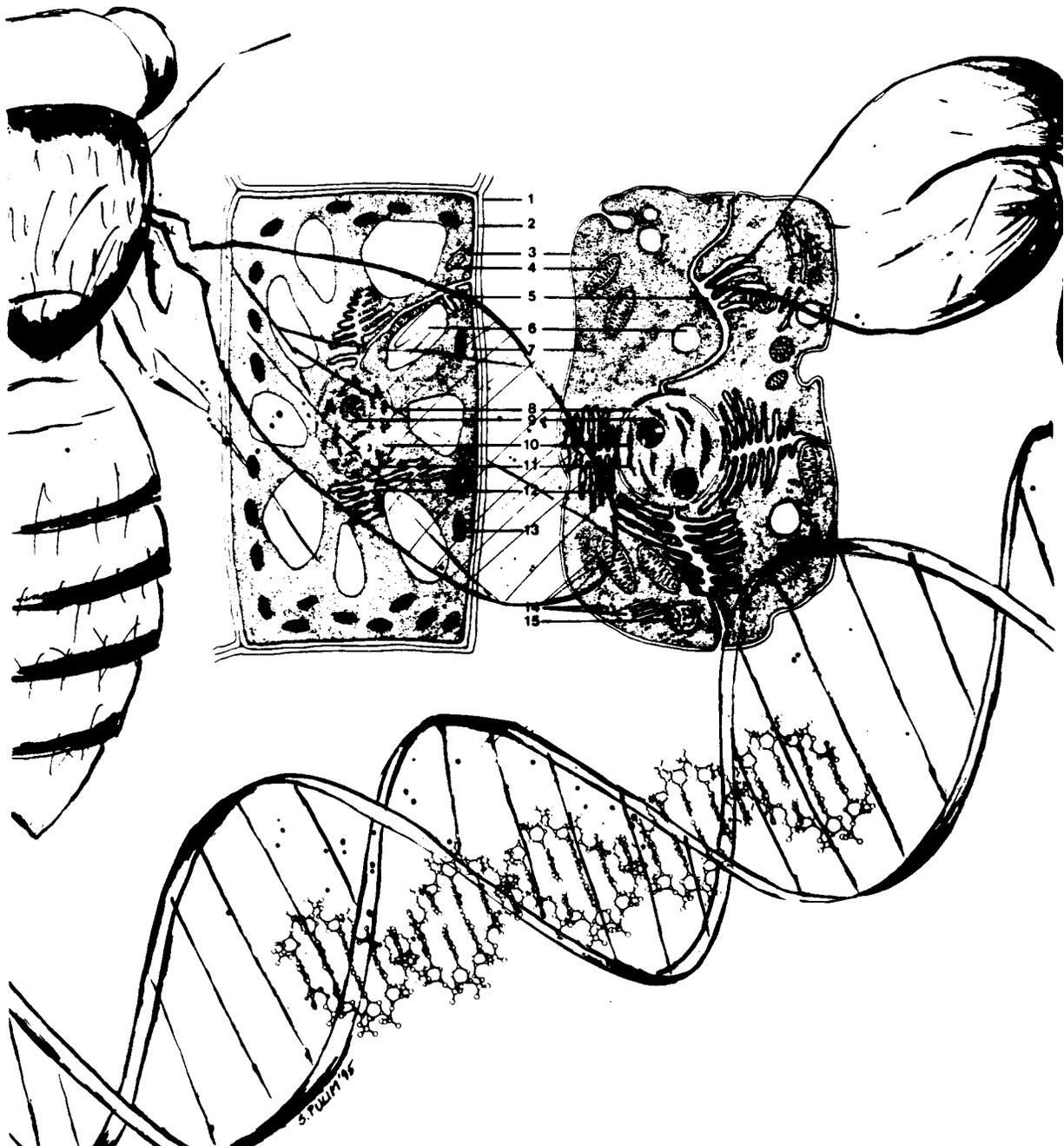


Washington University
ST. LOUIS MISSOURI
Department of Biology

Handbook for Majors and Prospective Majors



Spring 2018

Washington University in St. Louis

Department of Biology

Handbook for Majors and Prospective Majors

SPRING 2018

Welcome to the biology major. We hope that this handbook will be helpful whether you already have chosen or are considering a major in biology. A major in biology can prepare you for a broad range of careers, not limited to those discussed here. There has been no more exciting time to study the life sciences. Your studies here will be demanding, but should also be exciting to you, with numerous opportunities to explore new ideas about how the living world functions.

Mission Statement for the Biology Major

A student graduating with a major in biology should be well educated in the history of scientific discovery in biology, the logical and statistical procedures used to formulate and to test biological hypotheses, and technical skills needed for conducting contemporary biological research. Majors should appreciate the hierarchical nature of biological complexity, and the major structures and functions emerging at the molecular, cellular, organismal, populational and ecosystem levels. At least one dimension of contemporary research should be understood in sufficient detail that the student could describe the major hypotheses currently being tested and demonstrate familiarity with techniques used to test those hypotheses. Mastery of the material will be evident in a student's ability to critique published data, identifying ambiguities and uncertainties in conclusions drawn from those data, and in understanding the societal importance of the research. A student attaining these goals will be prepared to make creative contributions to biology through independent research and/or teaching, and will be ready for graduate training in biological research, education, health care, industrial biotechnology, and the computational, legal and business careers related to biotechnology. A major should appreciate the importance of biological knowledge for solving societal problems.

This booklet has been compiled by the Curriculum Committee of the Department of Biology, Washington University. See <http://www.nslc.wustl.edu/handbook/handbook.html> for an online version of this material. Our thanks to Sandeep Pulim for the cover art and Sidney Harris for the use of his apt cartoons.

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REQUIREMENTS FOR THE BIOLOGY MAJOR

Majors ordinarily begin work in biology with Biol 2960 in spring of freshman year*. After completing Chem 111A-112A and the accompanying laboratories Chem 151-152, also taken during the first year, students proceed to Biol 2970 and then upper-level classes in the sophomore year, accompanied by organic chemistry (Chem 261-262). Biol 2960 and Biol 2970 are required for majors and appropriate in sequence for premedical and pre dental students with other majors.

CHEMISTRY, PHYSICS AND MATHEMATICS REQUIREMENTS

In addition to Chem 111A-112A and the accompanying laboratory courses Chem 151-152, biology majors are required to take Chem 261 and either Chem 262 or Chem 401; Physics 117A-118A (or Physics 197-198); Math 132 (Calculus II) and one of the following: Math 2200, Math 233, or Math 3200. Courses taken in University College, Washington University's evening school, do not meet these or any other major requirements. Students who plan to take physical chemistry must take Math 233 (Calculus III). Math 2200 or 3200 (Elementary Probability and Statistics; required for tracks in Ecology and Evolution and in Genomics and Computational Biology, see pp. 4-5) and Math 322 (Biostatistics) are valuable, particularly in research.

A typical program for the first two years looks like this:

Fall - Year One	Spring - Year One	Fall - Year Two	Spring - Year Two
Chem 111A (3). Biol elective* (optional). Math 132 (3). Chem (Lab) 151 (2). Distribution (3), or English Comp 100 (3). Distribution (3).	Chem 112A (3). Biol 2960 (4) Math 233 or Math 2200 (3). Chem (Lab) 152 (2). English Comp 100 (3), or Distribution (3).	Chem 261 (4). Biol 2970 (4)- (Biol 2960 pre-req) Distributions (6).	Chem 262 (4). Biol 3XX (2-4)- (Biol 2970 pre-req) Distributions (6).

ADVANCED BIOLOGY REQUIREMENT

At least eighteen units in approved advanced Biology courses (numbered 300 or above) are required. Courses that may be counted toward these 18 units are listed following Biol 2960 and Biol 2970 in the section "Courses for Biology-Major Credit" beginning on page 44. At least one of the approved advanced laboratory courses in biology must be completed. At least one course in each of three distribution areas (A-C) and an advanced laboratory course must be taken; each of these courses counts toward the required 18 advanced biology units. Up to 6 units of Biol 500 may be counted toward the 18 advanced biology units.

THREE AREAS OF BIOLOGY REQUIRED (Fall 2018 offerings underlined)

- Area A.** Plant Biology and Genetic Engineering (Biol 3041); Cell Biology (Biol 334); Eukaryotic Genomes (Biol 3371); Microbiology (Biol 349); Immunology (Biol 424); Infectious Diseases: History, Pathology, and Prevention (Biol 4492); General Biochemistry (Biol 451); General Biochemistry I (Biol 4810); General Biochemistry II (Biol 4820).
- Area B.** Endocrinology (Biol 3151); Principles in Human Physiology (Biol 328); Principles of the Nervous System (Biol 3411); Introduction to Neuroethology (Biol 3421); Genes, Brains and Behavior (Biol 3422); How Plants Work: Physiology, Growth and Metabolism (Biol 4023); Biological Clocks (Biol 4030); Developmental Biology (Biol 4071); Principles of Human Anatomy and Development (Biol 4580).
- Area C.** Evolution (Biol 3501); Behavioral Ecology (Biol 372), Introduction to Ecology (Biol 381); Population Genetics and Microevolution (Biol 4181); Macroevolution (Biol 4182); Molecular Evolution (Biol 4183); Community Ecology (Biol 419); Behavioral Ecology (Biol 472).

* *Optional biology courses of interest to prospective majors are offered in fall of freshman year: Biol 112 (Introduction to Problem-Based Learning in Biology), Biol 1260 (The Secret Lives of Plants), Biol 171 (Neuroscience Futures 1), Biol 1770 (Genetics and Behavior of Dog Breeds), Biol 181 (Introduction to Cutting-Edge Research in Biology), Biol 1811 (Research and Conservation in Zoos and Botanical Gardens), Biol 191 (Phage Hunters Laboratory), Biol 2010 (The Science of Biotechnology), Biol 2431 (Missouri's Natural Heritage), Biol 2950 (Introduction to Environmental Biology).*

ADVANCED LABORATORY REQUIREMENT

An upper-level laboratory course chosen from the following list is required for the biology major. Students planning to pursue research careers in the biomedical sciences are strongly urged to take additional laboratory courses. **NOTE:** Biology 500 does not satisfy the laboratory course requirement for the biology major.

Biol 3110 Vertebrate Structure Laboratory (**fall**)
Biol 3491 Microbiology Laboratory (**fall, spring, summer session 1**)
Biol 3492 Laboratory Experiments with Eukaryotic Microbes (**spring**)*
Biol 3493 Bacterial Bioprospecting and Biotechnology (**spring**)
Biol 360 Biophysics Laboratory (**fall**)
Biol 373 Laboratory on the Evolution of Animal Behavior (**fall**)
Biol 404 Laboratory of Neurophysiology (**fall**)*
Biol 4193 Experimental Ecology Laboratory (**spring**)*
Biol 4241 Immunology Laboratory (**fall, spring**)*
Biol 4342/434W Research Explorations in Genomics (**spring**)*
Biol 437 Laboratory on DNA Manipulation (**fall**)
Biol 4520 Protein Function in Model Cellular Systems (**fall**)*
Biol 4522 Laboratory in Protein Analysis, Proteomics, and Protein Structure (**spring**)*
Biol 4523 Molecular Methods in Enzyme Analysis (**fall**)
Biol 4524 Structural Bioinformatics of Proteins (**fall**)

**Enrollment requires advance permission of the instructor.*

DECLARATION AND ADVISING OF BIOLOGY MAJORS

Students can declare a major in Biology online through WebSTAC under Major Programs. Upon declaring a major in biology, typically during sophomore year, a student gets a major advisor from the Biology Department faculty. Students can request specific Biology major advisors when placing a major declaration request. Each student then consults both a four-year advisor and a Biology major advisor each semester. Major advisors typically discuss course schedules, academic progress, career objectives, pre-professional testing (e.g. MCAT, GRE), medical-school applications, research interests, and internships. An academic program and extracurricular endeavors are thereby personally tailored to each student. Students interested in health professions (e.g. medical, dental, and veterinary schools) should consult the Pre-Health Advising Program (<http://prehealth.wustl.edu/advising/Pages/default.aspx>) to get a pre-health advisor.

GRADES

All courses counted toward major requirements must be taken for a letter grade if a letter grade is offered. **A grade of C- or better must be earned in all of these courses.**

RESEARCH EMPHASIS

An optional research emphasis pertains equally to students completing the biology major with or without one of the optional tracks (p. 4). The research emphasis and an appropriate grade performance qualify a student for Latin honors. A student who fulfills the research emphasis but does not meet the grade requirements for Latin honors receives a research milestone on the transcript. See the requirements (p. 3) for details on qualifying for Latin honors through biology. The research emphasis comprises the following work in addition to the biology major requirements.

1. Six units of independent research (Biol 500). In most cases, independent study leading to a research emphasis starts no later than spring of the junior year. Most students work full time on this research during the summer following their junior year and complete their work during the senior year.
2. A paper written by the student and judged by the mentor to be worthy of recognition. The paper should be written in the style of a scientific article for a professional journal, with abstract, introduction, materials and methods, results, and discussion. The research thesis should reflect substantial effort. The introduction should put the work into biological context and thoroughly review relevant literature. The methods section should be more extensive than a journal article's and should demonstrate that the student understands the methods used. Results and discussion may be combined or presented separately. Tables, figures, and bibliographies should be used to present results and should be in standard journal-style form. Extensive or complete results are not required

for a thesis to be acceptable. Discussion of incomplete results and problems encountered may be appropriate when experiments have not yielded significant results. Because a student rarely completely solves a problem within the available time, an indication of what should be done next is often appropriate.

3. A mentor's letter certifying acceptability of the thesis **MUST** accompany the thesis. **IMPORTANT:** No candidate is approved for graduation with a research emphasis in biology unless all requirements are met. An oral examination may be held at the discretion of the Department.

4. Presentation of the thesis work in the form of a poster or short talk at the spring Undergraduate Research Symposium.

TIMETABLE - Research theses are due the Monday following spring break of the senior year. (Students graduating in December have a different deadline - consult Patrick Clark.) To have an acceptable thesis, students must begin writing and submit draft versions of each part of their thesis to their mentors to get feedback well before this deadline. Students should consult their mentors about an appropriate timetable by the end of the Fall semester of senior year. Generally, writing should begin no later than January (start of spring semester) and preliminary drafts of sections should be presented to mentors for feedback beginning early in February. There should be several rounds of revision and discussion among the mentor, possibly others in the lab (bench mentor and others who are familiar with the project) and the student to generate the final version. The process is akin to writing a manuscript for publication, and students should seek advice as would any researcher presenting results for publication. Mentor approval is required on the final version. If a mentor has not seen and approved the final version prior to the deadline, the department will **NOT** recommend the student for a research emphasis. The spring Undergraduate Research Symposium is normally scheduled between the last day of spring-semester classes and the start of final examinations. If any delay or problem in submitting an acceptable thesis by the deadline is anticipated/suspected, a student and/or mentor must discuss the problem with the department (begin by notifying Patrick Clark) as soon as possible.

LATIN HONORS THROUGH A BIOLOGY MAJOR PROGRAM

To qualify for Latin honors through biology a student must meet the following requirements. For requirements 1, 2, and 3, only courses taken at Washington University are considered.

1. B+ average (3.3) or better in biology courses.
2. Cumulative average of B+ (3.3) or better in the related science subjects required (math, chemistry, and physics)
3. Overall 3.65 average.
4. Completion of the Research Emphasis (see p. 2)

COURSES FROM OTHER UNIVERSITIES

Some courses from other universities may substitute for Washington University courses. Such substitutions must be approved by the Biology Department prior to enrollment. Contact Allan Larson (larson@wustl.edu) for approval of biology courses. For approval of chemistry, mathematics and physics courses required by the biology major, contact the home department to ensure that transfer credit will appear on your record with the same course number that we require.

WRITING-INTENSIVE COURSES

The College of Arts and Sciences requires each student to take an upper-level writing-intensive (WI) course (at least 3 credits). Any course formally approved as WI may be used to satisfy this requirement, and a grade of C- or better must be earned. The following courses in biology may be used to satisfy the WI requirement: Biol 3010 (Biotechnology Project – Fall 2017 and later offerings only), Biol 3492 (Laboratory Experiments with Eukaryotic Microbes), Biol 404 (Laboratory of Neurophysiology), Biol 4193 (Experimental Ecology Laboratory), Biol 4270 (Problem-Based Learning in the Biomedical Sciences), Biol 434W (Research Explorations in Genomics [Writing Intensive]). Other writing-intensive courses of particular interest to Biology majors include EComp 309 (Writing the Natural World), EComp 311 (Exposition), EComp 3112 (Exposition: Writing and Medicine), EComp 312 (Argumentation), and Psych 4046 (Developmental Neuropsychology).

BIOLOGY MAJOR TRACKS

A student majoring in biology may choose one of four optional tracks within the major. A track provides strong training for graduate study in its subfield. All tracks require completion of the biology major requirements as stated above but provide concentrated study in one of the four fields.

ECOLOGY AND EVOLUTION TRACK

Core Requirements

(bold type indicates core courses not necessarily required by the generic biology major)

Biology	Chemistry	Math	Physics
Biol 2960	Chem 111A & 112A	Math 132	Phys 117 & 118
Biol 2970	Chem 151 & 152	Math 2200 or 3200	or Phys 197 & 198
	Chem 261 & 262		

Advanced Laboratory Requirement

One of the following:

Biol 373	Laboratory on the Evolution of Animal Behavior
Biol 4193	Experimental Ecology Laboratory
Biol 437	Lab on DNA Manipulation
Biol 4342	Research Explorations in Genomics

Advanced Evolution and Ecology Electives

Students whose main interest is ecology should take at least two ecological electives and one evolutionary elective; students whose main interest is evolution should take at least two evolutionary electives and one ecological elective.

ECOLOGY

Biol 372*	Behavioral Ecology
Biol 381	Introduction to Ecology
Biol 419	Community Ecology
Biol 472*	Behavioral Ecology

EVOLUTION

Biol 3501	Evolution
Biol 4181	Population Genetics and Microevolution
Biol 4182	Macroevolution
Biol 4183	Molecular Evolution

*A student may not take both Biol 372 and Biol 472 for credit.

Outside Elective Courses

Analytical Methodology (<i>Select one</i>)	Earth and Planetary Sciences (<i>Select one</i>)
CSE 131 Computer Science I	EPSc 201 Earth and the Environment
Math 322 Biostatistics	EPSc 323 Biogeochemistry

Biology Major Areas A & B Electives

Select one course each from biology major areas A and B according to personal interests.

GENOMICS AND COMPUTATIONAL BIOLOGY TRACK

Core Requirements

(bold type indicates core courses not necessarily required by the generic biology major)

Biology	Chemistry	Math	Physics
Biol 2960	Chem 111A & 112A	Math 132	Phys 117 & 118
Biol 2970	Chem 151 & 152	Math 2200 or 3200	or Phys 197 & 198
Biol 3371 (or 4183 or 548)	Chem 261 & 262		

Advanced Laboratory Requirement

One of the following:

Biol 3492	Laboratory Experiments with Eukaryotic Microbes
Biol 4342	Research Explorations in Genomics
Biol 437	Laboratory on DNA Manipulation
Biol 4524	Structural Bioinformatics of Proteins

Recommended Advanced Biology Electives

Biol 334	Cell Biology (major area A)
Biol 349/1	Microbiology with Microbiology Laboratory (major area A)
Biol 3422	Genes, Brains and Behavior (major area B)
Biol 4030	Biological Clocks (major area B)
Biol 4181	Population Genetics and Microevolution (major area C)

Biol 4183 Molecular Evolution (major area C)
Biol 4810 General Biochemistry I (major area A)

Biology Major Areas A, B & C Electives

Students should select one course each from biology major areas A, B and C according to personal interests (see recommended advanced biology electives above).

Outside Elective Courses

Required	Recommended
CSE 131 Computer Science I	Strongly: CSE 240 Logic and Discrete Mathematics
CSE 247 Data Structures and Algorithms	Math 217 Differential Equations
	Math 309 Matrix Algebra

MICROBIOLOGY TRACK

Core requirements

(Bold type indicates core courses not required by the generic biology major)

Biology	Chemistry	Mathematics	Physics
Biol 2960	Chem 111A & 112A	Math 132	Phys 117 or 197
Biol 2970	Chem 151 & 152	Math 2200 or 3200	Phys 118 or 198
Biol 349*	Chem 261 & 262		

Biol 451 or Biol 4810/4820

**Enrollment in Biol 349 is highly recommended at the Sophomore level. Biol 349 is a prerequisite for multiple courses in the Track.*

Advanced Laboratory Requirement

At least one of the following

Biol 3491 Microbiology Laboratory
Biol 3492 Laboratory Experiments with Eukaryotic Microbes
Biol 3493 Bacterial Bioprospecting & Biotechnology
Biol 437 Lab on DNA Manipulation
Biol 4520 Protein Function in Model Cellular Systems

Advanced Microbiology Electives

At least one of the following

Biol 4331 Algae: Cell Biology and Molecular Evolution* & Biol 4830 Bioenergy*
Biol 4492 Infectious Disease: History, Pathology & Prevention
Biol 4832 Molecular Mechanisms of Photosynthesis and Respiration
Biol 5426 Infectious Disease Gateway: Translational and Public Health

**Both Biol 4331 and Biol 4830 must be taken for Track credit. These half-semester long courses are designed to be taken sequentially in the same semester.*

Allied Elective Courses

At least one of the following

Biol 191 AMP: Phage Hunters* & Biol 192 AMP: Phage Bioinformatics*
Biol 424 Immunology
Chem 453 Bioorganic Chemistry
EPSC 323 Biogeochemistry

**Both Biol 191 and Biol 192 must be taken for Track credit*

Biology Major Areas B & C electives

Students should select one course each from biology major areas B and C. Biol 3501 Evolution is highly recommended for Area C.

Total upper-level (300+) credits earned in major-track biology courses and allied electives must be at least 24.

