research thesis, should begin to seek a faculty mentor by the end of their second year, with the prospect of starting research as early as possible.

## Committee

**Robert Meyer, Chair**
(Physics, Volen Center for Complex Systems)

**Laurence Abbott**
(Biology, Volen Center for Complex Systems)

**Karl Canter**
(Physics)

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**Jané Kondev**
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**Gregory Petsko**
(Biochemistry and Chemistry, and Director, Rosenstiel Center)

**Dagmar Ringe**
(Biochemistry and Chemistry, and Rosenstiel Center)

**Xiao-Jing Wang**
(Physics, Volen Center for Complex Systems)

## Requirements for the Undergraduate Major

**Degree of Bachelor of Science**
To satisfy the requirements for the major in biological physics leading to the degree of Bachelor of Science, students must successfully complete the foundation of this program, which are a set of required courses in the physical and life sciences. The **core courses**, divided by fields, are:

Physics: PHYS 11a,b or PHYS 15a,b, PHYS 19a,b, PHYS 20a,b, PHYS 30b, PHYS 39a, PHYS 40a.

Mathematics: MATH 10 a,b

Chemistry: CHEM 11a,b and CHEM 18a,b or equivalents

Biology: BIOL 18a,b and BIOL 22a,b

Biological Physics: BIPH 11a,b

The Seminar in Biological Physics (BIPH 11a,b) should be taken in the first or second year. Students are encouraged to participate in the seminar a second year without credit, for enrichment of their program.

Students with high enough Advanced Placement Examination scores may place out of some of the elementary courses. See the table of Advanced Placement Credit (pages 22-23) for details concerning the equivalent Brandeis courses for sufficient scores in the tests in Mathematics (AB or BC), Physics (C), and Chemistry. Concentration credit is given for all these tests except for Physics C: Electrical. Students who take advanced placement credit for Physics 11b will be required to take Physics 30a, the intermediate level course in this subject.

Beyond the core curriculum students are expected to explore areas of further inquiry by taking at least two **elective courses**. Possible topics and related courses are listed below. Other courses can be taken as electives with approval of the program advisor.

*Molecular structure:* The use of physical techniques including X-ray diffraction, electron microscopy, nuclear magnetic resonance, to elucidate the structure of bio-molecules. Electives: BIOL 102b, BCHM 171b*, BIOL 126b, BCHM 104b*.

*Single molecule biophysics:* The study of biological processes on the single molecule scale, such as enzyme function, ion transport through membranes, protein folding, molecular motors. Electives: BIOL 25a, BCHM 101a*.

*Modeling of biological structure and function:* The development and analysis of mathematical models for elucidating biological structure and function. Electives: CHEM 111a, PHYS 104a, NPHY 115a*, NBIO 136b.

*Systems and networks:* Study of topics including bio-informatics, neural networks, and networks of genes and proteins. Electives: BCHM 170b*, NBIO 140b.

*Required prerequisites for this course are not included in the core curriculum.

A student starting the biological physics major in the first year, with no advanced placement, should follow the recommended sequence:

Year 1: BIPH 11a,b, MATH 10a,b, PHYS 11a,b, PHYS 19a,b

Year 2: CHEM 11a,b, CHEM 18a,b, PHYS 20a,b

Year 3: BIOL 18a,b, BIOL 22 a,b, PHYS 40a

Year 4: PHYS 30b, PHYS 39a, two electives

A student with advanced preparation in math, physics and chemistry, who wants to emphasize biochemistry might take the following program:

Year 1: BIPH 11a,b, MATH 15a, MATH 20b, PHYS 19b, PHYS 20a,b

Year 2: BIOL 18a,b, BIOL 22a,b, CHEM 25a,b, CHEM 29a,b

Year 3: BCHM 100a, PHYS 40a, one elective

Year 4: PHYS 30a,b, PHYS 39a, one elective

Students with advanced preparation might choose additional courses in other areas, rather than organic and biochemistry. A student who has started as a premed and switched to biological physics (not completing the premed program) might have the following program:

Year 1: CHEM 11a,b, CHEM 18a,b, MATH 10a,b

Year 2: BIOL 18a, BIOL 22a, BIPH 11a,b, PHYS 11a,b, PHYS 19a,b

Year 3: BIOL18b, BIOL 22b, PHYS 20a,b, one elective

Year 4: PHYS 30b, PHYS 39a, PHYS 40a, one elective

In addition to the required courses students are urged to learn the necessary topics in organic chemistry as a preparation for biochemistry. This opens up additional options for undergraduate research and graduate programs in the life sciences. For medical school, a year of organic chemistry with laboratory, in addition to the required courses for biological physics, will complete the premed program requirements.