MOLECULAR BIOLOGY AND BIOCHEMISTRY TRACK

Core Requirements

(bold type indicates core courses not required by the generic biology major)

Biology	Chemistry*	Math	Physics
Biol 2960	Chem 111A & 112A	Math 132	Phys 117 & 118
Biol 2970	Chem 151 & 152	Math 233	or Phys 197 & 198
Biol 4810	Chem 261 & 262	or Math 2200	
Biol 4820		or Math 3200	

Advanced Biology Requirement

One of the following:

Biol 334	Cell Biology
Biol 3371	Eukaryotic Genomes
Biol 349	Microbiology

Advanced Laboratory Requirement

One of the following:

Biol 3491	Microbiology Laboratory
Biol 3492	Laboratory Experiments with Eukaryotic Microbes
Biol 3493	Bacterial Bioprospecting and Biotechnology
Biol 4342	Research Explorations in Genomics
Biol 437	Laboratory on DNA Manipulation
Biol 4241	Immunology Laboratory
Biol 4520	Protein Function in Model Cellular Systems
Biol 4522	Laboratory in Protein Analysis, Proteomics, and Protein Structure
Biol 4523	Molecular Methods in Enzyme Analysis
Biol 4524	Structural Bioinformatics of Proteins

Recommended Advanced Biology Electives

Biol 3041	Plant Bio & Genetic Engineering
Biol 4023	How Plants Work (major area B)
Biol 4071	Developmental Biology (major area B)
Biol 4183	Molecular Evolution (major area C)
Biol 4832	Molecular Mechanisms of Photosynthesis and Respiration
Biol 4833	Protein Biochemistry
Biol 5312	Macromolecular Interactions

Biology Major Areas B & C Electives

Students should select one course each from biology major areas B and C according to personal interests (see recommended advanced biology electives above).

*Students planning to enter Ph.D. programs in biochemistry should note that many such programs require physical chemistry (Chem 401 & 402; prerequisite Math 233)

NEUROSCIENCE TRACK

Core Requirements

(bold type indicates core courses not required by the generic biology major)

Biology	Chemistry	Math	Physics
Biol 2960	Chem 111A & 112A	Math 132	Phys 117 & 118
Biol 2970	Chem 151 & 152	Math 233	or Phys 197 & 198
Biol 3058	Chem 261 & 262	or Math 2200	
		or Math 3200	

Advanced Laboratory Requirement

Choose one of the following

Biol 404	Laboratory of Neurophysiology
Biol 360	Biophysics Laboratory*
Biol 373	Laboratory on the Evolution of Animal Behavior

Advanced Biology Requirements

Choose one in each area

AREA A	AREA B	AREA C
Biol 334 Cell Biology	Biol 3411 Principles of the Nervous System	Any area C course (see p. 1)
Biol 451 Biochemistry		
Biol 4810 Gen. Biochem. I		
Biol 4820 Gen. Biochem. II		

Advanced Biology Elective

Select at least one of the following

Biol 3110	Vertebrate Structure Laboratory
Biol 3151	Endocrinology
Biol 328	Principles in Human Physiology
Biol 3371	Eukaryotic Genomes
Biol 3421	Introduction to Neuroethology
Biol 3422	Genes, Brains and Behavior
Biol 4030	Biological Clocks
Biol 437	Laboratory on DNA Manipulation
Biol 4580	Principles of Human Anatomy and Development

Outside Elective Courses

Select at least one Psychology or Physics course from the following list

PSYCHOLOGY (Pre-req: Psych 100)	PHYSICS (Pre-req: Phys 117 or 197 & 118 or 198)
Psych 330 Sensory and Perception	Phys 350 Physics of the Brain
Psych 360 Cognitive Psychology	Phys 352 Physics of Biomolecules
Psych 3604/4604 Cognitive Neuroscience	Phys 355 Physics of Vision
	Phys 360 Biophysics Laboratory*

**Biophysics Lab may count as either the Advanced Laboratory Requirement or the Outside Elective Course but not for both requirements.*

Optional Seminar Courses in Neuroscience

Biol 171	First-Year Opportunity: Neuroscience Futures 1: How do we learn about the brain?
Biol 4934	Neuroscience Futures 2

Admission To The Neuroscience Track

Students with an interest in Neuroscience are encouraged to apply for admission to the Neuroscience Track. Contact Erin Gerrity (gerrity@wustl.edu) to complete the application. Those applicants with a current Washington University GPA of 3.6 or better after a minimum of 3 semesters are considered for admission to the Neuroscience Track. For each graduating class, decisions about applicants begin in January of sophomore year during the first week of the Spring Semester; decisions are based upon the student's academic record and upon an interview with a major advisor. Applications received after the deadline of the first week of Spring Semester of the sophomore year will be considered in January of the applicant's junior year.

Applications from the Graduating Class of 2020 are now being accepted. Interviews and decisions about admission to the Neuroscience Track for students in this graduating class begin in January 2018.

Applications from the Graduating Class of 2019 are being accepted on a waiting list. Applicants from the waiting list will be interviewed when space becomes available.

A student who successfully completes Biology 360, the Biophysics Laboratory, with a C- or better can use Biol 360 to satisfy the Advanced Laboratory Requirement of the Neuroscience Track of the Biology Major. The student is encouraged (but not required) to complete both the electrophysiology and the human bioelectricity experiments. For those students wishing to use this option: applications for the Neuroscience Track will be accepted from students only after the successful completion of Biology 360 with C- or better. Enrollment in Biol 360 is via WebStac and is limited to 14 students each fall semester.

REQUIREMENTS FOR THE ENVIRONMENTAL BIOLOGY MAJOR

Students interested in environmental biology typically take Biol 2950 (Introduction to Environmental Biology) during fall of the freshman year, although it may be taken later. Students planning to take Biol 2960 in spring of freshman year should begin the chemistry courses (Chem 111A and Chem 151) in fall of freshman year. A 400-level class to be required for Latin honors in Environmental Biology will be introduced at a later time.

Core Requirements

EPSC 201	Earth and the Environment (4 credits, lecture and lab)
Biol 2950	Introduction to Environmental Biology (3 credits)
Biol 2960	Introduction to Biology (4 credits, lecture and lab)
Biol 2970	Introduction to Biology (4 credits, lecture and lab)
Chem 111A/151	General Chemistry (5 credits, lecture and lab)
Chem 112A/152	General Chemistry (5 credits, lecture and lab)
Math 131	Calculus 1 (3 credits)
Math 132	Calculus 2 (3 credits)
Phys 117A /197	Physics 1 (4 credits)
Biol 381	Intro to Ecology (3 credits)

One of the following Chemistry courses

Chem 261	Organic Chemistry 1 (4 credits, lecture and lab)
EPSC 323	Biogeochemistry (3 credits)
EECE 210	Introduction to Environmental Engineering (3 credits)
EECE 505	Aquatic Chemistry (3 credits)
EECE 531	Environmental Organic Chemistry (3 credits)

One of the following courses in Statistics, GIS

Math 2200	Elementary Probability and Statistics (3 credits)
Math 3200	Elementary to Intermediate Statistics and Data Analysis (3 credits)
ENST 380	Applications in GIS (3 credits)

One Upper-Level Biology Lab Course (see listing on page 2)

Any lab course is acceptable; we recommend:

Biol 4193	Experimental Ecology Lab (4 credits, writing intensive)
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One of the following BIOL 300+ courses (Area A and B in Biology)

Biol 3041	Plant Biology and Genetic Engineering
Biol 3151	Endocrinology
Biol 328	Principles in Human Physiology
Biol 334	Cell Biology
Biol 3411	Principles of the Nervous System
Biol 3421	Introduction to Neuroethology
Biol 3422	Genes, Brains and Behavior
Biol 349	Microbiology
Biol 4023	How Plants Work: Physiology, Growth and Metabolism
Biol 4030	Biological Clocks
Biol 451/4810	General Biochemistry

One of the following BIOL 300+ (Area C in Biology)

Biol 3501	Evolution
Biol 372 or 472	Behavioral Ecology
Biol 4181	Population Genetics and Microevolution
Biol 4182	Macroevolution
Biol 419	Community Ecology

One additional Biol 300+ major-track course (may include Biol 500, see listing on p. 45-53)

One of the following EPSC 300+ courses

EPSC 323	Biogeochemistry (only if not already taken for chemistry requirement)
EPSC 352	Earth Materials
EPSC 353	Earth Forces
EPSC 385	Earth History
EPSC 408	Earth's Atmosphere and Global Climate
EPSC 409	Surface Processes
EPSC 413	Introduction To Soil Science
EPSC 422	Sedimentary Geology
EPSC 428	Hydrology
EPSC 443	Methods in Biogeochemistry
EPSC 444	Environmental Geochemistry

REQUIREMENTS FOR THE BIOLOGY MINOR

Students can declare a minor in Biology online through WebSTAC under Major Programs. All requests require department approval and are typically completed within a few days of the request. Supervising staff members are in the Biology Student Affairs office in the Jeanette Goldfarb Plant Growth Building, Room 105: Erin Gerrity, Student Coordinator, x5-5064, gerrity@biology2.wustl.edu and Patrick Clark, Registrar, x 5-6881, pclark@wustl.edu.

REQUIRED INTRODUCTORY COURSES

The Biology Minor requires two introductory courses in Biology (Biol 2960 and Biol 2970) and the following courses in Chemistry: Chem 111A, 112A, 151, 152 and 261. Chem 111A is usually completed prior to enrollment in Biol 2960, and Chem 112A taken concurrently with or prior to Biol 2960.

ELECTIVE COURSES

The biology minor requires 10 advanced units in biology selected from the following:

BIOL 3010	BIOTECHNOLOGY PROJECT	BIOL 4071	DEVELOPMENTAL BIOLOGY
BIOL 3041	PLANT BIO. & GENETIC ENGINEERING	BIOL 4181	POPULATION GENETICS & MICROEVOL.
BIOL 3058	PHYSIOLOGICAL CONTROL SYSTEMS	BIOL 4182	MACROEVOLUTION
BIOL 3100	R WORKSHOP IN BIOLOGY	BIOL 4183	MOLECULAR EVOLUTION
BIOL 3110	VERTEBRATE STRUCTURE LAB.	BIOL 419	COMMUNITY ECOLOGY
BIOL 3151	ENDOCRINOLOGY	BIOL 4193	EXPERIMENTAL ECOLOGY LABORATORY
BIOL 328	PRINCIPLES IN HUMAN PHYSIOLOGY	BIOL 424	IMMUNOLOGY
BIOL 334	CELL BIOLOGY	BIOL 4241	IMMUNOLOGY LABORATORY
BIOL 3371	EUKARYOTIC GENOMES	BIOL 4270	PROBLEM-BASED LEARNING IN BIOMED
BIOL 3411	PRINCIPLES OF THE NERVOUS SYSTEM	BIOL 4331	ALGAE: CELL BIOLOGY/MOLECULAR EVO
BIOL 3421	INTRODUCTION TO NEUROETHOLOGY	BIOL 4342*	RESEARCH EXPLORATION IN GENOMICS
BIOL 3422	GENES, BRAINS AND BEHAVIOR	BIOL 437	LAB ON DNA MANIPULATION
BIOL 347	DARWIN AND EVOL CONTROVERSIES	BIOL 4492	INFECTIOUS DISEASES
BIOL 349	MICROBIOLOGY	BIOL 451	GENERAL BIOCHEMISTRY
BIOL 3491	MICROBIOLOGY LABORATORY	BIOL 4520	PROTEIN FUNCTION MODEL CELL SYSTEM
BIOL 3492	LABORATORY EUKARYOTIC MICROBES	BIOL 4522	LABORATORY IN PROTEIN ANALYSIS
BIOL 3493	BACTERIAL BIOPROSPECTING BIOTECH.	BIOL 4523	MOLECULAR METHOD ENZYME ANALYSIS
BIOL 3501	EVOLUTION	BIOL 4524	STRUCTURAL BIOINFORMATICS PROTEINS
BIOL 360	BIOPHYSICS LABORATORY	BIOL 4580	PRINCIPLES OF HUMAN ANATOMY
BIOL 372**	BEHAVIORAL ECOLOGY	BIOL 472**	BEHAVIORAL ECOLOGY
BIOL 373	LAB EVOLUTION ANIMAL BEHAVIOR	BIOL 4810	GENERAL BIOCHEMISTRY I
BIOL 381	INTRODUCTION TO ECOLOGY	BIOL 4820	GENERAL BIOCHEMISTRY II
BIOL 4023	HOW PLANTS WORK: PHYSIOLOGY etc.	BIOL 4830	BIOENERGY
BIOL 4030	BIOLOGICAL CLOCKS	BIOL 4832	PHOTOSYNTHESIS & RESPIRATION
BIOL 404	LAB OF NEUROPHYSIOLOGY	BIOL 4833	PROTEIN BIOCHEMISTRY

*Writing-intensive course Biol 434W may be substituted for Biol 4342.

** A student may not take both Biol 372 and Biol 472 for credit.

GRADES

All courses utilized for the Biology minor (including chemistry) must be taken for a letter grade. A grade of C- or better must be earned in all of these courses.

ADDITIONAL PROGRAMS RELATED TO BIOLOGY

Bioinformatics Minor

Bioinformatics is a joint program of the Department of Computer Science and Engineering, School of Engineering and the Department of Biology, School of Arts and Sciences. Mindful of the emerging opportunities at the interface of biology and computer science, the Departments of Biology and of Computer Science and Engineering sponsor a Bioinformatics Minor that serves students from both departments and other students with an interest in this field. For online information see <https://cse.wustl.edu/undergraduate/programs/Pages/minors.aspx#minorbio>.

The Bioinformatics Minor requires six or seven courses (20-24 units) as described below:

Core: Biol 2960 (4u) plus Biol 2970 (4u), Math 2200 (or 3200) Elementary Probability and Statistics (3u) OR ESE 326 Probability and Statistics for Engineering (3u), CSE 131, Computer Science I (4u), and CSE 247 Data Structures and Algorithms (3u)

Advanced Biology Electives (choose one): Biol 3492 Laboratory Experiments with Eukaryotic Microbes (3u), Biol 4181 Population Genetics and Microevolution (3u), Biol 4342 Research Explorations in Genomics (4u), Biol 437 Laboratory on DNA Manipulation (4u)

CSE Electives (choose one): CSE 514A Data Mining (3u), CSE 584A Algorithms for Biosequence Comparison (3u), CSE 587A Algorithms for Computational Biology (3u), Biol 5495 Computational Molecular Biology (3u)

For students majoring in Biology or CSE, some portion of the introductory sequence will overlap with courses required for the major, and these courses will be applicable to both the major and the minor. All upper level courses in Biology and CSE used to fulfill the minor may not be used to fulfill another major or minor in Arts and Sciences. A minimum grade of C- is required for a course to count toward the minor.

Biomedical Engineering Major

The School of Engineering and Applied Science offers undergraduate programs in biomedical engineering with tracks in Bioelectrical Systems, Biomechanics, Biomolecular Systems, and Biotechnology. These tracks prepare students for the challenges posed by the integration of biology and engineering. Students take engineering course work along with biology courses. Biomedical engineering majors with strong interests in Biology may supplement the primary major with a Biology second major. See <https://bme.wustl.edu/undergraduate/Pages/undergraduate-curriculum.aspx> for further information.

Biophysics Minor

The Physics Department offers a minor for students interested in the application of methods and techniques from physics to biology and medicine. The program is of interest to the research-oriented science major or the premedical student. Requirements for the Biomedical Physics minor include Physics 117A and 118A (or Physics 197-198). TWO courses from the following four are required: Physics 314 Physics of the Heart (Spring course), Physics 350 Physics of the Brain (Spring course), Physics 351 Intro to Biomedical Physics (Fall course), Physics 355/455 Physics of Vision (Fall Course). In addition, one advanced laboratory course is required from the following current offerings: Physics 316 Optics Lab (Fall course), Physics 321 Electronics Lab (Fall course), Physics 322 Physical Measurement Lab (Spring course), Physics 360 Biophysics lab (Spring course). The lab requirement is intended to give students hands-on experience. Some challenging biomedically related experiments are available in Physics 322. Students registered for the biomedical physics minor can take Physics 322 after completing Physics 117A and 118A. See <http://physics.wustl.edu/undergraduate/biophysics-requirements> or contact Professor Anders Carlsson (x5-5739; aec@howdy.wustl.edu) in the Physics Department.

Certificate in Renewable Energy and the Environment

This is an organized channel for students who wish to pursue interdisciplinary energy studies in addition to their selected major and/or minor. The program combines academic courses, outreach interactions, hands-on research experiences, and networking opportunities. Courses are organized into three discipline clusters: (1) Social Sciences & Humanities; (2) Architecture; and, (3) Natural Sciences & Engineering. The Photosynthetic Antenna Research Center (PARC) grants the certificate in partnership with the International Center for Energy, Environment and Sustainability (InCEES). Certificates are awarded upon graduation at a celebration hosted by PARC and InCEES. See <http://parc.wustl.edu/certificate> for instructions on how to earn the certificate.

Environmental Studies Minor

In addition to the required introductory courses, students take at least 9 units of elective courses at the 300 level or above. Environmental Biology or Earth Science majors may substitute the advanced science course with another area; Environmental Policy Majors may substitute the advanced political science or law course with a course in another area. For detailed information on this minor program, see <https://enst.wustl.edu/programs/minor>.

Interdisciplinary Environmental Analysis Minor

This minor has been developed to better prepare students to tackle real-world environmental challenges by providing more robust opportunities for interdisciplinary knowledge and skill development. In particular, the minor is structured to provide students with opportunities to

strengthen their critical analysis and problem solving skills through participation in team-based learning experiences, and where possible by engaging on real-world issues. For details on this minor program, see <https://enst.wustl.edu/interdisciplinary-environmental-analysis-minor>.

Philosophy, Neuroscience, and Psychology (PNP) Major and Minor

Philosophy - Neuroscience - Psychology (PNP) is an interdisciplinary program that provides an opportunity to examine the mind from multiple perspectives. In addition to philosophy, neuroscience, and psychology, PNP draws upon other disciplines whose investigations contribute to understanding cognition, such as biology, linguistics, education, and cultural anthropology. Each of the disciplines employs different modes of inquiry to examine various aspects of cognition. For example, from the perspective of neuroscience, investigating the workings of the mind means investigating the workings of the brain; from the perspective of linguistics, we gain insight into the mind by investigating one of its most complex products, namely language; and from the perspective of cultural anthropology, we gain insight into the mind's workings by looking at the workings of society. The goal of the major is for students to develop an understanding of the differences among the approaches used by these disciplines, and an appreciation of how they can provide converging perspectives on issues in cognition.

PNP may be taken as a first major, second major or minor. For further information, contact Kimberly Mount (kmount@wustl.edu), look at the web page for the undergraduate PNP program, <http://pnp.artsci.wustl.edu/undergraduate>, and see the PNP listing in the Undergraduate Program Book.

Philosophy of Science Second Major and Minor

These programs are designed for science majors to reinforce their scientific training with knowledge of the conceptual, historical, and philosophical foundations of science. The Philosophy of Science track is available only as a second major in combination with work in one or more of the sciences. See <http://philosophy.artsci.wustl.edu/undergraduate/philosophy-science-track> for the major, <http://philosophy.artsci.wustl.edu/philosophy-science-minor-track> for the minor, or contact Dr. Carl Craver (Ccraver@wustl.edu) for details on these programs.

Requirements for the philosophy of science major track: Total Credits: 27

I. Core Courses: A. Contemporary/Analytic (6 Credits): Phil 301G Symbolic Logic and Phil 321G Philosophy of Science. B. History (3 Credits): Phil 347 Ancient Philosophy or Phil 349 Descartes to Hume or Conceptual Foundations of Modern Science.

II. Advanced Courses in Philosophy of Science (15 Credits total): A. Phil 4210 Advanced Philosophy of Science I (Causation, Laws, and Explanation Realism, Reduction, and Theory Change) and Phil 4211 Advanced Philosophy of Science II (Induction and Confirmation, Observation and Experiment). B. The remaining nine (9) of the fifteen (15) total credits are to be satisfied by choosing among General Philosophy (Phil 426 Theories and Concepts, Phil 390 Philosophical Writing), Logic and Method (Phil 403 Mathematical Logic I, Phil 404 Mathematical Logic II, Phil 405 Philosophical Logic, Phil 4051 Philosophy of Logic), Epistemology and Metaphysics (Phil 307 Metaphysics and Epistemology, Phil 4142 Advanced Metaphysics, Phil 4141 Advanced Epistemology, Phil 4332 Cognition and Computation), Life and Science (Phil 423 Philosophy of Biology, 452 Aristotle), Mind and Science (Phil 315 Philosophy of Mind, Phil 419 Philosophy of Psychology, Phil 418 Current Controversies in Cognitive Science, Phil 4210 Philosophy of Neuroscience, Phil 495 PNP Seminar (with approval of topic), and History (Phil 347 Ancient Philosophy, Phil 349 Descartes to Hume, Phil 452 Aristotle)

III. Capstone Experience (3 Credits): All students must complete a capstone experience in at least one of their majors. Within the philosophy major, this requirement may be satisfied in two ways: A. Pursuing an honors thesis in the Philosophy of Science by taking Phil 499 in the Fall and Spring. Three of these credits count toward satisfying (II) above. Students must have an overall GPA of 3.5, a major GPA of 3.5, and a 3.5 GPA in all advanced philosophy courses. B. Taking the Philosophy Capstone Course (Phil 3991). Only seniors in good standing can sign up for this course; preference is given to students not pursuing honors.

IV. Writing Intensive Requirement: Arts and Sciences requires all students to take a Writing Intensive class. If students wish to fulfill this requirement as part of their Philosophy major, they should take Phil390, listed under General Philosophy.

Requirements for the philosophy of science minor: 18 credits total: 1. Symbolic Logic (L30 301G); 2. One of the three courses in the main History of Philosophy cluster; 3. Philosophy of Science (L30 321G); 4. Advanced Philosophy of Science I; 5. Advanced Philosophy of Science II; 6. One other course chosen from the list under "Advanced Courses in Philosophy of Science" on the Philosophy of Science Major track.