An important component of the program is the opportunity for students to participate in research. Opportunities exist for research in the laboratories of physics, chemistry, neuroscience, biochemistry, and biology faculty.

**Honors Program**
Graduation with honors requires completion of a senior research thesis. Students must enroll in BIPH 99d in their senior year to carry out a research project. Students wishing to join the honors program should apply to the honors advisor in the program in the spring of their junior year.

## Special Notes Relating to Undergraduates

Students majoring in biological physics may not count required courses toward a minor in physics. By completing other required courses, they can complete a second major in physics. However, for the preparation for a career in biological physics, it might be more valuable to devote extra science courses to deeper preparation in chemistry and biochemistry.

## Courses of Instruction

### (1-99) Primarily for Undergraduate Students

**BIPH 11a Seminar in Biological Physics**
*Corequisite: PHYS 11a. May yield half-course credit toward rate of work and graduation*
Introduction to recent experimental and theoretical advances in biological physics at the first year physics level. Examples of topics include the physics of DNA and proteins, molecular motors, principles of laser tweezers, and atomic force microscopy. Can be taken before or after BIPH 11b. Usually offered every year. Will be offered in the fall of 2003.
Mr. Kondev and Mr. Meyer

**BIPH 11b Seminar in Biological Physics**
*Corequisite: PHYS 11b. May yield half-course credit toward rate of work and graduation*
Introduction to recent experimental and theoretical advances in biological physics at the first-year physics level. Examples of topics include the physics of DNA and proteins, molecular motors, principles of laser tweezers and atomic force microscopy. Can be taken before or after BIPH 11a. Usually offered every year. Will be offered in the spring of 2004.
Mr. Kondev and Mr. Meyer

**BIPH 98a Reading in Biological Physics**
*Signature of the instructor required.*
Open to students wishing to study a subject not available in the curriculum.
Staff

**BIPH 98b Reading in Biological Physics**
*Signature of the instructor required.*
Open to students wishing to study a subject not available in the curriculum.
Staff

**BIPH 99d Senior Research**
*Signature of the instructor required.*
Research and preparation of a report under the direction of an instructor. Open to students doing research in an approved topic in biological physics.
Staff

**BIOL 18a General Biology Laboratory**
[ wi sn ]
*Prerequisites: CHEM 18a or 19a, and BIOL 18b or permission of the instructor. BIOL 22a (formerly BIBC 22a) must be taken before or concurrently with this course. Does yield full-course credit toward rate of work and graduation. Four semester hour credits. Laboratory fee: $20 per semester. This lab is time intensive and students will be expected to come in to lab between regular scheduled lab sessions. Enrollment limited to 58 per section.*
Provides firsthand experience with a wide array of organisms and illustrates basic approaches to problem solving in genetics and molecular biology. Usually offered every year. Will be offered in the spring of 2004.
Ms. Tsipis

**BIOL 18b General Biology Laboratory**
*Prerequisites: CHEM 18a or 19a. BIOL 22b must be taken before or concurrently with this course. Does yield half-course credit toward rate of work and graduation. Two semester hour credits. Laboratory fee: $20 per semester. Enrollment limited to 48 per section.*
Provides firsthand experience with a wide array of organisms and illustrates basic approaches to problem solving in cell biology. Usually offered every year. Will be offered in the fall of 2003.
Ms. Tsipis

**BIOL 22a Genetics and Molecular Biology**
(formerly BIBC 22a)
[ qr sn ]
*Prerequisite: CHEM 10a or 11a or 15a. This course may not be repeated for credit by students who have taken BIBC 22a in previous years.*
An introduction to our current understanding of hereditary mechanisms and the cellular and molecular basis of gene transmission and expression. Usually offered every year. Will be offered in the spring of 2004.
Mr. Fulton

**BIOL 22b Cell Structure and Function**
[ sn ]
*Prerequisite: CHEM 10a or 11a or 15a.*
An introduction to the architecture of cells, organelles, and their macro-molecular components. Topics include fundamental processes that are common to all cells, and the functions of specialized cells. Usually offered every year. Will be offered in the fall of 2003.
Mr. Welte

**CHEM 11a General Chemistry**
[ qr sn ]
*This course may not be taken for credit by students who have passed CHEM 10a or 15a in previous years.*
A basic course in chemical principles, with examples drawn from the chemistry of living systems as well as from environmental chemistry and materials science. Topics covered include stoichiometry, acid-base chemistry, introduction to chemical equilibrium, properties of solutions, atomic structure and periodicity, molecular structure and bonding, and states of matter. Three class hours and one one-hour recitation per week. In addition, daily tutoring sessions will be available for students seeking extra help. The corresponding lab is CHEM 18a. Usually offered every year. Will be offered in the fall of 2003.
Mr. Epstein