PRIZES

The Department annually awards the Marian Smith Spector Prize to an undergraduate who has compiled an excellent academic record and submitted an outstanding thesis. The Prize is in memory of Marian Smith Spector (1916-1973) who received a B.A. in Zoology from Washington University in 1938. The award is made available through the generosity of Mrs. Spector's family and friends. The Marian Smith Spector Prize is awarded to a graduating senior majoring in biology who has demonstrated a capacity for outstanding scholastic achievement in both course work and independent study in the Life Sciences. The winner is chosen from among candidates for Latin Honors through biology and announced at Commencement. All Latin honors candidates in biology are eligible and no application for the competition is necessary. Mrs. Spector attended St. Louis Public Schools and entered Washington University in 1934. She majored in zoology and studied with Dr. Viktor Hamburger and participated in his research in embryology. In connection with this work, she spent summers at the Marine Biological Laboratories in Woods Hole, Massachusetts. She was a member of Phi Beta Kappa and Sigma Xi, graduating with honors in 1938. She was secretary of the Metropolitan Transit Survey commission and was active in other civic and community affairs. She was the author of "Survive or Succumb," a manual on how to accommodate to multiple sclerosis.

Established through a generous donation from Katherine Day Reinleitner, the Ralph S. Quatrano Prize is awarded annually to the thesis showing greatest evidence of creativity in design, research methodology, and/or broader scientific implications. The award is given in honor of Dr. Ralph Quatrano, the Spencer T. Olin Professor of Biology and former Chair of the Biology Department. Examples of creativity include, but are not limited to research that combines conceptual questions or approaches from multiple disciplines to address biological questions in a novel way, use of novel methodological strategies, and unexpected results that open unexpected new lines of inquiry.

The Department also awards the Harrison D. Stalker Prize annually to a graduating senior whose college career has been distinguished by scholarship, service, and breadth of interest. Professor Stalker was an evolutionary biologist, *Drosophila* geneticist, and dedicated teacher. In addition to science, he took great interest in the arts. He was also a photographer of professional ability. The Stalker Award is intended to honor a student who in addition to doing excellent work in science has demonstrated interest and competence in a variety of areas in the humanities.

STUDY OVERSEAS

With some planning and foresight, biology majors may include a study-abroad component in their undergraduate experience. Washington University offers an opportunity for junior biology majors to spend a semester at popular overseas programs including University College London, Danish Institute for Study Abroad, Trinity College in Ireland, the Organization for Tropical Studies in Costa Rica and South Africa, and the University of Queensland in Australia. For more information, see <http://artsci.wustl.edu/~overseas/programs/Biology.html> or contact the Overseas Programs Office (x5-5958; overseas@artsci.wustl.edu). For information on counting work done overseas toward the Biology major, contact Allan Larson (x5-4656; larson@wustl.edu).

A summer program offered at WU is the "France for the Pre-Med" program held in Nice during May and June. This program combines immersion in French language and culture with an opportunity to learn first-hand about the French medical system. Contact Professor Colette Winn (x5-5477) or Overseas Programs for more information.

There are several fellowship programs that fund 1-2 years of study abroad after the BA degree, including Rotary Scholarships (any country), Marshall Scholarships (British universities), Rhodes Scholarships (Oxford UK), and Churchill Scholarships (Cambridge UK). Contact Dean Warren Davis for more information. The Fulbright Program offers study, research, and/or teaching in 130 countries. Contact the Overseas Programs Office for more information. Applications for these programs are due in early fall of the senior year.

RESEARCH OPPORTUNITIES

Life Science Research During the Academic Year

An excellent way for new students to learn about the wide range of research occurring at Washington University is to enroll during their first semester in Biology 181, "First-Year Opportunity: Introduction to Cutting-Edge Research in Biology," a one-unit course in which different faculty members discuss the current work in their laboratories. The seminar course, First-Year Seminar: Introduction to Problem-Based Learning in Biology (Biol 112), provides training in use of research literature to solve problems; topics change from year to year. Students in the life sciences who wish to participate in research during the academic year may register for Biology 200, "Introduction to Research," if freshmen or sophomores, or Biology 500, "Independent Research," if juniors or seniors. Normally research students register for three units of credit, the equivalent of one course, committing themselves to 9-12 hours of lab work, plus preparation, every week.

There are several ways that Washington University students can get help in finding a research lab. Many gain familiarity with a particular lab as a Federal College Work-Study participant. In addition, individual research interests of the 300+ faculty members in the Division of Biology and Biomedical Sciences are available online (<http://www.nslc.wustl.edu/courses/Bio500/mentors.html>). Finally, faculty advisers willing to help students identify appropriate faculty mentors are available within each research area (contact the Biology Student Affairs Office for further advice). Participating in research in an area that has sparked one's interest can be the most engaging part of undergraduate study.

Biology 200/500

The Biology Department's purpose in offering undergraduate research is to allow students to gain experience using the scientific method to solve problems of scientific importance. This experience includes acquiring technical skills, reading and evaluating articles in the scientific literature that are relevant to the project being undertaken, designing and conducting experiments, learning to evaluate experimental data in relation to existing knowledge, and expanding skills in communicating results of research both orally and in writing. Biol 200 offers research experiences to students who have completed less than 60 units of credit at the time of enrollment, whereas Biol 500 provides research experiences in a similar format to students who have completed at least 60 units of credit at the time of enrollment. Biol 500 and Biol 500A are the same course; each prospective research mentor has an assigned section number in either Biol 500 or Biol 500A. The following information regarding Biol 500 applies equally to Biol 500A. A student may take only one of these course numbers per semester, with credit not to exceed 3 units per semester.

Students in Biol 200/500 conduct projects with defined goals. Often the goals may not be achievable in one semester. Students should have the opportunity to read relevant scientific literature and to receive help evaluating such past research efforts. Students present periodic oral reports on their research progress to the mentor's research group. Working full time in the summer significantly enhances the value of the research experience. In this circumstance, students are usually supported by fellowships or the mentor's research funds.

Students normally enroll for 3 units of credit. Students should expect to work 9-12 hours/week performing research to earn 3 units. Preparation for lab, data reduction and reading usually require additional time at home. (In this sense at least, the introduction to research is realistic.) Students are cautioned, however, not to become so absorbed in their research that course work is neglected. Single-minded concentration on research is the norm when working in the lab full time in summers.

Students find or are referred to active and productive laboratories, ones in which good work is done and then published. Often, but not invariably, mentors with a productive scientific history will have research grants that allow them to gather a critical mass of post-docs and graduate students who make a crucial contribution to the intellectual life of the research group. However, students are advised to avoid laboratories that are so large that the undergraduate might get lost in the shuffle. To enroll, see https://pages.wustl.edu/Bio_200-500_independent_research. Enrollment may be processed at any time but preferably prior to the start of the semester in which the work will be done. Reduced credit can be obtained for work started within the semester if approved by Professor Olsen. Extra time should be allowed for approval of any proposed work involving pathogens; such approval must be completed before the student begins work.

Typically a student starts Biol 500 in junior year, often in the spring, although an increasing number of students start earlier, some as early as their first year (Biol 200). Much of the first semester consists of learning techniques and mastering the background and intellectual context of

the ongoing research in the laboratory. The student should be given material to read and then report back to the mentor. Many mentors find a presentation by the student to be the best procedure. In addition, students should participate in lab meetings and journal club and should be asked to present at appropriate intervals. By the end of the first or second semester the student should have sufficient mastery of techniques and intellectual context to participate in developing an experimental plan, which will be the heart of the Biol 500 project. The Biology Department recommends that the student be asked for a brief formal report either at times dictated by the rhythm of the work or at the end of the semester. The student should be required to think hard about what (s)he has been doing, which is, of course, an extremely useful experience.

Usually students continue in Biol 500 for at least 3 semesters. In addition, they often have either fellowships or paying jobs in the laboratory during the summer. This support allows a student to spend full time on research. A student who wants to conduct research with a Washington University mentor through the summer, but whose summer work is not financially compensated by a fellowship or wages, may apply for 3 units of credit through Biol 500S/Biol 500T to be awarded upon completion of the following fall semester. Application for such credit should be processed no later than the end of Washington University Summer Session 1. A student may enroll for up to 3 credits of Bio 500 during the same fall semester in which Biol 500S/Biol 500T credit is awarded, but extra tuition is charged if the total credit for that fall semester, including Biol 500S/Biol 500T, exceeds 21 units. Credits earned in Biol 500S/Biol 500T are considered equivalent to Biol 500 with respect to meeting requirements for graduation, biology major programs, the research emphasis (see p. 2), and Latin honors through a biology major program (see p. 3).

A student may not receive for the same work both course credit and financial compensation (wages or fellowship). A student who receives financial compensation for research, but who wants the work to count toward the 6 units required for the research emphasis and any associated Latin honors, may enroll in Biol 500 using the audit grade option. Successfully audited units count toward the 6 total units of Biol 500 required to qualify for the research emphasis, which is required for Latin honors through a biology major program, but successfully audited units do not count as credit toward graduation or as credit toward fulfilling requirements of a biology major program. Units of Biol 500 taken using the audit option do count toward the 21-unit limit covered by normal semester tuition; if auditing Biol 500 causes the total units for a semester to exceed 21, extra tuition is charged for that semester.

Note that in addition to Biol 200/500, students can gain internship experience under General Studies 2991. Work done by a student in Biol 200 and 500 is either in preparation for undertaking an independent research project or is in direct pursuit of the research objective. There are occasions when a student would prefer to be involved with laboratory work without taking independent responsibility for the scientific work. That experience is provided by General Studies 2991. See <http://www.nslc.wustl.edu/courses/BIO500/bio500.html> for additional information.

Summer Research Opportunities

Undergraduate research fellowship programs provide intensive and rewarding research experiences for more than 40 Washington University students by providing financial support (living expenses plus a stipend) for 10-12 weeks of research during the summer. Summer fellowships are available in plant biology at the Donald Danforth Plant Science Center, and in field biology at the Tyson Research Center. A more general Undergraduate Research Fellowship Program supported by a grant from the Howard Hughes Medical Institute includes all of the scientific interests of members of the Division of Biology and Biomedical Sciences.

All summer programs welcome students new to research as well as those who already have research experience. The major emphasis of these programs is the research experience in the lab and/or field, but scholars also participate in weekly discussion sessions with graduate students and faculty on current research activities and literature, as well as a number of social events. Each program concludes with a one-day symposium at which all participants report on their summer research accomplishments through oral or poster presentations. Further information and application materials for these programs are available online at <http://www.nslc.wustl.edu/research.html>. Applications are due right before spring break.

In addition to students supported by these summer programs, many other Washington University undergraduates participate in full-time summer research with faculty members with whom they have begun research during the academic year. Usually such students receive support from their mentor's research grants. Summer research may lead to a senior thesis and co-authorship

of research publications. Many students who participate find their summer research experience particularly rewarding and useful in developing career interests and plans.

Check <http://www.nslc.wustl.edu/courses/Bio500/mentors.html> for a listing of possible research mentors.

INTERNSHIPS

Biol 265 Experience in Life Sciences: This course provides an opportunity to earn credit for non-classroom learning in the life sciences. A wide variety of activities qualify. For example, students might accompany a physician on rounds and prepare a paper on a specific organ system or disease, or participate in a field or ecological study and report on the findings. Participants must arrange to work with a supervisor with whom they will meet on a regular basis. Biol 265 does not count toward upper-division credits required for the major. Credit/No Credit only. The course may be repeated for a maximum of 6 units. See <http://www.nslc.wustl.edu/courses/Bio265/bio265.html> or contact Dr. Joan Downey (Downey@wustl.edu) for more information.

Biol 2651/Biol 2654. Med Prep Program (Parts I and II): Med Prep I is a unique lecture series designed specifically for students considering a career in medicine. Through a 2-hour weekly lecture, this course gives students accurate, honest, and detailed information regarding every step of the application and admissions process to medical school. MedPrep I is particularly useful for freshmen and sophomores in that it gives students a road map and strategy for their four years of college and reviews the common pitfalls encountered by unsuccessful applicants. There is no outside course work and no exams. Attendance at all classes is required. Biol 2651 is a pre-requisite for Biol 2654: MedPrep II – The Shadowing Experience. Med Prep II offers students a real-life, behind-the-scenes experience of a life in medicine. For three hours every other week, students shadow physicians in the Charles F. Knight Emergency and Trauma Center of Barnes-Jewish Hospital, the main teaching hospital of the Washington University School of Medicine. A weekly 1-hour meeting is also held on the Danforth campus for group discussion regarding the clinical experience. Only in the summer semester may students take both courses concurrently. There is no outside course work and no exams. Consult the website at <http://medprep.wustl.edu> for registration instructions.

Biol 2652. Pediatric Emergency Medicine Research Associates Program (PEMRAP) offers undergraduate pre-medical students an opportunity to participate in clinical, patient-oriented research projects in a hospital setting. Students work in the St. Louis Children's Hospital Emergency Department, a nationally recognized pediatric emergency medicine and trauma care facility. A number of research projects are currently underway in various areas of pediatric emergency medicine, including asthma, fluid management in dehydration, procedural pain and sedation, cervical spine trauma, head injury, wound care, and fracture healing. For details, see <http://www.nslc.wustl.edu/courses/Bio2652/index.html>.

Biol 2656. Introduction to Health Professions (spring)
This course provides students interested in Health Professions with an overview of Occupational Therapy, Physical Therapy, Audiology, Nursing, and Pharmacy. Students gain a better understanding of the scope of practice, markets, and skills required to succeed in these professions. Students learn about graduate and professional education options and how to build a competitive application for these programs. Finally, students participate in self-directed learning experiences (which may include observations, attending professional presentations, or sitting in on graduate-level classes) and culminate their study with an inter-professional education session illustrating the role of each of the professions within a case study format. Students finish the course with a better understanding of whether a career in health professions is right for them. Credit 1 unit.

Biol 2658. Pediatric Emergency Medicine Research Associates Program II (PEMRAP II)
PEMRAP II is a continuation of Biol 2652, Pediatric Emergency Medicine Research Associates Program – Experiences in Life Sciences. Returning PEMRAP Research Associates (RAs) actively participate in new and ongoing research projects in various areas of pediatric emergency medicine. RAs assist during the active period of patient enrollment through screening of ED patients for study eligibility, reading information about the studies to the patients, collecting data regarding patient history and certain physical examination findings, and generally facilitating the study enrollment process. PEMRAP Returning RAs are vital members of the Emergency Department research team in the St. Louis Children's Hospital Emergency Department.

ACADEMIC YEAR JOBS (TA's, TUTORS)

There are paying positions available each year for junior and senior undergraduates to serve as teaching assistants, tutors, and graders. Interested students should ask the faculty members in charge of a particular course. Courses that employ undergraduate students as TA's on a regular basis include Biol 2960, Biol 2970, Biol 3058, Biol 3110 and Biol 404. Tutors, who attend lectures and then work with small groups of students, are employed for Biol 2960 and Biol 2970. Students applying for these positions should have done very well when taking the course in question; however, students always learn more by helping to teach the course. Positions are available also to monitor and to assist in the Natural Sciences Learning Center, at the desk and in the computer lab. Contact Dr. Kathy Hafer (x5-4424; hafer@biology.wustl.edu) if interested. Work/study eligibility is a plus but not a requirement.

CAREERS IN THE LIFE SCIENCES

Information on careers in Life Sciences is available from the WU Career Center in the Danforth University Center (<http://www.careers.wustl.edu>). Many specific resources are listed here; in addition many professional societies can provide specific career information. Consult science journals published by professional societies for addresses of the societies. Information from most of the sources listed in this handbook is available in the Natural Sciences Learning Center.

B.A. Level Positions in Biomedical Research

University and industrial biomedical research laboratories provide the most abundant employment opportunities (both locally and nationally) for an individual with an A.B. degree in biology. Several hundred entry-level positions in such laboratories open each year in the St. Louis area alone, and experience of Biology Department faculty members who have sought to fill such positions in recent years suggests that the demand for well-prepared research assistants frequently exceeds the supply. In addition to the many Biology Department graduates who have established long-term, satisfying, and rewarding careers as research assistants in the St. Louis area or elsewhere, there are some each year who use such positions as a way of 'taking a breather' for a few years after college, to reassess their career goals, and to decide whether to undertake more advanced studies in graduate or professional schools.

The level of responsibility, independence and salary that one enjoys as a research technician depend strongly on one's training and experience, but they also vary with the type of laboratory. A large medical research lab, or an industrial research lab, frequently provides a significantly higher starting salary than does a small basic research lab, but the latter may offer more opportunity for rapid advancement in responsibility and independence--let us say, from starting technician, to senior technician, to 'lab manager.' (One should not expect, however, that in any of these situations one is free to work on projects of one's own choosing that are unrelated to the interests and goals of the director of the laboratory, but one can expect that with time and demonstrated ability there will come increasing opportunities to plan, to execute and to interpret experiments designed to achieve the director's research objectives, and perhaps to supervise work of others in the research group.)

If you think that you might be interested in such a position in the future, probably the most important single thing to do now in preparation is to get experience in a research lab, either through a part-time job during the academic year, a summer job or internship, or by enrolling in Biol 200 or 500. The first reason that this experience is important is self-assessment: does a research lab really provide the kind of environment in which you think you could be happy spending a significant portion of your life? The second reason for seeking such experience is to improve your competitiveness: few things would weigh more heavily in your favor as an applicant for an entry-level research position than a letter from a former supervisor stating that during your college years you have already demonstrated your ability to function effectively and responsibly in a research lab.

In addition, however, if you wish to keep this option a viable one, you should seriously consider selecting courses that help you to develop 'marketable' skills and knowledge. As just one example among many, the Laboratory on DNA Manipulation (Biol 437) provides practical experience with recombinant DNA techniques that many potential employers would consider extremely valuable. Among the many advanced courses that the Biology Department offers, ones that provide particularly good theoretical and/or practical background for various areas of biomedical research include (not in order of importance, but in the order listed in the catalog, and with those that provide relevant kinds of laboratory instruction underlined): Vertebrate Structure Laboratory (Biol 3110), Endocrinology (Biol 3151), Cell Biology (Biol 334), Eukaryotic Genomes

(Biol 3371), Principles of the Nervous System (Biol 3411), Microbiology (Biol 349), Microbiology Laboratory (Biol 3491), Laboratory Experiments with Eukaryotic Microbes (Biol 3492), Bacterial Bioprospecting and Biotechnology (Biol 3493), Laboratory of Neurophysiology (Biol 404), Developmental Biology (Biol 4071), Immunology (Biol 424), Immunology Laboratory (Biol 4241), Research Explorations in Genomics (Biol 4342/ Biol 434W), Lab. on DNA Manipulation (Biol 437), Protein Function in Model Cellular Systems (Biol 4520), Laboratory in Protein Analysis, Proteomics, and Protein Structure (Biol 4522), Molecular Methods in Enzyme Analysis (Biol 4523), Structural Bioinformatics of Proteins (Biol 4524), and General Biochemistry (Biol 451, or Biol 4810 & Biol 4820). In addition, training in the use of computers and/or laboratory work in the Department of Chemistry beyond that required for the Biology degree would be highly regarded by many potential employers.

When ready to seek employment, you should visit Washington University's Career Center (110 Danforth University Center) for help finding jobs in your area of interest. The Career Center's Junior Jumpstart program is highly recommended for all students. For further information, see <http://careercenter.wustl.edu/Pages/default.aspx> or contact the Career Center at extension 5-5930 or careers@wustl.edu.

B.A. Positions in Ecology

There is no specific agency that serves as an outlet for positions in ecologically-related areas, so the job seeker must consider a wide variety of approaches. An A.B. in Biology, strengthened with some ability in programming, chemistry, artistic capabilities, business background, etc., does have a relatively wide range of job opportunities, which will vary seasonally and geographically. On the local level, commercial enterprises such as specialized gardening outlets, pet shops and exterminators should be investigated for beginning-level management positions. Environmental consulting firms can be a prime target for graduates with experience not only in biology, but in geology and environmental studies. Other local institutions, such as zoos, botanical gardens, museums, parks and ecological preserves, can offer opportunities leading to advancement. Research universities and industries producing products that have ecological consequences hire persons as research assistants or higher. Both federal and state agencies devoted to ecological issues (U.S. Fish & Wildlife, Environmental Protection Agency, Bureau of Land Management, Department of the Interior [National Parks], Department of Agriculture [Forestry Service], State Conservation Departments, etc.) hire trained personnel to fit their specific needs. There are internships, particularly federal, which give the appointee an opportunity to become familiar with the interaction of government with environmental issues. Many recent graduates in this area have entered the Peace Corps (<http://www.peacecorps.gov>).



"This place is all right. Two more weeks and I'll be a molecular biochemist."

OPPORTUNITIES IN EDUCATION

Secondary School Teaching

Teaching at the high-school level can be rewarding, both personally and financially. Washington University offers a graduate level (MAT, Master of Arts in Teaching) teacher-certification program in biology (see http://artsci.wustl.edu/%7Eeduc/ma_teaching.html). Certification essentially entails completing an undergraduate major in biology followed by 1 year of graduate study in biology and education.

Washington University's teacher preparation programs provide the professional education that qualifies a student for certification to teach in public schools. On the recommendation of the Department of Education, the Missouri State Department of Education will issue a teaching certificate to an individual who successfully completes a Washington University teaching preparation program. For other states, additional study may be required to qualify for a certificate.

Creating a program of courses that satisfies the biology major, the distribution requirements of the College of Arts and Sciences, and the undergraduate education courses necessary for graduate study in education in the fifth year is not easy. Completing a five-year program and obtaining an MAT degree (Master of Arts in Teaching) at WU simplifies this dilemma somewhat. Students interested in securing admission to the WU teacher education program should contact Madonna Riesenmy (mriesenm@wustl.edu) in the Department of Education as early as possible. A sample program is as follows:

Freshman Year

Math 131 (3-4 u) Calculus	Biol 2960 (4 u) Biology I
Chem 111A (3 u) General Chemistry I	Math 132 (3 u) Calculus
Chem 151 (2u) General Chemistry Lab	Chem 112A (3 u) General Chemistry II
Psych 100B (3 u) Intro. to Psychology	Chem 152 (2 u) General Chemistry Lab
Biol 181 (1 u) Introduction to Cutting-Edge Research in Biology	

Sophomore Year

Biol 2970 (4 u) Biology II	Biol 3058 (2 u)
Chem 261 (4 u) Organic Chemistry	Chem 262/401(3 u) Org Chem II or Phys Chem I
	Chem 257 (2 u) Organic Chem Lab
	Ed 301C (3 u) American School

Summer Session 1: Biol 3491 (4 u) Microbiology Laboratory

Junior Year

Phys 117 (4 u) General Physics I	Phys 118 (4 u) General Physics II
Biol 3110 (3 u) Vertebrate Structure Lab	Biol 334 (3 u) Cell Biology
Biol 3501 (4 u) Evolution	Biol 349 (4 u) Microbiology
	Ed 408 (3 u) Exceptional Children
	Phil 321G (3 u) Philosophy of Science

Senior Year

EPSC 201 (4 u) Earth and the Environment	Ed 4052 (4 u) Educational Psychology
Phil 233G (3 u) Biomedical Ethics	Biol 3041 (3 u) Plant Biology
	Biol 381 (3 u) Introduction to Ecology

Well-prepared science teachers are in demand. Teaching positions usually offer good benefits and job security, although working conditions are often far from ideal. The job usually allows one to develop an individual approach, exploring one's own interests and initiative; many teachers derive considerable satisfaction from the success of their students. Information about teaching science at all levels is available from the National Science Teachers Association, 1840 Wilson Blvd., Arlington, VA 22201-3000 (phone 703-243-7100; <http://www.nsta.org>).

Primary-School Teaching

It is unusual to combine a major in the sciences with preparation to teach at the elementary level, but it can be done and would allow one to make a unique contribution. Again, early planning is essential; interested students should contact the Department of Education. Students wishing to test their interest level should take one of the Foundations of Education courses (Ed 301C, Am. School) or Ed 313B, Childhood and Society, during their sophomore year.

Teaching in Community and Junior Colleges

Community colleges and junior colleges are two-year institutions whose students enter from high school. The work a student does may be the final formal instruction or it may serve to allow entrance to a four-year college or university. The number of community colleges and the students enrolled has increased enormously in the last several decades.

To teach in a community college, one must meet two criteria: knowledge of the specific field and ability to teach. Sometimes specific course requirements in education must be met. Preparation in the specific field requires a Master's degree in Biology or a specific discipline within biology. Increasingly, a Ph.D. is required and in many regions it is an absolute requirement. Someone interested in becoming a member of a community college faculty should acquire as much teaching experience as possible and still gain mastery in the subject matter. Often a faculty member in a community college will need to teach a rather wide variety of courses, and thus must have an understanding of many areas, sometimes even in related sciences. A few doctoral programs are available in science education and are designed for those whose primary objective is education, not research. Many graduates of these programs join community college faculties and schools of education. Anyone who prefers to teach in a particular region of the country should contact institutions in that region for specific information.

Master of Arts in Teaching (MAT) programs mix courses in education with courses in the discipline in which the student wants to teach and in which undergraduate work has been done. Although these programs are generally more suitable for high-school teaching than community-college teaching, some MAT graduates find employment in community colleges.

Faculty salaries at community colleges vary considerably; many are comparable with those in four-year colleges. Teaching loads are heavy by comparison with those in universities, but faculty research usually is not emphasized. Rewards in personal satisfaction can be high; many community college students are very intelligent and highly motivated, and an instructor may have enormous impact on individual students and on the community.

Informal Science Education (museums, etc.)

Most science museums and zoos maintain active education departments that present a variety of programs to the public, usually with a focus on primary-school children. Staff members that present these programs typically have an undergraduate degree in science, often biology. Coursework or summer employment in education would also be appropriate preparation. These positions are not well paid and typically bring no job security (there is no tenure), so there is often significant turnover in the staff of these education departments. While not a financially inviting career, such positions can be fun. Summer positions may be available, but inquire early.

OPPORTUNITIES IN HEALTH

The College of Arts and Sciences provides detailed personal guidance on preparing for the careers in this section. For further information, see their PREHEALTH Handbook for Students, available online at <http://prehealth.wustl.edu/Documents/Handbook2017Online.pdf>.

Medicine

Many students enter WU with an interest in going to medical school after the BA degree. A biology major provides excellent preparation for medical school; a biology major that includes at least 2 semesters of independent research (Biology 500) provides outstanding preparation for biological and/or biomedical research in graduate and/or medical school.

A typical program would look like this:

Fall - Year One

Chem 111A (3).
Biol elective
(optional, see p. 1).
Math 132 (3).
Chem (Lab) 151 (2).
Distribution (3),
or English Comp 100 (3).
Distribution (3).

Spring - Year One

Chem 112A (3).
Biol 2960 (4)-

Math 233 or Math 2200 (3).
Chem (Lab) 152 (2).
English Comp 100 (3),
or Distribution (3).

Fall - Year Two

Chem 261 (4).
Biol 2970 (4)-
(Biol 2960 pre-req)

Distributions (6).

Spring - Year Two

Chem 262 (4).
Biol 3058 (2),
Biol 334 (3).

Distributions (6).

All students who plan to major in biology who have an interest in pre-medicine should enroll in Chemistry 111A in the fall of freshman year. In addition to providing relevant material, this course teaches helpful study skills for success in a science curriculum.

Biology 2960 and 2970 (Principles of Biology I and II) are the introductory courses required of both biology majors and premedical students. Biology 2960 is normally taken in the spring of freshman year. Chemistry 112A is a corequisite of Biol 2960. Biology 2970 is normally taken in the fall of sophomore year. Both Biol 2960 and Chem 112A are prerequisites for Biol 2970. These courses in Principles of Biology are designed to be taken consecutively and together provide a strong foundation for further study in the life sciences. Biology 3058 Physiological Control Systems covers material critical for the MCAT exam. Many students find Biol 3058 and Biol 334 Cell Biology mutually relevant and take them concurrently.

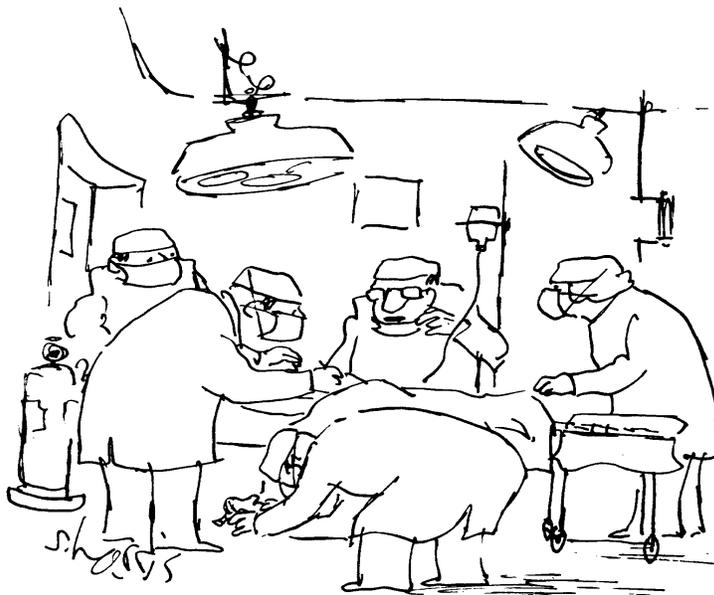
Mathematics 131-132 is required for all biology majors and satisfies medical-school requirements for one year of college calculus. Mathematics 233 and 2200/3200 are useful for students with interests in basic research. Physics 117A-118A (or 197-198) is generally taken in the junior year by biology majors or pre-med students majoring in an area outside the sciences. Premedical students considering either a chemistry, a physics, and/or an engineering major should follow the recommendations of the appropriate department concerning the timing of Physics 117A-118A.

MCATs (Medical College Admission Tests) are usually taken in April of the junior year. MCATs are also offered in August just prior to the senior year; scores from the August MCATs arrive at medical schools after some admissions decisions have been completed, however. All of the above required courses: (1) should be completed for the MCATs; (2) are needed if the student will attend medical school; and (3) are needed by all biology majors. Biology 181, a 1-unit credit/no credit course is highly recommended (but not required) for students with interests in biological and/or biomedical research. The freshman seminar Biol 112 is a good choice for those with interests in biology and/or medicine who want an additional biology course in the fall of freshman year.

There are 9-11 distribution courses outside of the natural and physical sciences that are required for the B.A. in the College. It is useful for the student to take 4-5 of these courses by the end of the second year to allow flexibility in course planning and scheduling in the junior and senior years, especially if the student chooses to take Independent Research. A research experience can be critical if the student wishes to be competitive for admission to (1) Ph.D., (2) M.D., or (3) joint M.D./Ph.D. programs at research-oriented schools. The joint M.D./Ph.D. program is quite attractive for students with an interest in academic medicine and basic research; some of these programs cover the costs of tuition and pay a yearly stipend for all years spent in medical and graduate training. See <http://www.nigms.nih.gov/Training/InstPredoc/PredocInst-MSTP.htm> for a list of medical schools with M.D./Ph.D. programs. An excellent time to take independent research (Biology 500) is in the junior and senior years. Large open blocks of time in those years are very important since much of the independent research requires long hours not interrupted by classes; in addition, many students conduct their research at our Medical School and transportation time between the Medical School and the Main Campus is a factor in schedule planning during these semesters. Completing half of the distribution requirements outside of the sciences by the end of the second year can be very helpful to students who enroll in independent research.

Many medical schools require a course in English Composition such as EComp 100 as well as an additional course in English, English Literature, or English Composition; see the requirements of specific medical schools for details. Courses in social sciences are increasingly required by medical schools; Psychology 100B is a good choice in this area. Many medical schools expect students to have a course in biochemistry (Biol 451, or Biol 4810 & Biol 4820) and sometimes one in microbiology (Biol 349) prior to matriculation.

All students with interests in medicine should demonstrate their abilities to assist others by serving as a volunteer. Important volunteer experiences can be obtained in a variety of ways, e.g., at a hospital, at a nursing home, in a camp or school for individuals in need of help, serving as a tutor, etc. The Campus Y is an excellent resource to assist students in placement for volunteer experiences. Vicki May, Outreach Coordinator, (x5-6846; may@biology.wustl.edu) is also an excellent person to contact about placement. Students who would like academic credit for a volunteer "Experience in the Life Sciences" should consider enrollment in Biology 265.



"ALL RIGHT, SO HE DROPPED THE HEART. THE FLOOR IS CLEAN."

©1989 by Sidney Harris-"Einstein Simplified," Rutgers Univ. Press.

For further information about medical schools and the medical school application process, contact Dean Carolyn Herman (x5-6897) in the College of Arts and Sciences Office. For questions about these guidelines in medicine, contact Professor Paul Stein (x5-6824; stein@biology.wustl.edu) in the Biology Department. For further information on medical schools see The American Medical College Application Service at <http://www.aamc.org/start.htm> and the Medical College Admission Test (MCAT) at <https://www.aamc.org/students/applying/mcat>.

Dentistry

The field of Dentistry covers a broad spectrum of opportunities. The General Dentist or Family Dentist is an individual involved in the routine maintenance and clinical diagnosis of the oral cavity. This individual is trained in minor surgical procedures, oral prosthetic work, and some cosmetic Dentistry. The General Dentist is usually associated with a number of specialists. Typically, an individual spends four years in Dental School (undergraduate dental degree) and one or two years in a family-practice residency program before joining a dental group or starting a practice. There are also opportunities in the military and in such cases the US government will subsidize the cost of dental education. Other areas of dentistry generally require advanced training in postgraduate Master's or specialty programs. Such areas include orthodontics, periodontics, prosthodontics, pediatric dentistry, oral maxillofacial surgery, oral pathology, and forensic dentistry. There is also opportunity for dental research careers with a combined DDS-Ph.D. training program. Typically, such individuals are employed as faculty of Dental Schools or by pharmaceutical companies.

For information on these advanced programs it is recommended that individuals contact the Greater St. Louis Dental Society (13667 Manchester Road, St. Louis, MO, PH: 965-5960) or the American Dental Association (ADA), (211 E. Chicago Avenue, Chicago, IL 60611-2678, PH: 1-800-621-8099).

Suggested courses for a student who is considering a career in dentistry would include Biol 3110, Biol 3151, Biol 334, Biol 3411, Biol 349 and Biol 4580. Art 107-108 would be helpful since excellent eye-hand coordination is required for the profession. Many dental schools request that students applying to dental school take the standardized dental aptitude test before consideration for admission. Finding summer work in a dental office is recommended to get first-hand experience of the profession.

The first year of Dental School is similar or identical to Medical School in the basic science courses required. These usually include: Human Gross Anatomy, Physiology, Histology, Cell

Biology, Biochemistry, and Immunology/Microbiology. There are also preclinical courses to prepare students to interact with patients and staff and, in general, learn the basic operation of the Dental Clinics. The sophomore year includes courses such as oral pathology, radiology, and other preclinical courses to understand the clinical problems confronting dental clinicians. Usually it is not until the second semester of the sophomore year and that summer when students begin to experience interactions with patients. This period can best be described as a team apprentice-approach at most US Dental Schools. In the sophomore year, the student is required to take and pass Part I of a National Dental Board Exam. In the junior and senior years the student continues to take a variety of courses to understand and to treat oral diseases. A majority of time is involved in fulfilling certain clinical objectives. If all requirements are fulfilled, the individual must take Part II of a Dental National Board exam in order to receive his or her dental degree. Some states require additional testing. See <http://www.ada.org/education.aspx> for further information.

Optometry

Optometrists (Doctors of Optometry O.D.'s) are primary health-care providers for the diagnosis and non-surgical remedy of eye diseases and visual refractive disorders. An optometrist's services overlap with those of medical doctors specializing in ophthalmology but do not include eye surgery. Optometrists detect and prescribe medication to correct eye diseases such as glaucoma, cataracts, retinal disorders, lid disorders, and infections such as conjunctivitis. They evaluate and treat vision conditions such as nearsightedness, farsightedness, and astigmatism, often by prescribing glasses or contact lenses. Optometrists provide pre- and post-operative care, especially for glaucoma, laser, refractive, and cataract patients. Optometrists work in private practices, multidisciplinary medical practices, hospitals, teaching institutions, research positions, community health centers and the ophthalmic industry. Optometrists also work in the military, public health and government service. There are 19 accredited colleges of optometry in the United States and Canada, including in Saint Louis the University of Missouri at Saint Louis School of Optometry. For additional information on this profession and for a list of accredited programs, see the website of the American Optometric Association at <http://www.aoa.org>.

Genetic Counseling

A genetic counselor helps individuals or families afflicted with genetic disease. As genetic knowledge has increased, the definition of genetic disease has been broadened from the classic Mendelian diseases and chromosomal abnormalities to include common diseases (such as coronary artery disease, hypertension, Alzheimer's disease, etc.) that have a strong genetic component. The duties of a genetic counselor vary, but can include helping to diagnose the disease, counseling individuals about the nature of the disease and its genetic basis, informing individuals and their relatives about the risk of carrying the disease or being affected by it, requesting and/or performing



"There's another hereditary disease that runs in the royal family. Your grandfather was a stubborn fool, your father was a stubborn fool, and *you* are a stubborn fool."

genetic tests either to assess risk or to evaluate the genetic state of the individual, and working with patients and physicians in choosing treatment options.

There are two principal career paths for entering the field of genetic counseling. The first is to obtain an M.D. Medical doctors with an interest in genetic counseling have traditionally specialized in pediatrics because the bulk of classic Mendelian diseases and chromosomal abnormalities first become apparent in infants (about a third of all pediatric inpatients in U.S. hospitals are afflicted with a genetic or chromosomal disease). However, this situation is beginning to change as genetics is increasingly being used to assess risk and effective treatment of diseases affecting older individuals. Those individuals choosing the medical path to genetic counseling are usually involved primarily in diagnosis and treatment of the diseases. The other path to genetic counseling is to pursue graduate work in human genetics, either at the Master's or doctoral levels. There are now several Master's degree programs in genetic counseling that lead to accreditation as a genetic counselor by the American Board of Medical Genetics. Individuals pursuing this path often emphasize risk assessment and prediction, family counseling, and the performance of genetic testing.

For either career path, biology majors interested in genetic counseling should take additional courses in genetics, such as Biol 3371 (Eukaryotic Genomes), Biol 4181 (Population Genetics and Microevolution), Biol 4183 (Molecular Evolution), Biol 4342/434W (Research Explorations in Genomics) and Biol 437 (Laboratory on DNA Manipulation). Because genetic counseling involves risk prediction and the manipulation of probabilities, students also should take Math 2200 or 3200 (Elementary Probability and Statistics). For those students wishing to work with the common diseases that affect older individuals and have a strong genetic component, additional courses in mathematics and statistics are strongly recommended, such as Math 439 (Linear Statistical Models), Math 493 (Probability), and Math 494 (Mathematical Statistics).

Additional information can be obtained from the National Society of Genetic Counselors, Executive Office, 233 Canterbury Drive, Wallingford, PA 19086 (phone: 215/872-7608) or the American Board of Genetic Counseling <http://www.abgc.net/home>.

Genetic Epidemiology

Genetic epidemiology is the scientific study of familial distributions of human traits to understand how genetic and environmental factors interact to produce various diseases. Genetic epidemiology utilizes data from the Human Genome Project and computational methodology to conduct statistical analyses on large samples of subjects from relevant populations. Population dynamics affect the frequencies and distributions of both genetic and environmental factors, and thus, their net effect on the phenotype of interest. Knowledge of populational histories is exploited for use in gene discovery and mapping.

Genetic epidemiologic studies investigate complex disorders such as coronary heart disease, hypertension, diabetes, cancer, and allergies, and neurological disorders. An understanding of the genetic underpinnings of such diseases promises to revolutionize medicine in the 21st century, enabling better preventive measures, diagnosis, prognosis, and treatments. Courses of particular relevance to genetic epidemiology include Eukaryotic Genomes (Biol 3371), Population Genetics and Microevolution (Biol 4181), and Molecular Evolution (Biol 4183). Courses in computer science (CSE 131, CSE132, CSE241) and statistics (Math 2200 or 3200, Math 322) are particularly useful for students interested in genetic epidemiology. See the information on graduate study at <https://biostatistics.wustl.edu/education/certificate-in-genetic-epidemiology>.

Health Administration

Students who are considering a career in health care, but who think that they might be more interested in management and administration rather than in patient care, should consider a career in health administration. Because of changes in our health-care system, there are now many diverse career options for those trained in health administration. For example, health-care executives typically have management positions in hospitals, clinics, nursing homes, ambulatory care facilities, health maintenance organizations (HMOs), health-related associations, consulting firms, public health organizations and other government agencies. By working in these positions, health-care administrators have the opportunity to make significant contributions to improving health care in the communities served by these institutions and organizations.

Qualifications for an entry-level position in health administration include a Master's degree, usually in health-care management from an accredited school, and an internship, fellowship or previous work experience in a health-care organization or other business setting. There are many

accredited colleges and universities in the USA and Canada (including Washington University) that offer suitable graduate programs. In general, earning a Master's degree from these graduate programs takes two years. The programs include course work in health-care policy and law, marketing, health-care financing, human resources and other topics relevant to health-care management. Many programs include supervised internships, residencies or fellowships in a clinic, hospital or health-care agency.

As an example of the requirements for admission into a Master's degree program in health administration, the requirements for admission to Washington University Medical School's Master in Health Administration Program are a bachelor's degree and completion of the Graduate Record Exam (GRE) or the Graduate Management Admission Test (GMAT). No specific undergraduate major field of study is required for admission to the program. However, an introductory course in accounting is required. Previous experience working in health care is recommended. A double major in biology and economics would provide strong preparation.

The Natural Sciences Learning Center has a pamphlet containing additional information on careers in Health Administration and a list of accredited graduate programs. For further information contact Marilyn Hummert, Administrative Coordinator at the Washington University Health Administration Program (362-3274) or the American College of Healthcare Executives, One North Franklin St.; Suite 1700; Chicago, IL 60606-3491 (phone: 312-424-2800; <http://www.ACHE.org>).

Occupational Therapy

Occupational therapists are dedicated to helping people to develop skills and to adapt to disabilities so that their lives become more productive and meaningful. As an applied social and biological science, occupational therapy benefits persons of all ages whose ability to engage in life's tasks is impaired by physical or mental disease, injury, birth defect or aging. Occupational therapists help individuals develop, regain or retain the skills they need to learn, to play, to earn a living and to tend to their personal needs.

At the present time this is a highly marketable career with salaries (for Master's degree) ranging from \$32,000 (starting) to \$80,000 per year. Students interested in a Master's degree program in occupational therapy need specific prerequisite courses; most of these courses are part of the Washington University B.A. in Biology (an upper-level course in biology such as Biol 3110; Chem 111A-112A and Chem 151-152, Physics 117A; and English Composition). However, several concern specific areas in biology, psychology, and sociology/anthropology. Courses most often required include a course in human physiology (such as Biol 328, Principles in Human Physiology); a course in abnormal psychology (such as Psych 354); a course in developmental psychology (such as Psych 321); a course in sociology/anthropology (such as Anth 301B, Individual, Family, and Community); a course in political science or economics (such as Econ 103B, Microeconomics or Econ 352, Health Economics); a course in statistics (such as Psych 300 or Math 2200 or 3200); and a course in ethics or logic (such as Phil 100G, Introduction to Logic and Critical Analysis, or Phil 233F, Biomedical Ethics). Competence in medical terminology is often required and can be gained through Classics 325D or through guided study. However, entrance requirements vary among schools; one should consult the catalogues or application brochures for the schools of interest.

Typically, a professional Master's Degree in occupational therapy takes approximately 2.5 complete years. This time includes a 6-month internship (non-paid), which is arranged by the degree-awarding institution. A final certification exam is required.