**CHEM 11b General Chemistry**
[ qr sn ]
*Prerequisite: A satisfactory grade (C- or better) in CHEM 11a or the equivalent. This course may not be taken for credit by students who have passed CHEM 10b or 15b in previous years.*
A basic course in chemical principles, with examples drawn from the chemistry of living systems as well as from environmental chemistry and materials science. Topics covered include kinetics, chemical equilibrium, thermodynamics, electrochemistry, coordination compounds, nuclear chemistry, and descriptive chemistry. Three class hours and one, one-hour recitation per week. In addition, daily tutoring sessions will be available for students seeking extra help.The corresponding lab is CHEM 18b. Usually offered every year. Will be offered in the spring of 2004.
Mr. Petsko

**CHEM 18a General Chemistry Laboratory I**
*Corequisite: CHEM 11a. Dropping CHEM 11a necessitates written permission from the lab instructor to continue with this course. May yield half-course credit toward rate of work and graduation. Two semester hour credits. Laboratory fee: $45 per semester. Enrollment limited to 44 per section. This course may not be taken for credit by students who have passed CHEM 19a in previous years.*
Introduction to methods for characterizing pure substances and methods of qualitative and quantitative analyses. Included in the analytical methods are gas chromatography-mass spectroscopy and infrared measurements. A synthesis project that includes analyzing the product by titration. Analysis of the metal content of substances by visible absorbance and atomic absorption. One laboratory lecture per week. One, one-hour optional recitation per week. Usually offered every year. Will be offered in the fall of 2003.
Mr. Dolnik

**CHEM 18b General Chemistry Laboratory II**
*Prerequisites: A satisfactory grade (C- or better) in CHEM 18a and CHEM 10a or CHEM 11a. Corequisite: CHEM 11b. Dropping CHEM 11b necessitates written permission from the lab instructor to continue with this course. May yield half-course credit toward rate of work and graduation. Two semester hour credits. Laboratory fee: $45 per semester. Enrollment limited to 44 per section. This course may not be taken for credit by students who have passed CHEM 19b in previous years.*
The second semester of the general chemistry laboratory program. Continued use of probes interfaced with computers to monitor pH and electrical conductivity changes in titrating amino acids, to monitor pressure changes as part of a kinetics study, and to monitor voltage changes of electrochemical cells with temperature so as to establish thermodynamic parameters for redox reactions. Also microscale syntheses of coordination compounds is included followed by characterization of the compounds. Usually offered every year. Will be offered in the spring of 2004.
Mr. Dolnik

**CHEM 19a Honors General Chemistry Laboratory I**
*Corequisite: CHEM 15a. Dropping CHEM 15a necessitates written permission from the lab instructor to continue with this. May yield half-course credit toward rate of work and graduation. Two semester hour credits. Laboratory fee: $45 per semester. Enrollment limited to 14 per section. This course may not be taken for credit by students who have taken CHEM 18a in previous years.*
An advanced version of CHEM 18a. Develops modern laboratory techniques at a higher level than CHEM 18a, using more advanced topics and equipment. One afternoon of laboratory per week. One laboratory lecture per week. Usually offered every year. Will be offered in the fall of 2003.
Mr. Dolnik

**MATH 10a Techniques of Calculus (a)**
[ sn ]
*Prerequisite: MATH 5a or placement by examination. Enrollment limited to 25 per section.*
Introduction to differential (and some integral) calculus of one variable, with emphasis on techniques and applications. Usually offered every semester in multiple sections. Will be offered in the fall of 2003.
Ms. Parker and Staff (fall)
Mr. Kleber (spring)

**MATH 10b Techniques of Calculus (b)**
[ sn ]
*Prerequisite: MATH 10a or placement by examination. Enrollment limited to 25 per section. Continuation of 10a.*
Introduction to integral calculus of one variable with emphasis on techniques and applications. Usually offered every semester in multiple sections. Will be offered in the fall of 2003.