Courses in a Master's degree program typically include "Functional Assessment," "Applied Anatomy," "Therapeutic Intervention," and "Administration" as examples. A complete description of course work and prerequisites for the Washington University Program in Occupational Therapy, and a description of occupational therapy careers are present in the Natural Sciences Learning Center. Also, the Occupational Therapy Program at Washington University can be reached at 314-286-1600. Career advisors are willing to discuss occupational therapy as a career with anyone interested. Further information is available at <http://www.otjoblink.org>.

Pharmacy

Pharmacists distribute drugs prescribed by physicians and inform patients about medications and their use. They advise health practitioners on the selection, dosages, interactions, and side effects of medications. Pharmacists also monitor the health of patients during drug therapy to ensure that treatments are safe and effective. Pharmacists must understand the uses, clinical effects, and chemical compositions of drugs and their chemical, biological, and physical properties.

Careers in pharmacy cover a wide range of occupations including academic pharmacy, public health, community pharmacy, consultant and long-term care pharmacy, hospital and institutional practice, managed-care pharmacy, and pharmaceutical industry. Colleges of Pharmacy include both undergraduate and graduate institutions. The American Association of Colleges of Pharmacy (<http://www.aacp.org>) provides detailed information on these academic programs and admissions procedures.

Physical Therapy

Physical Therapy is a health profession that applies scientific principles to prevent and to remedy problems in human movement. Physical therapists evaluate patients to diagnose problems with movement that impair normal function. Treatment for these conditions is directed to optimize a patient's ability to move and to function in everyday life. Treatment is performed to improve strength, endurance, coordination, flexibility, and range of joint motion, and to provide training for mobility at home and in the community.

Traditionally physical therapists have worked in many settings including hospitals, private offices, outpatient clinics, nursing homes, schools, home-care agencies, and rehabilitation centers. Physical therapists are trained to work with adult, pediatric and geriatric patients with musculoskeletal, neurological, cardiopulmonary or medical problems. Today's trends in health care are leading to increased demands for therapists to aid in preventing as well as treating musculoskeletal problems, to work with patients having acute conditions, and to focus on care needed by a population represented by a large, and growing, number of older individuals.

Physical therapy programs now offer baccalaureate, Master's or doctoral degrees at the professional entry level. Programs are now offered in all of the United States (except Hawaii, Alaska, Nevada, and Wyoming), the District of Columbia, and the Commonwealth of Puerto Rico. The length of time for the prerequisite and professional components of education vary from program to program, and the total time required to prepare graduates ranges from four to seven years of college. Licensure is required after graduation before a physical therapist can practice.

Individuals entering the Master of Science Degree Program at Washington University are required to have:

- 1) completed a Bachelor's degree (any baccalaureate major is acceptable; most students enter with degrees in Biology or Psychology, but almost every possible major has been represented);
- 2) taken and passed the prerequisite courses;
- 3) taken the GRE (Graduate Record Exam). Over 50% of Master's programs require the GRE.

Generally Required Courses

1 year of Physics with labs
1 year of Chemistry with labs
Introductory Biology
Anatomy
Physiology
Trigonometry or Calculus
Statistics
1 year of English to include EComp
1 year of Psychology to include Abnormal Psych
At least 1 other course in the Social Sciences
Medical Terminology competence

Washington University Courses

Physics 117A, 118A
Chemistry 111A, 112A, 151-152
Biology 2960, 2970
Biology 3110
Biology 328
Math 131
Psychology 300, Math 2200 or Math 3200
EComp 100 and an English elective
Psychology 100B, 354
Social Science elective
Classics 225D

Additional courses recommended for students interested in entering the Master of Science Degree Program in Physical Therapy are 3411 (Principles of the Nervous System) and Biol 451 or 4810 (General Biochemistry).

For general information about programs in Physical Therapy students should write to the American Physical Therapy Association, 1111 North Fairfax Street, Alexandria, VA 22314 or call 703- 684-2782, or use the web (<http://www.Apta.org>). Additional information about the Washington University Program may be obtained by calling 314-286-1400.

Psychology

Psychology is the study of mind and behavior. Biology and psychology intersect mainly in studies of neuroscience and ethology. Neuroscience encompasses anatomical, biochemical and physiological studies of the nervous system, whereas ethology is the study of animal behavior,

usually in an ecological or evolutionary context. Students interested in the interface of these disciplines may choose a double major in biology and psychology, or may choose either single major and supplement it with courses from the other discipline.

There are several career paths for students of psychology. Psychiatry is a medical profession devoted to the diagnosis and treatment of emotional, mental and behavioral disorders of patients by psychoanalytical and pharmacological means. Standard medical training (M.D. degree) with a residency in psychiatry is required. Clinical psychology also involves the study and treatment of disturbed or maladaptive behaviors, but substitutes completion of a Ph.D. or equivalent degree in psychology for medical training. Both psychiatrists and clinical psychologists may operate private practices, or may be employed by medical institutions, public school systems, juvenile correction centers, and rehabilitation centers. A third career path in psychology involves academic research and teaching. This path also requires a Ph.D. in psychology, but the emphasis is on experimental study of behavior and neurobiology rather than treatment of patients. These psychologists often are employed at universities as professors of psychology.

The study of psychology also can lead to careers that do not require doctoral-level training. Careers in social work and rehabilitation counseling usually require Master's degrees in these disciplines, but entry-level jobs are often available for people having only baccalaureate degrees with an emphasis on psychology. Study of psychology also provides a good background for careers in education, public relations, advertising, sales, personnel and many areas of business. Graduates with training in biology and psychology may find work as technicians in research laboratories in medical schools, universities and governmental institutions. Detailed information on career options in psychology is available through the Career Center (157 Karl Umrath Hall).

Students interested in the interface between biology and psychology may choose the standard biology major and include advanced courses in the neurosciences (Biol 3411, Biol 404) among their electives. At least one course in statistics is recommended for students with interests in psychology (Math 2200 or 3200 and Psych 300 are appropriate introductory courses). Also recommended is a minor (minimum 15 units in psychology) or major (minimum 24 units in psychology) in the Department of Psychological and Brain Sciences (see requirements of the Department of Psychological and Brain Sciences for specifics, <http://psychweb.wustl.edu>).

Public Health

The mission of public health is to "fulfill society's interest in assuring conditions in which people can be healthy" (Institute of Medicine, Committee for the Study of the Future of Public Health, Division of Health Care Services. 1988. *The Future of Public Health*. National Academy Press, Washington, DC). Public health serves this mission through organized interdisciplinary efforts that address the physical, mental and environmental health concerns of communities and populations at risk for disease and injury. Health promotion and disease prevention technologies encompass a broad array of functions and expertise, including three core public health functions: (1) assessing and monitoring the health of communities and populations at risk to identify health problems and priorities; (2) formulating public policies, in collaboration with community and government leaders, designed to solve identified local and national health problems and priorities; (3) assuring that all populations have access to appropriate and cost-effective care, including health promotion and disease prevention services, and evaluation of the effectiveness of that care. For detailed information on public-health professions and schools offering graduate degrees in public health, see the website of the Association of Schools and Programs of Public Health (ASPH): <http://www.aspph.org>. A centralized application service is available at <http://sophas.org>.

Veterinary Medicine

Veterinarians treat and prevent animal disease. Because of the great diversity of species treated, there is great variety in the work of veterinarians. Most veterinarians work in private practice, either on their own or as partners in a group practice. Many private practices specialize in the treatment of small animals, primarily dogs and cats. Increasingly such practices also treat birds and a variety of exotic animals. Mixed animal practices may also work with a variety of farm animals, as well as some nondomestic animals. Some veterinary practices specialize in large animals, usually with an emphasis on horses and cattle. There are many opportunities for veterinary work in areas other than private practice. For example, in private industry veterinarians may conduct research on nutrition or drug effects for pharmaceutical companies or safeguard the health of laboratory animal colonies. Veterinarians also work for zoos and aquariums, and may act as consultants to wildlife preservation groups. A variety of government agencies employ veterinarians

in the areas of meat inspection, animal quarantine, and the care of wildlife in our parks. Academic institutions in the biomedical fields employ veterinarians as clinicians, researchers, and teachers.

Licensing to practice general veterinary medicine requires graduation with a Doctor of Veterinary Medicine (DVM) degree from an accredited college of veterinary medicine. Licensing requires satisfactory performance on the national board examination, as well as other requirements controlled by the states. After graduation, many veterinarians choose to specialize, either in a clinical specialty or in work with a particular species. Specialization involves a one-year internship followed by two or three years of residency training.

Students interested in a veterinary career should obtain experience working in a veterinary practice, as such experience is required for admission to most or all veterinary schools. Course requirements vary with the institution, but always include a solid basis of chemistry (both inorganic and organic), physics, and biology. Generally, courses in biochemistry, genetics, microbiology, and nutrition are also specified. Biology majors interested in veterinary medicine should take our upper-level Vertebrate Structure Laboratory (Biol 3110) and Endocrinology (Biol 3151).

Additional information can be obtained from the Association of American Veterinary Medical Colleges, 1101 Vermont Avenue NW, Suite 710, Washington DC 20005-3521 (phone 202-371-9195; <http://aavmc.org>), or the American Veterinary Medical Association, 1931 North Meacham Road, Suite 100, Schaumburg, IL 60173-4360 (phone: 1-800-248-AVMA; <http://www.avma.org>). Excellent books entitled "Veterinary Medical school Admission Requirements in the United States and Canada" and "The Preveterinary Planning Guide" are available from the Betz Publishing Co., P.O. Box 1745, Rockville MD 20849-9947 (phone: 1-800-634-4365).

OPPORTUNITIES IN BIOTECHNOLOGY AND BUSINESS

The societal impact of the genetic engineering revolution is only beginning to be felt in the marketplace, and most molecular biologists agree that the biotechnology industry is only in its infancy. Because of the need for substantial investment of venture capital for research and development of new products, and the long time and additional capital required to bring a product to market, many new companies have struggled and remained small. Many also have folded or have been acquired by larger companies. However, as more products are approved by federal regulatory agencies and begin to yield profits for the companies involved, it is likely that this industry will mature and expand significantly to provide excellent opportunities for students with training in the biological sciences and chemistry. Industries that are especially large and active developers of biotechnology include the pharmaceutical industry, food and natural products processing industries and agricultural (plant and animal) industries.

Agriculture

According to a USDA National Report, the shrinking supply of graduates is the most critical force that will affect the agricultural human resource market. Current enrollment in higher education programs that produce graduates with expertise in food, agriculture, and natural-resource disciplines suggests further erosion of the number of graduates who will become available in the near future. Thus, a market demand for graduates specialized in agricultural sciences appears to be on the rise. Areas that will have a shortage in qualified graduates include forestry, horticulture/ornamental horticulture, agronomy/soils, animal sciences, and food science/food industry.

A successful career in agriculture is dependent on a solid training in biology. In addition to the basic requirements in the Biology Major, courses in plant biology (for example, Biol 3041, Biol 4023) should be taken. For students interested in animal science, additional courses in animal physiology and development are desirable (for example, Biol 3110, Biol 328, Biol 4580). See Peterson's Guide for graduate programs in agriculture. Information on employment opportunities in agriculture is available from USDA, Washington, D.C. 20250 (<http://www.ams.usda.gov>).

Biostatistics

Biostatisticians are much in demand in the nation's medical schools, biotechnology businesses and government agencies. Washington University's School of Medicine established a masters program in biostatistics in part to meet the institution's need for biostatisticians. Graduates of the program (<https://biostatistics.wustl.edu/training/msibs/prospectivestudents/MS/Pages/default.aspx>) are so much in demand that they do not exhaust the supply of job openings even within this

institution. A biology major interested in this 18-month masters program should have Math 233 Calculus III, a course in statistics (Math 2200 Elementary Probability and Statistics or Math 3200 Elementary to Intermediate Statistics and Data Analysis) and a course in computer programming (CSE 131). Also helpful would be Math 309 Matrix Algebra. Further information on careers in biostatistics at the masters and doctoral levels, and on choosing between these levels, is available from the American Statistical Association; see their web sites on biostatistics as a profession (<http://www.amstat.org/careers/biostatistics.cfm>) and "How to Prepare for a Career in Biostatistics" (<http://stattrak.amstat.org/2011/08/01/biostatisticscareer>).

Biotechnology

Students with A.B., B.S. and M.S. degrees can find numerous positions in which they do hands-on work at the lab bench. Such work may involve research and development, production or quality-control testing. Students interested in helping to formulate company policy, helping to choose company research directions or running a research project involving multiple scientists are likely to need a Ph.D. Some companies will subsidize (or pay for entirely) additional education for employees with B.S. degrees who wish to obtain an M.S. (or M.A.) degree at a nearby university.

Students interested in biotechnology should develop a strong background in areas including genetics, molecular genetics, cell biology, biochemistry, and microbiology. These fields are mostly represented within Area 1/A of the advanced courses for the Biology major. However, two other courses that are particularly relevant are the Laboratory on DNA Manipulation (Biol 437) and Plant Biology and Genetic Engineering (Biol 3041). In addition, interested students should gain as much real-life laboratory experience as possible, earning Biol 200 and Biol 500 credits while pursuing an independent research project in a lab that uses the techniques of molecular biology. There are approximately 300 laboratories on the Hilltop and Medical School campuses that together form the Departments of the Division of Biology and Biomedical Sciences. The vast majority of these labs utilize the general tools of molecular biology while applying these tools to investigate a variety of biological processes and phenomena. It must be emphasized that with the tools of molecular biology (DNA, RNA and protein purification and analyses, DNA cloning, DNA sequencing, etc.) one can study a variety of problems in virtually any organism. Therefore, it is not as important to work on any single research problem as it is to gain basic training in the tools of the trade. Molecular Biology is both a science and a craft for which one must develop "good hands" at the research bench. As in any trade that requires skill and creativity, one develops "good hands" only through experience and practice. The biotechnology industry and graduate and medical schools preferentially accept students who develop these skills, can work independently with minimal supervision, and can obtain strong letters of recommendation from their research mentors.

Biology 2010 The Science of Biotechnology is an excellent entry-level course for students interested in this topic. The campus Career Center, Career Information Days, advertisements in the back of journals such as Science, Nature, Cell, and local newspaper want ads are all good sources for current job openings. In addition to the library and journals such as "Biotechnology," there are also sites on the internet that allow users to browse biotechnology information resources. Online job listings and career information are available at:

<http://www.faseb.org/Professional-Development-and-Diversity-Resources/Professional-Development-and-Career-Resources.aspx>

<http://www.jobs.nih.gov>

<http://www.lilly.com/careers>

<http://www.bms.com/careers/Pages/home.aspx>

<http://www.gene.com/gene/careers>

Business-Finance and Marketing

Supporting the scientific research endeavor is another industry in which students with a good background in biology and business can excel. The biotechnology industry needs people who combine management skills with knowledge of the biological basis of their industry. This industry supplies equipment, supplies, and reagents to labs within the universities, hospitals, companies and government agencies in which scientific research is conducted. Many salespeople in this industry must meet one-on-one with laboratory managers to sell their products, and first-hand knowledge of the uses of, and scientific bases for, the products they sell is a strong advantage in this competitive area. Biology students may want to consider a minor in business or economics to position themselves to excel in this industry, either in sales or management.

Biology majors specifically interested in finance or marketing may complete a second major in one of these areas by taking a minimum of 24 credit hours of courses through the Olin School of Business. General requirements for a second major in either finance or marketing include MGT

100 (The Managerial Environment), MECO 290 (Microeconomics; or substitute Econ 103B plus Econ 401), QBA 120 (Managerial Statistics I, or substitute Math 2200 or 3200, Psych 406, SSM 325 or SSM 326), QBA 121 (Managerial Statistics II, or substitute Econ 413, Math 439 or Psych 407), ACCT 2610 (Principles of Financial Accounting) and ACCT 2620 (Principles of Managerial Accounting). Additional requirements for the Finance second major include FIN 340 (Capital Markets and Financial Management), FIN 442 (Options Pricing), either FIN 447 (Information Flow in Financial Markets) or FIN 448 (Advanced Financial Management), and at least two other advanced finance electives. Additional requirements for the Marketing second major include: (1) MKT 370 (Principles of Marketing), (2) MKT 480 (Marketing Strategy - Spring semester of senior year), and (3) at least three of the following, with at least one course from group A. Group A: MKT 377 (Consumer Behavior), MKT 470E (Pricing), MKT 473 (Marketing Research); Group B: MKT 373 (Retail Management), MKT 470 (Advertising Management), MKT 476 (Advanced Retail Management), MKT 477 (International Marketing). For advising on the business curriculum, contact the Olin School of Business (<http://www.olin.wustl.edu>).

Computational Biology

With the sequencing of the human genome and development of high-throughput strategies to collect information on a genomic scale, we have a growing need to design new computational strategies for processing and analyzing biological data, particularly DNA and protein sequences. The application of information science to such problems is often called ‘bioinformatics.’ Other areas, such as biochemistry, cell physiology, evolutionary biology, and neurobiology, increasingly need to use mathematical approaches and computer modeling. Such an approach is often termed “computational biology.” Training in computational biology ideally should include a major in biology with course work selected from the appropriate areas of interest, and training in mathematics and computer science. Recommended courses in computer science include CSE 131 (Computer Science I), CSE 240 (Logic and Discrete Mathematics), CSE 247 (Data Structures and Algorithms). Recommended courses in mathematics include Math 2200 or 3200 (Elementary Probability and Statistics); Math 233 (Calculus III, required if you wish to take Physical Chemistry), Math 217 (Differential Equations), and Math 309 (Matrix Algebra). A student interested in bioinformatics would select biology courses from among biochemistry (Biol 451, or Biol 4810 & Biol 4820), computational biology (Biol 4523, Biol 4342 or Biol 434W), molecular biology (Biol 3371), molecular evolution (Biol 4183), and experimental methods (Biol 3491, Biol 3492, Biol 4342/434W, Biol 437, Biol 4520, Biol 4522, Biol 4523). Computational biology is important also in the study of physiology of biological systems, including the nervous system, as covered in Biol 3151, Biol 328, Biol 3411, Biol 4030, and Biol 404. Because computational biology is a newly developing field, independent research (Biol 500) in bioinformatics is strongly recommended for anyone entering this specialty.

The following sample program provides a biology major with strong training in computational biology (Biology major, bioinformatics orientation):

Fall Semester	Spring Semester
<i>Freshman Year</i>	
Math 132 Calculus (3)	Math 233 Calculus (4)
Biology Seminar 118 (1)	Biology 2960 Biology I (3)
Chem 111A General Chemistry (3)	Chem 112A General Chemistry (3)
Chem 151 Gen Chem Lab (2)	Chem 152 Gen Chem Lab (2)
E Comp 100 Expository Writing (3)	Distribution requirement (3)
CSE 131 Computer Science I (3)	
Fall Semester	Spring Semester
<i>Sophomore Year</i>	
Math 309 Matrix Algebra (3)	Math 217 Differential Equations (4)
Biol 2970 Biology II (4)	Biol 3XX/4XX Biology major elective (3-4)
Chem 261 Organic Chem I (4)	Chem 262 Organic Chem II (4)
CSE 247 Data Structures & Algorithms (3)	Distribution requirement (3)
Distribution requirement (3)	
<i>Junior Year</i>	
Biol 4181 Population Genetics (3)	Biol 500 Independent Research (3)
Biol 3371 Eukaryotic Genomes (4)	Math 3200 Elem Prob & Statistics (3)
CSE 240 Logic and Discrete Math (3)	CSE 241 Algorithms & Data Structures (3)
Phys 117 General Physics I (4)	Phys 118 General Physics II (4)
Distribution requirement (3)	Distribution requirement (3)

Senior Year

Biol 500 Independent Research (3)
Biol 437 Lab on DNA Manipulation (4)
CSE 587 Algorithms Comp. Biol. (3)
Distribution requirement (3)
Distribution requirement (3)

Biol 5496 Seminar Computational Molecular Biol. (1)
Biol 328 Principles in Human Physiology (4)
Biol 500 Independent Research (3)
Open (3)
Distribution requirement (3)

Environmental Engineering

Environmental engineers take the skills and tools of engineers and apply them to environmental problem solving. Traditionally, environmental engineers have been involved in issues of water and air quality, although recent years have seen new areas emerge, such as bioremediation. Students at Washington University have a number of opportunities if they wish to become environmental engineers. One set of options, of course, is to pursue a background in engineering in the School of Engineering. There, a student can participate in an Environmental Resources program, the Environmental Engineering Science minor, or the Environmental Engineering Science option for a B.S. in Biological and Engineering Science. In addition, within the School of Arts & Sciences, the Environmental Studies major provides students with a good background. Students who major in biology can do quite well in environmental engineering; bioremediation requires extensive knowledge of biology as well as engineering.

The most important skill that a student majoring in biology can gain in preparation for a career in environmental engineering is a ready facility with mathematics. Students should consider taking Math 217 (Differential Equations) and perhaps also Math 233 (Calculus III) and/or Math 2200 or 3200 (Elementary Probability and Statistics). Other courses students might consider include Chem. Eng. 142 (Introduction to Chemical Engineering), where the important concepts of mass and energy balance are covered, Chem. Eng. 320 (Thermodynamics, also offered as Mech. Eng. 320), and Earth and Planetary Sciences 323 (Biogeochemistry). Within the biology major, students would want to be sure to take Microbiology (Biol 349) and Ecology (Biol 381 or Biol 419).

See <http://mase.wustl.edu/Academics/minorinenvironmentalengineeringscience.asp> for further information. In addition, students may contact the Air and Waste Management Association, either at its St. Louis Section (currently c/o David Shanks, Boeing Aircraft Co., Mail Code 1111099, P.O. Box 516, St. Louis, MO 63166) or its national headquarters (1 Gateway Center, 3rd Floor, Pittsburgh, PA, 15222; phone: 412-232-3444; <http://www.awma.org>).

A related career that can combine engineering, math, and biology is Industrial Hygiene, a field involving recognition, evaluation and control of environmental factors in the workplace. For information, write to the American Industrial Hygiene Association, 2700 Prosperity Avenue, Suite 250, Fairfax, VA 22031; phone 703-849-8888; <http://www.aiha.org>.

Pharmaceutical Industry

The pharmaceutical industry is diverse, with opportunities in small biotech start-up companies as well as in the large well-established multi-national firms. The industry is focused on the development of diagnostics for the rapid accurate identification of individuals with various disease states caused by infectious disease agents, hereditary diseases or acquired progressive disease states, with the development of therapeutic regimens to treat these diseases and with the development of means to prevent disease, often by immunization regimens. The pharmaceutical industry is also involved in the design, development and evaluation of prosthetic devices. In the area of development of diagnostic reagents and processes, the disciplines of microbiology, infectious disease research, immunology and molecular biology are particularly useful. In terms of drug discovery, a background in organic and physical chemistry and computer science, especially with regard to drug receptor interaction modeling, is useful. Of course, if the drugs are biologics produced by microorganisms or plants, an expertise in microbiology and plant natural products becomes important. Much modern drug development requires gene cloning and expertise in molecular biology and genetics. Ultimately, because all drugs must be fully evaluated for teratologic and toxic activities in animals, animal-science training also becomes important. In the development of vaccines and immunization protocols, individuals require expertise in microbiology and infectious disease research, as well as in immunology, molecular biology, and molecular genetics. In the manufacture of vaccines one gets into chemical engineering, fermentation, and bioprocess technologies that rely heavily on engineering as well as industrial microbiology. The development of prosthetic devices relies heavily on knowledge of human anatomy and physiology, and requires considerable engineering skills. In evaluation of all products developed in the

pharmaceutical industry, out of necessity one must conduct clinical studies and these studies involve appropriate veterinary and/or medical training, as well as familiarity with experimental design, statistical analysis, toxicology, etc. Attending to regulatory issues with governmental regulatory agencies requires more of a business background as does marketing. These activities all require additional background and skills, but can be based on biology and biomedical science disciplines. Several schools offer Pharm.D. degrees, but be aware that some programs specifically require a B.S. in pharmacy for admission to the Pharm.D. program. Information on schools of pharmacy can be obtained from the American Association of Colleges of Pharmacy, 1426 Prince Street, Alexandria, VA 22314-2841 (phone: 703-739-2330; <http://www.aacp.org>).

WORK AND GRADUATE STUDY IN BIOLOGY AND PUBLIC POLICY, LAW, SCIENCE COMMUNICATIONS, AND FORENSIC SCIENCE

Science and public policy is an area much in demand today in both the public and private sectors. People who work in this area advise governmental agencies such as the Department of Energy (DOE), the Environmental Protection Agency (EPA) or the Congressional Office of Technology Assessment (OTA) on issues relating to environmental law, environmental impact, alternative energy sources, feasibility of various technology programs from the space shuttle to funding for linear accelerators. Policy experts are also employed by private corporations to research environmental regulations, to provide information to Congress on legislation that affects the introduction or regulation of new technology of interest to a company, etc. With the recent expansion of the biotechnology business, many aspects of newly engineered plants or animals require knowledge of public policy issues.

Students interested in pursuing careers in science and public policy can either enter the field directly after receiving a B.A., or enroll in graduate work for an M.A. or Ph.D. degree. Entering the job market directly after college provides practical experience as well as the opportunity to decide whether the field is attractive as a career choice. Opportunities for such work can be obtained not only with the larger government agencies mentioned above, but also with state environmental agencies, fish and wildlife services, and, of course, private companies. Long-range career advancement may be limited, however, without an advanced degree. M.A. and Ph.D. programs prepare students for managerial positions, as well as for teaching in the general area of science, technology and society at the university level. The following schools, and programs, offer advanced degrees in the field: Massachusetts Institute of Technology, Cambridge, Massachusetts (Program in Science, Technology and Society); Rensselaer Polytechnic Institute, Troy, New York (Science and Technology Studies), Georgia Institute of Technology, Atlanta, Georgia (School of History, Technology and Society), and Cornell University, New York (Program on Science, Technology and Society). Washington University also offers both a major and minor leading to the B.A. in Engineering and Public Policy through the School of Engineering.

Biology courses that would prepare students for either direct entry into the job market or further graduate work in science and public policy might include: Biol 3041 (Plant Biology and Genetic Engineering), Biol 349 (Microbiology), Biol 381 (Intro. to Ecology), Biol 3491 (Microbiology Laboratory), Biol 4342/434W (Research Explorations in Genomics), Biol 437 (DNA Manipulation), Biol 4520 (Protein Function in Model Cellular Systems), Biol 4522 (Laboratory in Protein Analysis, Proteomics, and Protein Structure). Preparation in statistics is also highly recommended, as well as general preparation in economics and political science. Students wanting more information on graduate programs and opportunities in the area of Science and Public Policy should consult the Science, Policy and Society Programs page of the American Association for the Advancement of Science (<http://www.aaas.org/program/center-science-policy-and-society-programs>).

Biology/Law

There is growing interest in science majors who want to pursue a law degree, particularly to work in areas of patent law, environmental law, and health-related issues. Students interested in this area should consult http://college.artsci.wustl.edu/pre_law.

Appropriate course selection in biology would depend on the area of interest. Anyone interested in environmental issues should take Biol 3501 (Evolution) and Biol 381 (Introduction to Ecology), as well as other courses from the Environmental Sciences. A student interested in patent law might consider preparation in Microbiology (Biol 349), the Lab on DNA Manipulation (Biol 437) and Biochemistry (Biol 451 or Biol 4810). Anyone with an interest in forensics would want to take Biol 3110 (Vertebrate Structure Laboratory), Biol 4183 (Molecular Evolution) and Biol 437 (Lab on DNA Manipulation).

Science majors usually have well-developed analytical thinking skills. Law-school admission committees also look for evidence of very skilled writing. Washington University offers advanced courses in composition (e.g. EComp 211), advanced exposition (EComp 311) and argumentation (EComp 312).

Washington University graduates who have attended law school consistently cite the need for strong writing skills. These law students also indicate that basic undergraduate courses in economics, American history, political science/government, and political theory helped them feel prepared for legal study. Many also recommend a basic course in financial accounting.

The Pre-Law Advising Office in 104 Cupples II has a wealth of resources to help individuals determine whether law is a good career option. The office also offers a letter-of-recommendation service, advice about the LSAT, and other services to assist students with the law-school application process. Members of the Law School Admissions Office also are available to consult with students; call 5-4536 to arrange a class visit or tour of the law school.

Science Writing

Science writers serve as one important interface between the public and the scientific community. Science writers fall into two broad categories: journalists (working for newspapers, magazines and periodicals) and those who work in public relations/information capacities for institutions, societies, and government agencies. The latter prepare press releases, public information documents and fund-raising materials.

Most science writers have earned at least a bachelor's degree in one of the sciences. Course work in various aspects of journalism, including newspaper or magazine writing and copyediting, would also be beneficial. Washington University has a number of journalism courses offered through University College (See Communications and Journalism), including one entitled, "Popular Writing in Science, Medicine, and Health" (U48 Comm 358).

Although not required, many science writers have a Master's or a certificate in journalism. Some graduate journalism programs permit specialization in science writing, most notably the University of California, Santa Cruz (1-year certificate) and New York University (Master's). More information on various journalism programs is available through the WWW sites listed below.

Students interested in science writing should seek internships to gain experience and make contacts in the field. Students can contact newspapers, university public affairs or news offices, and medical/scientific institutions (e.g., the Smithsonian), to investigate internship opportunities. The Washington University Office of Public Affairs staff includes a number of science writers, and advice and internship possibilities may be sought on campus through the Public Affairs offices at the Medical School (x2-8528). Students also can explore the possibility of receiving credit for independent projects or internships through the English Department (EComp 300: Journalism: Communications Internship). Additional information can be obtained from the following sources:

- National Association of Science Writers (NASW); P.O. Box 294, Greenlawn, NY 11740; (516)757-5664; e-mail: sciwriters@aol.com (Howard J. Lewis, newsletter editor)
<http://www.nasw.org>
- Society of Environmental Journalists (SEJ); 9425 Stenton Ave., Suite 209, Philadelphia, PA 19118; (215) 247-9710 (Beth Parke, Executive Director); e-mail: sejoffice@aol.com;
<http://www.sej.org>
- Journalism and Communications Academic site: <http://www.jou.ufl.edu/default.asp>

Scientific/Medical Illustration

While the use of computers is rapidly changing this field, there remains a small group of people that work at the interface of art and science. It is possible to become a Certified Medical Illustrator; generally this profession requires completion of a Master's degree program such as the Master of Arts in Medical and Biological Illustration offered by Johns Hopkins University School of Medicine (Baltimore). Programs are available also at the Medical College of Georgia (Augusta), the University of Michigan (Ann Arbor), The University of Texas Southwestern Medical Center at Dallas, and the University of Chicago. Each school accepts 5-10 students a year. The University of Toronto offers a three-year Bachelor of Science degree in Biomedical Communications.

Students entering these programs most often have majored in Graphic Communications (illustration, graphic design, or advertising) with a minor in biology but can also major in biology

with a minor in art. Required prerequisite courses vary, but generally include introductory biology and chemistry (here Biol 2960, Biol 2970; Chem 111A, 112A, 261), vertebrate structure (Biol 3110), physiology (Biol 328); drawing, basic painting (including watercolor), advanced life drawing (figure drawing), a graphic design course, basic photography, and computer graphics. Detailed information can be obtained from the institutions given above, or one might contact the Association of Medical Illustrators, 1819 Peachtree Street, N.E., Atlanta, GA 30309; also see information at the following website: <http://www.ami.org>.

Forensic Science

Any science used for the purposes of the law is a forensic science. Forensic science is a rewarding career where the love of science can be applied to the good of society, public health, and public safety. A forensic scientist provides information and expert opinion to investigators, attorneys, judges, and juries in determining the innocence or guilt of a defendant. Forensic scientists work in laboratories, at crime scenes, in offices, and in morgues. They may work for federal, state and local government, forensic laboratories, medical examiners offices, hospitals, universities, toxicology laboratories, police departments, medical examiner/coroner offices, or as independent forensic science consultants.

Forensic scientists must have a bachelor's degree in science and some forensic sciences require advanced degrees; take biology, chemistry, math, and English composition.

The American Academy of Forensic Science, the largest forensic science organization in the world, comprises over 5,000 scientists organized into ten sections representing the different areas of expertise of individual members. Biology-related sections include Odontology, Pathology/Biology, Physical Anthropology, Psychiatry & Behavioral Science, and Toxicology. Forensic dentistry (odontology) applies dental science to the identification of unknown human remains and bite marks, using both physical and biological dental evidence. Identification of the human remains of natural disasters, terrorist activities, and missing and unknown persons is a central activity. Forensic pathology is the application of the principles of pathology (a medical specialty in the study of disease) to needs of the legal system. Forensic pathologists perform autopsies to determine what caused a person's death. They also investigate circumstances surrounding the death to infer the manner of death — natural, accident, suicide, homicide, or undetermined.

Forensic anthropologists identify individuals killed in disasters such as plane crashes, explosions, fires, and other tragedies resulting in the loss of life and mutilation of bodies. Forensic psychologists and psychiatrists address a broad range of legal issues as they work with criminal and civil cases and other areas such as family and domestic-relations law. In criminal law, such issues as competence (e.g., competency to stand trial and to testify, to waive legal representation, or to be executed), and the assessment of mental illness as it relates to diminished responsibility or innocence by reason of mental illness or defect are the focus. Civil law requires assessment of such issues as involuntary psychiatric hospitalization, right to refuse treatment, competency to participate in do-not resuscitate decisions, and disability compensation among others. Issues in family and domestic relations may include juvenile delinquency, child custody, parental fitness, domestic abuse, adoption, and foster care.

For more information on career opportunities and preparation in forensic science, see the career page of the American Association for Forensic Science, from which this summary is condensed (<http://aafs.org>).

GRADUATE SCHOOL IN BIOLOGY

If you are interested in teaching and/or doing research at the college/university level in biology, a Ph.D. in a specialized area of biology is required. In addition, many research positions in industry, particularly directing a research project, require a Ph.D. A Ph.D. would be of benefit in some other (non-research) positions in industry as well (see information on biotech/business). Ph.D.-level biological scientists also can fill important needs in the areas of public policy, law, and teaching at other levels (i.e., informal science education, junior-college teaching, etc.). Please also see information on these related areas in this booklet if you are interested.

Most Ph.D. programs in the biological sciences provide a tuition waiver and pay stipends to cover living expenses to enrolled students. Completing a Ph.D. usually takes about five years, most of which is spent performing research. Most programs begin with a year of course work, during which a research lab is identified through a series of research rotations. Teaching assistantships are often part of the training. Generally, in addition to completing a Ph.D., most Ph.D. biological

scientists spend several years (2-4) as post-doctoral fellows, performing additional research, often to specialize further in their research area before seeking a faculty position or another job. It is no longer common or necessary for those who plan to get a Ph.D. first to complete a Master's degree.

The Biology Department recommends that those interested in entering Ph.D. programs consult with their Biology Faculty advisors for recommendations about courses that will best prepare them. To some extent, the courses selected depend on the area of biology that the student finds particularly interesting and in which (s)he plans to specialize (see below), but all students interested in pursuing Ph.D. studies should take the core sequence, Biol 2960/2970. A rigorous and broad program of biology courses (rather than taking only the minimum courses required to complete the major) is recommended. To obtain a comprehensive view of many modern techniques used by biologists in a large number of areas of specialization, Biol 334, Biol 3371, Biol 437, and Biol 451 or Biol 4810 are suggested, although some specialty areas will emphasize other programs of study. Students also should get involved in research as early as possible; participation in Biol 500 during the junior and senior years is highly recommended. Summer research opportunities are particularly valuable for students interested in entering Ph.D. programs. Such opportunities exist on campus (see section on research opportunities, pp. 13-15) and at other universities. Information on research opportunities at other universities is being compiled in the Natural Sciences Learning Center. Participation in a summer research program at a university where a graduate program of potential interest is located can be particularly valuable. These summer programs often serve as recruiting tools for graduate programs. Students known to the faculty of the program through successful participation in their institution's summer research programs have a decided advantage in admissions.

Most graduate programs look very favorably upon research experience gained through working for 1-2 years as a research assistant (technician) after graduation. Those who take "time off" to work in lab often have the advantage of more advanced skills, greater familiarity with how research problems are approached, and greater focus upon entering graduate school. This type of experience can be invaluable in determining whether pursuing Ph.D. studies is an appropriate path.

Information on graduate programs in biology can be found in Peterson's Guide to Graduate Study. Peterson's Guides in all areas are in Olin Library. Peterson's Guide is available via internet (site <http://www.petersons.com/graduate-schools.aspx>). Peterson's Guide lists the faculty associated with the various graduate programs. Identifying faculty associated with a program is the first step to evaluating the suitability of the program. Often reading recent published work of faculty in a program of potential interest is the best way to evaluate whether a program is appropriate. An additional resource for information on graduate study is the Career Center, or "Cell and Molecular Biology Online," (<http://www.cellbio.com>).

Biochemistry

An understanding of the molecules that compose the cell - their structure, function, and interactions - is the core of our efforts in biochemistry. Like all of the other subdisciplines, the intellectual possibilities in this area have expanded rapidly with new molecular tools. Students interested in graduate study in biochemistry are in most cases best served by completing either the biology track in Molecular Biology and Biochemistry (see p. 6) or the chemistry major with concentration in Biochemistry. These programs require that the student take physical chemistry (Chem 401 and 402) and a selection of upper-level biology and chemistry classes, including Biol 4810 and Biol 4820. Microbiology (Biol 349) provides a strong foundation in biochemistry of bacteria. A good grounding in genetics, cell and molecular biology is also advised; this preparation can be obtained by taking Biol 334, Biol 3371 and Biol 4183. Biology 4832, Biol 4833 and Biol 4933 offer advanced study of biochemistry. Research experience is essential and should be sought as early as practical.

There are many excellent graduate programs throughout the country. Reading research literature as well as university materials can help you to identify ones of interest to you.

Biophysics/Biomathematics

A biomathematician or biophysicist utilizes physical and/or mathematical approaches to help solve biological and biomedical problems. A biophysicist may for example use x-ray crystallography to study protein structure, and a biomathematician may develop mathematical models to explain electrical activity in the heart.

Common to all of these fields is the application of techniques traditionally employed by physicists or mathematicians. A biophysicist may develop and use complex instrumentation or computer software, or may apply physical laws to biological problems. Examples include the design of better brain scanners, the development of computer programs to analyze and to compare DNA sequences, or the modeling of cell motility based on the laws of mechanics. A biomathematician employs rigorous mathematical analysis in biological problems. Examples here include the development of mathematical models to describe changes in population structure, or the use of statistics to analyze complicated quantitative data resulting from biological experiments.

For graduate work in these fields, prospective students should look beyond program names. Some universities offer specific graduate programs entitled Biophysics or Biomathematics. Other universities often have researchers working in the same fields, but they may be part of a larger department such as biology, physics or engineering. Guidance in selecting appropriate schools can come from reading some of the primary scientific literature in the field to identify prospective graduate mentors, and also by consulting local experts. A good place to start on campus is with faculty members in the areas mentioned above.

Students interested in these fields should take course work in mathematics and physics beyond that required for the biology major. To get a head start, it may be advisable to take Physics 117A/118A during the summer after the freshman year. Recommended courses beyond those required for the biology major are Math 1201 (C programming), Math 233 (multivariable calculus), Math 309 (matrix algebra) and Math 3200 (probability and statistics). The preceding plus Math 318 and one other upper-level elective course in math are sufficient for a math minor. Other courses of particular interest in math include Math 217 (differential equations) and Math 312 (dynamical systems).

For students with an interest in biophysics, 17 units of physics are sufficient for a minor. Physics courses that should be considered are Phys 217, Phys 218 (quantum physics), Biol/Phys 360 (Biophysics Laboratory) and Phys 421, Phys 422 or in Electrical Engineering EE 314M (electromagnetism). For details on the Biophysics Minor, see p. 10. Also of interest in Electrical Engineering is EE 280 (electrical networks). Students interested in biomechanics should consider Mechanical Engineering ME 231, 232, 241, 370 and Phys 314. For those interested in biomathematics, courses in Systems Science and Mathematics may be relevant, such as SSM 144, SSM 202, SSM 351A. For those with interests in biomedical imaging, relevant courses include SSM 147, EE 455, 468A and Phys 316.

In addition, summer research opportunities or Biol 200/Biol 500 experiences should be sought with faculty at the Institute for Biomedical Computing, in the Bioengineering program (see also Bioengineering in this brochure), the Department of Physics, and the Department of Biochemistry and Molecular Biophysics. Note that Hughes Fellowships are available on a competitive basis to support summer work in this area.

For additional information about biophysics, students may wish to contact the Biophysical Society. Besides providing answers to specific questions and helping students make contacts with professionals in the field, the society also publishes a brochure entitled "Careers in Biophysics". For information, contact the Biophysical Society, 9650 Rockville Pike, Bethesda, MD 20814; phone 301-530-7114. A website for biophysics (<http://www.biophysics.org>) contains information about the Biophysical Society and has links to abstracts from the Biophysical Journal, as well as a listing of biophysics graduate programs with links to the home pages for these programs.

Developmental Biology

For those interested in developmental biology, the core sequence (Biol 2960/Biol 2970), Biol 3371 (Eukaryotic Genomes), Biol 334 (Cell Biology), Biol 4071 (Developmental Biology), Biol 437 (Laboratory on DNA Manipulation), and Biol 451 or Biol 4810 (General Biochemistry) are highly recommended to provide sufficient background in the areas of biology upon which the student will need to draw. Also of interest is Biol 3041 (Plant Biology and Genetic Engineering). Biol 4182 (Macroevolution) covers topics at the interface of development and evolution.

For help in finding an appropriate graduate program, students can consult faculty members with interests in Developmental Biology (see faculty listings of the Division of Biology and Biomedical Science). If a student has an interest in a particular area of development, one effective method of finding appropriate programs is to determine the graduate program affiliations of the prominent researchers in the area, using research papers to identify their university affiliations and catalogs or Peterson's guide to identify programs available at that university. Other faculty

participating in the program can be identified through Peterson's guide or by writing to the program for information. The range of interests of the faculty in the program is often the key factor in identifying which programs are the best match for the individual. Below, some programs that are noted for developmental biology research opportunities are listed. However, there are many other programs where students would find excellent research opportunities in this area. Many combined programs in cell and molecular biology have significant numbers of faculty with interests in developmental biology; in many cases, developmental biology is not listed in the program title.

University of California at San Francisco: Programs in Biological Sciences

University of California at Berkeley: Cell and Development Program

University of California at Irvine, School of Biological Sciences: Graduate Program in Molecular Biology, Genetics and Biochemistry

University of Colorado: Molecular, Cell and Developmental Biology Program

Harvard University: Biology and Biomedical Sciences

Indiana University: Department of Biology

Ecology and Evolution

Graduate study in this area combines population genetics, phylogenetics and ecological perspectives to study the origins and maintenance of biodiversity. It is a diverse and synthetic area that can combine field studies with molecular biology and mathematics to gain an understanding of evolutionary history and environmental biology. Population-genetic studies ask: "What kinds of genetic variation occur in natural populations? How do population-genetic processes lead to the evolution of new species and adaptation? How does population structure affect rates of speciation and adaptive evolution, and which breeding strategies are optimal for conserving genetic variation to enhance the survival of endangered species?" Studies of phylogeny ask "What are the evolutionary relationships of different plant and animal species? How do historically acquired developmental and functional constraints channel morphological and ecological evolution in different lineages, and what kinds of developmental processes underlie the evolutionary diversification of different plant and animal groups?" Ecological experiments provide crucial information on how organisms meet environmental challenges: "At which stages of the life cycle is mortality most severe and how do different species interact to establish ecological communities?"