**PHYS 11a Basic Physics I**
[ qr sn ]
*Corequisite: MATH 10a,b or the equivalent. Enrollment limited to 100.*
Classical mechanics, plus topics from kinetic theory and thermodynamics. Usually offered every year. Will be offered in the fall of 2003.
Mr. Roberts

**PHYS 11b Basic Physics II**
[ qr sn ]
*Prerequisite: PHYS 11a. Enrollment limited to 100.*
Elementary electromagnetism presented from a modern point of view, plus topics in special relativity. Usually offered every year. Will be offered in the spring of 2004.
Mr. Roberts

**PHYS 15a Honors Basic Physics I**
[ qr sn ]
*Prerequisite: MATH 10a,b or the equivalent. Corequisite: PHYS 19a*
Advanced version of PHYS 11a for students with good preparation in physics and mathematics. Newtonian mechanics. Kinetic theory and thermodynamics. Usually offered every year. Will be offered in the fall of 2003.
Mr. Roberts

**PHYS 15b Honors Basic Physics II**
[ qr sn ]
*Prerequisite: MATH 10a,b or the equivalent. PHYS 11a or 15a or the equivalent Corequisite: PHYS 19b*
Advanced version of PHYS 11b for students with good preparation in physics and mathematics. Elementary electromagnetism presented from a modern point of view. Special relativity. Usually offered every year. Will be offered in the spring of 2004.
Mr. Roberts

**PHYS 19a Physics Laboratory I**
*May yield half-course credit toward rate-of-work and graduation. Two semester hour credits. Total enrollment in lab sections limited to 100.*
Laboratory course designed to accompany PHYS 11a. Introductory statistics and data analysis including use of microcomputers and basic experiments in mechanics. One afternoon or evening of laboratory per week. One, one-and-a-half hour lecture per week. Usually offered every year. Will be offered in the fall of 2003.
Mr. Fell

**PHYS 19b Physics Laboratory II**
*May yield half-course credit toward rate-of-work and graduation. Two semester hour credits. Total enrollment in lab sections limited to 100.*
Laboratory course designed to accompany PHYS 11b. Basic experiments in electricity, magnetism, and optics. Basic electrical measurements. Determination of several fundamental physical constants. One afternoon or evening of laboratory per week. One, one-and-a-half hour lecture per week. Usually offered every year. Will be offered in the spring of 2004.
Mr. Canter

**PHYS 20a Modern Physics I**
[ sn ]
*Prerequisites: PHYS 11a, 11b, or equivalent.*
A survey of phenomena, ideas, and mathematics underlying modern physics—special relativity, waves and oscillations, optics, thermal and statistical physics, and introductory quantum mechanics, as well as a selection of topics such as nuclear physics and radioactivity, elementary particles, cosmology, and electronic properties of crystals, semiconductors, and metals. Usually offered every year. Will be offered in the fall of 2003.
Mr. Fell

**PHYS 20b Modern Physics II**
[ sn ]
*Prerequisite: PHYS 20a.*
Continuation of PHYS 20a. Usually offered every year. Will be offered in the spring of 2004.
Mr. Wardle

**PHYS 30b Quantum Theory**
[ sn ]
*Prerequisites: PHYS 11a,b and PHYS 20a,b; or permission of the instructor.*
Introduction to quantum mechanics: atomic models, Schrödinger equation, angular momentum, and hydrogen atom. Multielectron atoms and interaction of atoms with the electromagnetic field. Usually offered every year. Will be offered in the spring of 2004.
Mr. Canter

**PHYS 39a Advanced Physics Laboratory**
[ sn ]
*Prerequisite: PHYS 20a. Signature of the instructor required. This course may be repeated once for credit with permission of the instructor.*
Experiments in a range of topics in physics, possibly including selections from the following: wave optics, light scattering, Nuclear Magnetic Resonance, x-ray diffraction, scanning tunnelling microscopy, numerical simulation and modeling, holography, electro-optics, phase transitions, rubber elasticity, laser tweezers, chaotic dynamics, and optical microscopy. Students work in depth on three or four experiments during the term. Usually offered every semester. Will be offered in the fall of 2003.
Mr. Meyer

**PHYS 40a Introduction to Thermodynamics and Statistical Mechanics**
[ sn ]
Statistical approach to thermal properties of matter. Theoretical tools are developed for studying questions such as: "Why does a rubber band contract upon heating?" or "What is the size of a white dwarf star?" Usually offered every year. Will be offered in the fall of 2003.
Mr. Wang

## Elective Courses

The following courses are approved for the program. Not all are given in any one year. Please consult the *Course Schedule* each semester.

**BCHM 101a**
Advanced Biochemistry: Enzyme Mechanisms

**BCHM 104b**
Physical Chemistry of Macromolecules

**BCHM 170b**
Bioinformatics

**BCHM 171b**
Protein X-Ray Crystallography

**BIOL 25a**
Molecular Motors

**BIOL 102b**
Structural Molecular Biology

**BIOL 126b**
Protein Structure and Disease

**CHEM 111a**
Computational Chemistry

**PHYS 104a**
Condensed Matter I

**NBIO 136b**
Computational Neuroscience

**NBIO 140b**
Principles of Neuroscience

**NPHY 115a**
(formerly PHYS 115a)
Dynamical Systems, Chaos, and Fractals