Graduate study in evolutionary and population biology prepares students for careers in ecology, evolutionary biology, systematics, and in the biological aspects of environmental and conservation sciences, either in academic institutions, in governmental agencies such as U.S. Fish and Wildlife, or in private conservation agencies such as the Nature Conservancy or World Wildlife. Students interested in graduate study in this area should include some of the following courses, which offer excellent preparation for graduate-level study: Biol 3501, (Evolution), Biol 4181 (Population Genetics and Microevolution), Biol 4182 (Macroevolution), Biol 4183 (Molecular Evolution), Biol 419 (Community Ecology), and Biol 4193 (Experimental Ecology Laboratory). Students should take Math 2200 or 3200 (Elementary Probability and Statistics) and Math 322 (Biostatistics) for important background in statistics. Biol 437 (Lab on DNA Manipulation) will be useful in many cases. Opportunities for research experience, either during the academic year or in the summer, should be sought. Information on summer field opportunities that come to the Biology Department can be found in the Natural Sciences Learning Center.

Genetics

With the advent of gene cloning and the undertaking of the Human Genome Project, the field of genetics is changing rapidly. Geneticists are actively involved in studying patterns of development, mechanisms of inheritance, the basis of human genetic disease, and the nature of inherited behaviors. Geneticists work in medical centers, assist in forensic cases, teach and do research in universities, colleges, and institutes, and participate in the biotechnology industry. Genetic analysis, and potentially genetic therapy, are becoming increasingly important in health care, and are leading toward a paradigm shift in the way we think about the practice of medicine.

The biology major provides good preparation for work towards a Ph.D. in genetics. Majors with interests in this area should include Biol 437 (Lab on DNA Manipulation) in their programs. Depending on the particular area of interest, Biol 3041 (Plant Biology and Genetic Engineering), Biol 334 (Cell Biology), Biol 3371 (Eukaryotic Genomes), Biol 3422 (Genes, Brains and Behavior), Biol 4071 (Developmental Biology), Biol 4181 (Population Genetics and Microevolution), Biol 4183 (Molecular Evolution), and Biol 4342/Biol 434W (Research Explorations in Genomics) also should be considered. Advanced courses available on the Medical School Campus include Biol 5491, Advanced Genetics (requires permission of the instructor) and

Biol 5011, Ethics and Research (a one-unit course open to undergraduates). A student interested in graduate school in this area should pursue research in a relevant lab using Biol 500.

Many universities offer strong graduate programs in genetics. Genome Centers of the Human Genome Project are located at Baylor College of Medicine, University of California at Berkeley (campus and Lawrence Berkeley Lab), Salk Institute, Stanford University, University of Iowa, University of Michigan, University of Texas Health Science Center at San Antonio, University of Utah, Washington University in St. Louis, and Whitehead Institute at MIT. Further information on careers in genetics can be obtained from The Genetics Society of America, 9650 Rockville Pike, Bethesda, MD 20814-3998, or The American Society of Human Genetics at the same address.

Neuroscience/Physiology

Neurosciences (NS) form a diverse and fascinating field including Behavioral NS, Cellular NS, Cognitive NS, Developmental NS, Molecular NS, and Systems NS. The annual meeting of the Society for Neurosciences (<http://www.sfn.org>) in the USA attracts more than 20,000 participants. An undergraduate Biology major is excellent background for graduate study in NS. In addition, a minor or major in Psychology is helpful for those interested in Behavioral NS or Cognitive NS. In the Biology Department, Dr. Yehuda Ben-Shahar studies molecular genetics and neurobiology of behavior in *Drosophila melanogaster*, Dr. Bruce Carlson studies electrosensory systems of freshwater fishes, Dr. Erik Herzog studies the neural mechanisms responsible for circadian rhythms, and Dr. Paul Stein studies the neural mechanisms of the turtle's motor behavior.

Many courses in NS are offered by the Biology Department and by the Psychological and Brain Sciences Department. On the Medical Campus, the Neurosciences Program in the Division of Biology and Biological Sciences offers many graduate courses in NS. The Neuroscience Program at Washington University is among the top graduate programs for doctoral training (the Washington University NS program brochure is located at the website <http://neuroscience.wustl.edu>). The Department of Philosophy offers a doctoral program in Philosophy, Neuroscience, and Psychology (PNP).

(A) Courses offered in the Department of Biology.

The following courses for general background should be taken by all students with interests in NS:

Biol 2960	Fundamentals/Principles of Biology I
Biol 2970	Fundamentals/Principles of Biology II
Biol 3058	Physiological Control Systems

At least one, preferably two, of the following basic courses should be taken by students with interests in neuroscience.

Biol 3411	Principles of the Nervous System (same as Psych 344)
Biol 3421	Introduction to Neuroethology
Biol 3422	Genes, Brains and Behavior
Biol 404	Laboratory of Neurophysiology
Phys 350	Physics of the Brain

At least two semesters of Independent Research (Biol 500) should be taken by any student interested in doctoral studies in NS. Students with strong interests in molecular, cellular, and/or developmental NS should also consider the following courses.

Biol 334	Introduction to Cell Biology
Biol 3371	Eukaryotic Genomes
Biol 4071	Developmental Biology
Biol 437	Laboratory on DNA Manipulation
Biol 451 or 4810	General Biochemistry

The following seminar-style courses encourage neuroscience students to form an interactive community of colleagues:

Biol 171	First-Year Opportunity: Neuroscience Futures 1: How do we learn about the brain?
Biol 4934	Neuroscience Futures 2

Students with strong interests in Systems NS also should consider Biol 328, Principles in Human Physiology. Students with special interests in the auditory system may consider this somewhat specialized course: Biol 5811 Neural Basis of Acoustic Communication.

(B) Courses offered in the Department of Psychological and Brain Sciences.

Psychology courses of direct physiological relevance include Psych 330, Sensation and Perception; Psych 340, Biological Psychology; Psych 360, Cognitive Psychology; and Psych 3604,

Cognitive Neuroscience. Students should consult the Department of Psychological and Brain Sciences for further details.

(C) Courses offered on the Medical School Campus.

Most courses offered by the Neuroscience Graduate Program are designed for graduate students, require considerable reading in the research literature, and meet at times that are not compatible with most undergraduate schedules. These courses are best taken in graduate school after the biology major is completed.

(D) Graduate schools with Neuroscience Programs.

Almost all universities have neuroscientists as members of their faculty; many universities have a neuroscience program, especially those with medical schools. Washington University has one of the strongest Neuroscience programs in the country and the world.

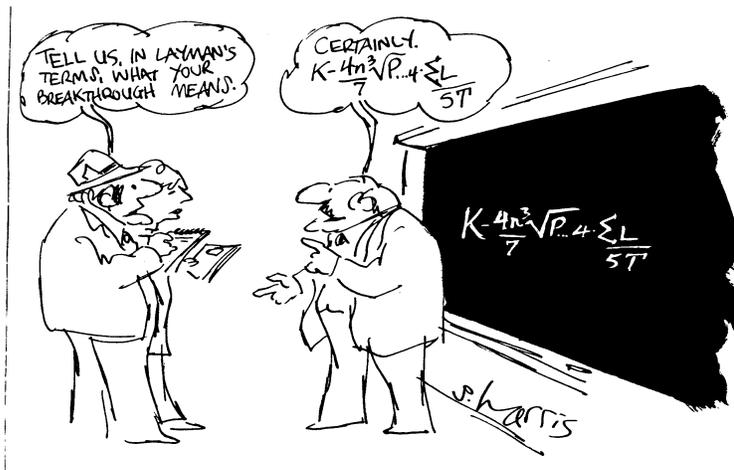
To find neuroscience training programs, see <http://sfncareers.applicantpro.com/jobs> A student interested in the field of Neurosciences should first examine this website and then make an appointment with Professors Erik Herzog (314-935-8635) and Paul Stein (314-935-6824) to discuss his/her interest regarding a choice of graduate schools. Students also should examine for research opportunities the research-interest website for the Neuroscience Program at Washington University (<http://neuroscience.wustl.edu>). Undergraduates seeking opportunities in neuroscience research, outreach to the community, or clinical experience may want to consult Synapse, the WU student interest group in neuroscience (<http://synapse.wustl.edu>).

Plant Science

All life on earth depends on plants. Plant photosynthesis provides by far the dominant mechanism for capturing energy from outside the earth and converting it to the usable components of the biosphere. For this reason, plant biologists often say: "Plants are primary. Everything else is secondary and derivative." Studying plant biology allows the student and the professional biologist an opportunity to understand and to investigate fundamental general life processes as well as processes unique to plants. Experimental plant biology is informed by the insights of evolution, the mechanisms of chemistry and the techniques of biochemistry and molecular biology. The areas of the systematic relationships among plants, the dynamics of plant populations, diversity and plant ecology are other areas that command the detailed attention of biologists all over the world.

Students of plant biology take the same core science courses as all students completing a biology major. Additional chemistry, math and physics can open more areas of investigation to you. A student who likes chemistry might consider a second semester of organic lab, synthetic organic chemistry, and physical chemistry. Take as much statistics as you enjoy. If you have a background in electronics, build on that. In addition to courses that focus on plants (Biol 3041 Plant Biology and Genetic Engineering; Biol 4023 How Plants Work: Physiology, Growth, and Metabolism; Biol 4025 (Current Approaches in Plant and Microbial Research) no plant biologist should miss Cell Biology (Biol 334), Biochemistry (Biol 451 or 4810), Eukaryotic Genomes (Biol 3371), and the Laboratory on DNA Manipulation (Biol 437). Biology 4520 (Protein Function in Model Cellular Systems), Biol 4522 (Laboratory in Protein Analysis, Proteomics, and Protein Structure), and Biol 4832 (Molecular Mechanisms of Photosynthesis and Respiration) are directly relevant to plant biology. Finally Biol 349 will introduce you to microbiology. For a student whose interests are in natural history, plant systematics, ecology or population biology, courses to consider include Ecology (Biol 381 or Biol 419), Evolution (Biol 3501), Population Genetics and Microevolution (Biol 4181), and Molecular Evolution (Biol 4183).

Students interested in a career in plant biology should participate in research early, perhaps the first or second semester of sophomore year. Students are welcome in the research laboratories of the plant biology faculty on the main campus, the Missouri Botanical Garden, one of the premier plant systematics institutions in the world, and the Danforth Plant Science Center. Students interested in field biology should pay special attention to summer courses and research at biological field stations; announcements of such opportunities are kept in the Natural Sciences Learning Center.



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BIOLOGY COURSES

Note: Listed here are recently offered courses and ones anticipated for the coming two years. Faculty responsibilities may change during this period. To help you make informed selections, courses are indicated as small (<20), medium (20-60), or large (>60) based on recent past enrollment. The semester in which a course is normally offered is indicated. If the year is specified, the course is being planned for the semester indicated, but it is uncertain when that course will be offered again. Otherwise, courses are offered every year or every other year as specified.

Elective Courses (Not for Biology-Major Credit)

These courses do not count toward the biology major but may be of interest to majors and prospective majors as elective credit toward graduation, except for courses specifically restricted to nonmajors (Bio 303A).

Biol 112. First-Year Seminar: Introduction to Problem-Based Learning in Biology (fall, summer)

Same as FYP 112. Small groups of students all take responsibility for their own active learning in their team with guidance from an instructor. Each group in rotation considers four problems of biological importance such as rainforest destruction, coral reefs, laboratory diagnoses, sleep, high altitude, deafness, infertility, modern epidemics, clinical cases, genetic engineering, and cloned animals. Students find the background information by library searches and integrate this knowledge in group discussions. Intended for but not limited to prospective biology majors. **For freshmen only.** Prerequisite: high school biology, preferably an AP class. Small groups. Credit 3 units. **D. Thotala** (Radiation Oncology, WUMS), **J. Wang** (University College) and staff

Biol 1260. First-Year Seminar: The Secret Lives of Plants (fall)

Same as FYP 1260. This course is designed to familiarize undergraduate students with the fascinating lives of plants, their evolution, their remarkable structural and morphological diversity, how they grow, and how they have been modified to feed the planet. Topics include: how plants can survive with just water, minerals and light, how they transport water astonishing distances, their unusual sex lives, why they make seeds, how they can grow nearly forever, how plants survive extreme environments without running to hide, why they synthesize caffeine, nicotine, THC and opiates, how they defend themselves from pathogens without an immune system, how they sense their environment without dedicated sensory organs, how plants have been modified by humans to provide food, fiber and fuel, and how genetically modified (GMO) crops are made and their implications to the environment and society. Overall goals are to enhance an understanding and appreciation of the plant kingdom, to help young scientists understand the primary scientific literature, and as a starting point for possible careers in plant biology. Class includes field trips to the Missouri Botanic Gardens and a local plant biotech company/institute. Where appropriate, the class will also emphasize key differences between plants and animals. This course is primarily for freshmen interested in majoring in biology, with a possible emphasis on plants. This course is also for those that want to know more about where their food comes from, how these amazing creatures survive and flourish, and how GMO crops are engineered. Upper-level students with an interest in food and sustainable agriculture but not necessarily focusing on plants will also be welcome. Course will be lecture/discussion/hands-on format for 2 of the 3 hours per week. Students will

present 30-minute papers discussing topics relevant to their interests for the remaining 1 hour (two students per class). Prerequisites: Students must have taken both biology and chemistry in high school and at least one at the AP or IP levels; or have taken Biol 2960 or Chem 111A/112A. Both freshmen and upper level undergraduates may take this course, with a preference given to freshmen. Small class. Credit 3 units. **R. Vierstra**

Biol 171. First-Year Opportunity: Neuroscience Futures 1: How do we learn about the brain? (fall)

Same as FYP 1710. In this seminar course for first-year students, students learn about how neurobiologists conduct and communicate research. We focus our discussion on primary research papers written by WUSTL neurobiologists, who visit the class to present their work. Discussion then focuses on the formulation of scientific questions, evaluation of evidence and interpreting data within the context of a broader field. Students meet neuroscience colleagues in two joint class periods with participants in a neurobiology seminar for 2nd, 3rd and 4th year students. May be repeated for credit; preference given to students who have not previously taken the course. Small class. Credit 1 unit. **M. Kundel**

Biol 1770. First-Year Opportunity: Genetics and Behavior of Dog Breeds (fall)

Same as FYP 1770. This freshman seminar uses the topic of dog behavior and genetics to teach fundamental scientific tools and to engage students in contributing to the building of an online public resource that summarizes the scientific literature on breeds. Our first task is learning to read and dissect primary scientific literature. We parse out the difference between scientific questions, hypotheses, and predictions through a guided case-study exercise. We then apply the experience to outlining primary research articles, identifying the key components of the author's arguments and summarizing the results and implications. The second half of the semester is spent searching the scientific literature, sorting information into the new dog breed resource, and presenting results to peers around the seminar table. Small class. Credit 2 units. **S. Braude**

Biol 181. First-Year Opportunity: Introduction to Cutting-Edge Research in Biology (fall)

Same as FYP 181. A lecture course, intended for first-year students, which focuses on the practice and culture of biological research. Active researchers describe the biological context of their research, the specific questions they have formulated, the means by which they pursue the answers, and their data and conclusions. The focus is on process: how biologists pursue their profession, what happens in a research setting. Additional topics of contemporary and clinical interest are often included. Must be taken Credit/No Credit. Medium-size class. Credit 1 unit. **P. Stein**

Biol 1811. First-Year Opportunity: Research and Conservation in Zoos and Botanical Gardens (fall)

Same as FYP 1811. An introduction to the world of zoos and botanical gardens. Students will learn of the diverse and cutting-edge ways in which scientists and conservationists study the world's biological diversity and work to conserve it. Taking advantage of two world-class institutions a short distance from the Danforth campus, the class will meet every week at an off-campus site (primarily the Saint Louis Zoo and Missouri Botanical Garden, but also several other institutions) to hear lectures from leading authorities at these institutions, as well touring facilities to see first-hand how research is conducted and how these institutions work to preserve endangered species. Students will write three short papers; each paper will be based upon a class lecture and its associated readings. Must be taken Credit/No Credit. Small Class. Credit 2.0 units. **J. Losos**

Biol 191. AMP: Phage Hunters (fall)

Same as FYP 1910. A research-based laboratory class for freshmen. Students join a national experiment organized by HHMI, with the goal of isolating and characterizing bacteriophage viruses found in the soil outside Rebstock Hall. Laboratory work includes isolation and purification of your own phage, DNA isolation and restriction mapping, and EM characterization of your phage. One WU phage is selected for genome sequencing over winter break. Prereqs: High school courses in biology, chemistry and physics, at the AP or International Baccalaureate level; permission of the instructor. Limited to 40 students. One hour lecture, one hour discussion, and 3 hours laboratory per week. Prerequisite: admission to the AMP program. Small Class. Credit 3 units. **K. Hafer**

Bio 192. AMP: Phage Bioinformatics (spring)

Same as FYP 1920. A research-based laboratory class for freshmen. Students join a national experiment organized by HHMI, with the goal of genomic characterization of a local phage. Laboratory work focuses on learning computer-based tools for genome analysis followed by annotation and comparative analysis of the genome of the WU phage, which was isolated fall semester and sequenced over winter break. Prerequisites: High school courses in biology, chemistry, and physics, at least one at the AP or International Baccalaureate level; permission of the instructor.

Limited to 40 students; preference given to those completing Biol 191, AMP: Phage Hunters. One hour lecture, one hour discussion, and 3 hours laboratory per week. Prerequisite: admission to the AMP program. Small Class. Credit 3 units. **K. Hafer, C. Shaffer**

Biol 200. Introduction to Research (spring/fall)

An introduction to laboratory and field research in biology for first- and second-year students. Students work under the supervision of a sponsor in a setting of established, ongoing research. Prerequisites: less than 60 units completed, permission of sponsor and the department. Register at <http://www.nslc.wustl.edu/courses/bio500/bio500.html>. Credit/No Credit only. Credit 3 units. **K. Olsen**

Biol 2010. AMP: The Science of Biotechnology (fall)

Same as FYP 2010. Biotechnology is truly interdisciplinary with a myriad of pieces from biology, chemistry, engineering, physics, computer sciences, management, public policy, and law that apply the scientific process to societal challenges. This course introduces topics for science and engineering majors with an interest in biotech and teaches scientific concepts to business students considering careers in biotech management and entrepreneurship. Students completing Biol 2010 understand key science concepts, how discoveries lead to applications addressing global challenges, effectively use a variety of resources to explore connections between science and biotech business, synthesize information from different fields, exhibit strong teamwork skills, and communicate information in written and oral forms. This course also provides a gateway for students interested in the two-year Biotech Explorers Program (BEP). The first two weeks of the course introduce students to the history of biotechnology, the BEP, and the use of case studies. The remainder of the course uses a series of four 3-week units that combine lecture material, in-class group assignments, and readings to introduce the science and scope of biotechnology. For each unit, student teams also develop short case studies of St. Louis biotech companies and present their findings to the class. A series of site-visits introduce students to the vibrant St. Louis biotech community. Limited to 20 students. Credit 3 units. **J. Jez**

Biol 2020. AMP: Biotechnology Entrepreneurs Seminar (spring)

Same as FYP 2020. Although the biotech industry is science-based, the risks of product and technology development, legal issues, and market pressures make the landscape full of uncertainty. Lectures and textbooks fall short of delivering true insight about the process and challenges of bringing ideas to real-world products. This second semester freshman seminar course is designed to develop an appreciation of how biotech companies achieve their goals by engaging students through interactions with experienced executives and entrepreneurs, who's shared knowledge and stories add depth and context to the learning process. This 1 credit seminar course introduces students to the basics of innovation and entrepreneurship as a framework for marketable discoveries, builds an appreciation of how biotech companies start, obtain funding, and navigate intellectual property, provides an overview of career options in biotech, and insight on the hiring process. Prerequisite: Students need to have completed Biol 2010: The Science of Biotechnology for enrollment in this course and be currently enrolled in Biol 2960: Principles of Biology I. Limited to 20 students. Credit 1 unit. **J. Jez**

Biol 2342. Wilderness First Aid (spring)

The National Outdoor Leadership School (NOLS) has developed a comprehensive curriculum to instruct individuals in backcountry first aid. After successfully completing a detailed 18-hour Wilderness First Aid course, students in this course will write-up a full assessment and treatment plan (5-7 page minimum) for one of the wilderness casualties described in Peter Stark's Last Breath. Students will meet for a half-day seminar during which each student will present their case, assessment, and treatment plan, with special attention to the underlying physiology. They will receive feedback from one another, and from the instructor, about their assessment, explanation of the relevant physiology, and action of their proposed intervention. Prerequisite or Co-requisite: Wilderness First Aid Course (18 hours). Credit 1 unit. **S. Braude**

Biol 2431. AMP: Missouri's Natural Heritage (fall)

Same as FYP 2431. Missouri's Natural Heritage is a multidisciplinary two-semester Freshman AMP course. The first semester of the sequence will focus on Missouri geology, climate, archaeology, and native megafauna. This will provide a foundation on which to examine the ecology, restoration, and management of our diverse habitats (prairie, forest, glade, and stream) and the biology of our diverse plant and animal wildlife (arthropods, mollusks, fish, salamanders, lizards, birds, and mammals) in the second semester. We will also introduce basic concepts in biodiversity and resource management with attention to resolution of conflicts of interest. In addition to weekly lecture and discussion, students in this class will visit sites across the state during 3 weekend camping trips and a longer camping trip during winter break. Attendance on field trips is an essential component of the course

and grade. Lab fee of \$480 covers transportation and meals for all field trips. Small Class. Credit 3 units. **S. Braude**

Biol 265. Experience in the Life Sciences (spring/fall)

Earn credit for nonclassroom learning in the life sciences in a variety of activities: accompany a physician on rounds and prepare a paper on an organ system or disease; participate in a clinical or applied ecological study and report on it; participate in science outreach teaching, etc. Participants must meet regularly with a supervisor and commit at least 140 hours over two semesters. A work plan is approved prior to registration. A progress report is due after one semester and a final paper after two semesters. See <http://www.nslc.wustl.edu/courses/BIO265/bio265.html> for details. Credit/No Credit only. Students are registered by the department after approval is granted. Forms are available in 105 Plant Growth. Credit variable, maximum 1.5 units/semester. **J. Downey** (Pediatrics, WUMS)

Biol 2651. Med Prep I: The Lecture Series (fall, spring, summer)

MedPrep I is a unique lecture series taught by a physician, medical school Course Master and member of the Committee on Admissions for the School of Medicine. Through a weekly two-hour lecture, this course gives students accurate, honest and detailed information regarding every step of the application and admissions process to medical school and the educational process and life of a physician. MedPrep I is particularly useful for freshmen and sophomores in that it gives students a road map and strategy for their four years of college and reviews the common pitfalls encountered by unsuccessful applicants. There is no outside course work and no exams. Attendance at all classes is required. Consult the website at <http://pages.wustl.edu/medprep> for registration instructions. Biol 2651 is a pre-requisite for Biol 2654: MedPrep II – The Shadowing Experience. It may not be taken concurrently with Biol 2654, except during the summer semester. Large Class. Credit 1 unit. **G. Polites** (WUMS)

Biol 2652. Pediatric Emergency Medicine Research Associates Program - Experiences in Life Sciences (fall, spring, summer)

The Pediatric Emergency Medicine Research Associates Program (PEMRAP) offers undergraduate pre-medical students the opportunity to participate in clinical, patient-oriented research projects in a hospital setting (<http://www.nslc.wustl.edu/courses/Bio2652/index.html>). Students have the opportunity to work in the St. Louis Children's Hospital Emergency Department, a nationally recognized pediatric emergency medicine and trauma care facility. A number of research projects are currently underway in various areas of pediatric emergency medicine. Topic areas include bronchiolitis, fluid management in dehydration, procedural pain and sedation, cervical spine trauma, head injury, wound care, and fracture healing. Research Associates will be expected to work two 4-hour shifts per week and to attend a weekly 2-hour meeting on Tuesdays from 1:30 pm - 3:30 pm at St. Louis Children's Hospital. Weekly meeting include lectures given by Emergency Department faculty members. This program offers students the unique opportunity to be a vital part of the ED research team. In addition, the RA's experience in the ED may help him/her determine if medicine is truly the career path he/she wishes to choose. Prerequisite: Approval of Instructor. Grading by Credit/No Credit option only. Credit 3 units. **F. Ahmad, C. Gemignani** (WUMS)

Biol 2654. Med Prep II - Experience in Life Sciences (fall, spring, summer)

Med Prep II offers students a real-life, behind-the-scenes experience of a life in medicine. For three hours every other week, students shadow physicians in the Charles F. Knight Emergency and Trauma Center of Barnes-Jewish Hospital, the main teaching hospital of the Washington University School of Medicine. A weekly 1-hour meeting is also held on the Danforth campus for group discussion regarding the clinical experience. Successful completion of MedPrep I (Biol 2651) is required to take this course. Only in the summer semester may students take both courses concurrently. There is no outside course work and no exams. Consult the website at <http://pages.wustl.edu/medprep/medprep-ii> for registration instructions. Small Class. Credit 1 unit. **G. Polites** (WUMS)

Biol 2656. Introduction to Health Professions (spring)

This course provides students interested in Health Professions with an overview of Occupational Therapy, Physical Therapy, Audiology, Nursing, and Pharmacy. Students gain a better understanding of the scope of practice, markets, and skills required to succeed in these professions. Students learn about graduate and professional education options and how to build a competitive application for these programs. Finally, students participate in self-directed learning experiences (which may include observations, attending professional presentations, or sitting in on graduate-level classes) and culminate their study with an inter-professional education session illustrating the role of each of the professions within a case study format. Students finish the course with a better understanding of whether a career in health professions is right for them. Credit 1 unit.

S. Taff, M. Valente (WUMS)

Bio 2658. Pediatric Emergency Medicine Research Associates Program II (PEMRAP II)
PEMRAP II is a continuation of Bio 2652, Pediatric Emergency Medicine Research Associates Program – Experiences in Life Sciences. Returning PEMRAP Research Associates (RAs) actively participate in new and ongoing research projects in various areas of pediatric emergency medicine. RAs assist during the active period of patient enrollment through screening of ED patients for study eligibility, reading information about the studies to the patients, collecting data regarding patient history and certain physical examination findings, and generally facilitating the study enrollment process. PEMRAP Returning RAs are vital members of the Emergency Department research team in the St. Louis Children's Hospital Emergency Department. For registration information, see <http://pages.wustl.edu/pemrap/registration>. Credit 1 unit. **F. Ahmad, C. Gemignani** (WUMS)

Biol 2950. Introduction to Environmental Biology (fall)
Introduction to Environmental Biology is designed to teach important principles of environmental biology and general science literacy skills. We cover the foundational biological principles and contemporary issues within four main topics: human population growth, transfer of energy and carbon in the ecosystem, biodiversity, and food production. We focus on the biological principles involved as we examine these topics in the context of some contentious and confusing issues related to environmental biology in everyday life. The science literacy skills that you master in this course will help you address the issues you face in your everyday life regarding scientific and pseudoscientific claims about the environment and society and will form the foundation for your development as a critical consumer of science information in the media. This course is required for all environmental biology majors and the environmental studies minor. Large Class. Medium-size class. Credit 3 units. **E. Pardini** (*required course for the Environmental Biology Major*)

Biol 2961. Collaborative Phage Bioinformatics (spring)
A research-based laboratory for those enrolled in Bio 2960, this class provides an opportunity to join a research team with the goal of genomic characterization of a locally isolated phage (a virus that infects a bacterial host). Similar to Biol 192, but using a condensed format and a larger team to tackle each phage. Lab work focuses on learning computer-based tools for genome analysis, followed by careful annotation of several genes from your phage and in-depth investigation of one gene. Requires concurrent enrollment in Biol 2960 Principles of Biology I; not open to students enrolled in Biol 192. One 2-hr pre-class online review/preparation session, nine 2-hr laboratory sessions, and a final poster presentation. (Lab does not meet in weeks with a scheduled Bio 2960 midterm.) May be taken for a letter grade or Credit/No Credit. Credit 1 unit. **K. Hafer, C. Shaffer**

Biol 2962. Biomolecules in the Third Dimension (spring)
A computer-based laboratory for students enrolled in Bio 2960. This class gives students the opportunity to learn biology in a new way. Students are exposed to experimental data and software visualization tools currently used in cutting edge research. Each week, biomolecules presented in Biol 2960 lecture will be downloaded, viewed and manipulated in 3D using the molecular viewer PyMOL. Students will be able to study molecular interactions in greater depth than is possible in lecture. Ultimately, the laboratory is designed to help students develop their visuospatial thinking skills and to gain a deeper understanding of the macromolecules discussed in lecture. The class is highly recommended to students who identify themselves as visual/interactive learners. Topics include: protein and nucleic acid structure, signal transduction, energy transfer, replication, transcription and translation. Requires concurrent enrollment in Biol 2960 Principles of Biology I. Lab does not meet in weeks with a biology exam. Class taken for Credit/No Credit. Credit 1 unit. **K. Hafer, C. Smith**

Biol 303A. Human Biology (spring)
How did Elvis, Jimi Hendrix, John Lennon and Michael Jackson die? How have David Letterman and Dick Cheney survived? In this course we work towards understanding the biology behind human health, disease, and disaster. We examine cases from the news, literature and history and work like detectives to understand what happened. We also work at distinguishing honest science and medicine from junk science and scams. This course is designed for students who do not plan to major in science. Therefore, no prior science background is expected. Prereq: Sophomore standing or permission of instructor. A student may not receive credit for both Biol 303A and Biol 100A, 2960, 2970. Medium-size class. Credit 3 units. **S. Braude**

Biol 307A. Human Variation (fall)

Same as Anthro 307A. A survey of human biological diversity, considering its adaptive and taxonomic significance from the perspective of origins and distribution of traits and adaptation. Medium-size class. Credit 3 units. **E. Wroblewski** (Anthropology)

Bio 374. Drugs, Brain and Behavior (fall)

Same as Psych 374. This course reviews information pertaining both to medications used to treat psychiatric disorders and to psychoactive drugs of abuse. By learning principles of pharmacology and mechanisms of action of these agents, students develop an enhanced knowledge of the brain mechanisms underlying abnormal human behavior. Enrollment limited to 40. Prerequisite: Psych 354 or 3401 or 344. Medium-size class. Credit 3 units. **E. Rubin** (Psychiatry, WUMS).

Biol 387, 388; 487, 488. Undergraduate Teaching (spring/fall)

Exceptional undergraduates serve as teaching assistants for laboratory and/or discussion sections in departmental courses. Students may elect to receive course credit instead of being paid. Normally 2 or 3 units are given a semester, subject to the approval of the instructor and the department. Credit may not be counted toward fulfilling the biology major or minor; application form in Department of Biology office. Prerequisite: permission of instructor. Credit/No Credit only. Credit 2 or 3 units.

Biol 4202. Anthropological Genetics (fall, intermittent)

Same as Anthro 4202. This course will examine the principles of evolutionary genetics as applied to complex characters such as morphology, behavior, life history, and disease. Mathematical models of quantitative inheritance and evolution will be discussed. Special topics include kin selection, sexual dimorphism and conservation genetics. Prerequisite: Anthro 150A or introductory biology. Credit 3 units. Large class. **E. Wroblewski** (Anthropology)

Biol 4213. Plants and the American People: Past and Present (spring, intermittent)

This interdisciplinary course examines the relationship between plants and the American people. Topics include the natural diversity of plants used by Native Americans for food, fiber, and medicine; the significance of plants in the 'Columbian Exchange' for the history of the U.S. and the economies of the Old World; Native American and Euro-American farming practices; modern agribusiness including transgenic crops; and the modern conservation movement in the U.S. Several optional Saturday field trips are planned. Prerequisite: Junior standing or above. **B. Schaal, G. Fritz** (Anthropology)

Biol 429. Cellular Transformations (fall)

Cellular Transformations is a course developed for students interested in using emerging technologies and cross-disciplinary approaches in design production and implementation. This course allows each student to develop abstract thinking and learn modern design and fabrication processes including digital media and 3D technologies. In this course, students learn the basic principles underlying biological architecture, with a particular emphasis on structures and processes responsible for complex architectures within cells. Students then use biological design principles as inspiration for their individual projects. Through digital modeling and scanning of biological structures, each student will develop a transformation process that analyzes the performative aspects of a new emerging design. These designs will be modeled through CAD/CAM (laser cutting) and Rapid Prototyping (3D Printing) for physical outputs. Prerequisites: Bio 2970 or Bio 334. Small class. Credit 3 units. **R. Dixit, S. H. Kim** (Architecture), **C. Topp** (Danforth Plant Science Center)

Courses for Biology-Major Credit**Biol 2960. Principles of Biology I** (spring, summer)

The course provides an introduction to biochemistry, cell biology, and molecular biology. An understanding of cellular architecture and mechanism, and the properties of biological macromolecules are integrated with a discussion of the flow of genetic information within cells. The course ends with the application of this understanding to selected areas in modern biology. Weekly labs reinforce concepts from lecture and explore common laboratory techniques and computer-based resources. Completion of Chem 111A and concurrent enrollment in Chem 112A are strongly recommended but not required. Three hours of lecture and 2 hours of lab per week. Large Class and small lab sections. Credit 4 units. **B. Kunkel, K. Hafer**

Biol 2970. Principles of Biology II (fall, summer)

A broad overview of genetics, including Mendelian assortment, linkage, chromosomal aberrations, variations in chromosome number, mutation, developmental genetics, quantitative genetics, population genetics, mechanisms of evolution, and phylogenetics. Three lectures and one laboratory period per week. Does not count toward the laboratory requirement of the biology major. Students

must sign up for a lab during preregistration. Prerequisite: Biol 2960, or permission of instructor. Large class and small lab sections. Credit 4 units. **D. Chalker, K. Hafer**

Biol 3010. Biotechnology Project (fall)

This second year Biotech Explorers Pathway (BEP) course introduces students to the process used to generate project ideas, write proposals, and evaluate concepts, with peer evaluation applied at all steps of the process. Students completing Biol 3010 will gain experience in science proposal writing with peer review, public speaking, team building, and leadership training. The first four weeks of the course will focus on individual pre-proposal brainstorming, writing, and pitching, while the remainder of the course will be dedicated to the development of full proposals by teams of students. This 3-credit project development course complements introductory courses by making connections between fields and building teams of students with experience in the process that nurtures ideas to products. Pre-requisites: Students need to have completed Biol 2010: The Science of Biotechnology and Biol 2020: Biotech Entrepreneurs Seminar for enrollment in this course. Limited to 20 students. Medium-size class. Credit 3 units. **J. Jez**

Biol 3041. Plant Biology and Genetic Engineering (spring)

A 4 credit lecture course that provides an introduction to plant development, genetics, physiology and biochemistry with emphasis on processes that can be manipulated or better understood through genetic engineering. The course is divided into 3 sections. The first section of the course discusses basic plant biology, development and genetics. The second part of the course emphasizes gene structure, expression, and cloning as well as methods for introducing foreign DNA into plant cells and regenerating fertile plants in tissue culture. During the third part of the course we discuss a variety of examples of genetically engineered traits, including: herbicide resistance; fruit ripening; pathogen and/or insect resistance; the use of plants for production of industrial and pharmaceutical compounds. Friday discussion sections focus on critical reading of the primary literature related to the material covered in lecture. Prereqs: Biol 2960 and Biol 2970. Small class. Credit 4 units. **E. Haswell**

Biol 3058. Physiological Control Systems (spring)

Systems physiology with emphasis on human physiology. Two hours of lectures per week. Prereqs: Biol 2960 and Chem 112A. Large class. Credit 2 units. **P. Stein**

Biol 3100. R Workshop in Biology (fall)

Biologists in all areas increasingly find that they have the need and opportunity to work with large data sets. The goal of this 1-credit course is to provide students with an opportunity to gain skills in data analysis and presentation using R, a free software environment for statistical computing and graphics (<http://www.r-project.org>). Topics include an introduction to basic programming in R, data types and manipulation, graphics, hypothesis testing and statistics, and applications to various fields of biology ranging from ecology to genomics. The course consists of ten, two-hour workshops that include a brief introduction to key concepts in R and applications in biology, followed by interactive, hands-on tutorials. Prerequisites: concurrent or prior course in statistics (Math 2200 or Math 3200) or permission of instructor. Credit 1 unit. **J. Myers, C. Shaffer**

Biol 3110. Vertebrate Structure Laboratory (fall)

A lecture/laboratory course designed to provide an integrative framework for how vertebrate form and function evolved. The pre-lab lectures will emphasize development and the relationship between the structural and functional design of organ systems, the importance of these relationships in maintaining homeostasis while providing opportunity for adaptation and examples of how vertebrate organ systems communicate to accomplish functional and physiological integration. 1 hr lecture plus 5 hrs lab each week. Prerequisite: Bio 2970. Medium-size lecture and small sections. Credit 4 units. **P. Osdoby, T. Keadle**

Biol 3151. Endocrinology (spring)

An overview of mammalian endocrine systems with an emphasis on human physiology and development. The interplay between systemic, local cell, and tissue interactions as well as the cell and molecular events associated with hormone action are discussed. Examples of endocrine evolution and pathological conditions associated with endocrine imbalances also are included. Prerequisite: Biol 2970. Medium-size class. Credit 3 units. **P. Osdoby**

Biol 328. Principles in Human Physiology (spring)

This course is designed to provide students with an understanding of the function, regulation, and integration of the major organ systems of the body. Course content will include basic cellular function, control of neural and hormonal homeostatic mechanisms, and study of the circulatory, respiratory, digestive, urinary, musculoskeletal, nervous, endocrine, and reproductive organ

systems. Prerequisite: Biol 3058 or equivalent is strongly recommended but not required. Large class. Credit 4 units. **R. Clark** (Physical Therapy)

Biol 334. Cell Biology (spring)

Eukaryotic cell structure and function viewed from the perspective of modern cell biology. Lectures cover such topics as membrane transport, endocytosis and secretion, intracellular trafficking, hormones and signal transduction, extracellular matrix and tissue formation, cytoskeleton and motility, cell cycle, apoptosis, and the cellular basis of disease. Prerequisite: Biol 2970. Large class. Credit 3 units. **R. Dixit**

Biol 3371. Eukaryotic Genomes (fall)

An advanced exploration of the structure and function of DNA within the eukaryotic nucleus. Lectures will cover topics of chromatin and chromosome structure, control of gene transcription, RNA processing, and DNA replication and repair. The relevance of these topics to the genetic basis of human disease will be discussed. Throughout, the experimental data that shape our current understanding will be emphasized. Course grades based on exams, problem sets and short papers. Lecture 3 hours per week plus required discussion section every other week. Prerequisites: Biol 2970, Chem 261 (may be taken concurrently). Small class. Credit 4 units.

Biol 3411. Principles of the Nervous System (fall)

Same as Psychology 344. The basic anatomical, physiological, and chemical organization of the nervous system; how nerve cells communicate with each other, the ionic basis of nerve signals, the function and properties of chemical agents in the nervous system, the development of neural circuitry, and how neurons interact to produce behavior. Prerequisite: Biol 2960, Biol 2970 recommended, Biol 3058 recommended or Psych 3401 and permission of instructor. Large class. Credit 3 units. **K. Hengen**

Biol 3421. Introduction to Neuroethology (spring, even years)

The neural mechanisms of animal behavior from an evolutionary and ecological perspective. Topics include: contributions of model systems to understanding fundamental properties of nervous system structure and function; electrical signals of sensory cells, neurons, and muscle; neural processing of sensory input; neural control of behavioral output; anatomy and physiology of sensory and motor systems; learning and memory; evolution of neural circuits. Prerequisite one of the following courses: Biol 3058, Biol 3411, Psych 3401. Medium-size class. Credit 3 units. **B. Carlson**

Biol 3422. Genes, Brains and Behavior (fall)

Genetic studies of physiological systems underlying animal behavior, including the genetic basis for normal and abnormal behaviors in animals and humans. Topics include: history of behavioral genetics; the ongoing debate about "nature vs. nurture"; contributions of genetic model systems including the nematode *Caenorhabditis elegans*, the fruit fly *Drosophila melanogaster*, zebrafish, the mouse *Mus musculus*, and other animal models; molecular mechanisms underlying the evolution of behavioral phenotypes; the emerging role of epigenetics in regulating nervous-system functions and behavior; the use of genetic and genomic analyses in studies of human behavior and psychiatric disorders. Prereq: Biol 2970. Medium-size class. Credit 3 units. **Y. Ben-Shahar**

Biol 347. Darwin and Evolutionary Controversies (fall)

Focus is on controversies in evolutionary biology from Darwin's day to the present. Most of the controversies concern scientific issues such as Kelvin's estimate of age of the earth, Jenkin's argument against blending inheritance, neutral variations, effects of isolation on the role of selection, mass extinction and "nemesis," but some address social issues such as evolutionary ethics and "scientific creationism." Emphasis in the readings is on primary sources, including Darwin's Origin of Species. Writing Intensive. Small class. Credit 3 units. **A. Larson**

Biol 349. Microbiology (spring)

This four-credit lecture course focuses on the molecular biology of bacteria, archaea, and viruses. Topics include: the bacterial cell cycle, gene regulation, stress response, cell-cell communication, viral and bacterial pathogenesis, microbial ecology, and metabolic diversity. Friday tutorials stress analysis of the primary literature with an emphasis on current research related to material covered in lecture. Prereqs: Biol 2960, and Biol 2970, or permission of instructor. Credit 4 units. **A. Bose**

Biol 3491. Microbiology Laboratory (fall, spring, summer session 1)

After introducing students to the basics of bacterial growth and maintenance, this laboratory class employs genetics, cell biology, and genomics to explore various aspects of bacterial physiology, identification, gene structure and mutational analysis of physiological pathways. One hour lecture and five hours of laboratory per week. Fulfills the upper-level laboratory requirement for the

Biology major. Prereq: Biol 2970, Biol 349 recommended. 3 units. **M. Schlarman** (fall & spring), **C. Smith** (summer)

Biol 3492 Laboratory Experiments with Eukaryotic Microbes (spring)

This research-intensive course provides an introduction to diverse molecular and cytological techniques used in model experimental organisms to explore fundamental biological questions. Experiments are performed using selected fungi and protozoans commonly used in major research efforts. Emphasis is placed on choosing the appropriate organism for the question posed using the most current technologies. Each semester, one cellular process is studied in detail and original research is conducted. Writing assignments model the components of scientific articles. The final project is a poster presentation of each student's results at the undergraduate research symposium. Prerequisites: Biol 2960 and Biol 2970 and permission of instructor. One hour of lecture and six hours of laboratory a week. This course fulfills the laboratory requirement for the Biology major and the Arts & Sciences writing-intensive course requirement. Enrollment limited to 18. Credit 3 units. **D. Chalker**

Biol 3493 Bacterial Bioprospecting and Biotechnology (spring)

Many bacteria are essential in food industry (fermentation of meats, cheeses, and beverages), agriculture (crop protection against weeds, pathogenic bacteria, and fungi), biotechnology (producing fine chemicals, cofactors, amino acids, and industrial enzymes) and the pharmaceutical industry (producing clinical antibiotics, anticancer, antiviral, veterinary, and immunomodulatory drugs). This laboratory course examines how basic biological understanding can lead to discovery of bacterial products, enzymes and activities useful to humankind. We combine core concepts from biochemistry, bacterial genetics, bioinformatics, chemistry and enzymology to study bacteria from the genus *Streptomyces* and close relatives. Lines of inquiry include environmental isolations, molecular toolbox and host development, plus bioinformatic and laboratory-based analyses of secreted proteins and antibiotics. Prerequisites: Biol 2960, Biol 2970. Biol 349 is strongly recommended but NOT required. Permission of Dr. Joshua Blodgett is required. One hour of lecture and six hours of laboratory per week. This course fulfills the laboratory requirement for the Biology major. Enrollment limited to 16. Credit 3 units. **J. Blodgett**

Biol 3501. Evolution (fall)

A general survey of organic evolution covering both micro and macroevolution. Topics include natural selection, adaptation, evolution of pathogens, formation of species, and phylogeny. Prerequisite: Biol 2970. Medium-size class. Credit 4 units. **K. Olsen**

Biol 360. Biophysics Laboratory (fall)

Same as Phys 360. This laboratory course consists of "table-top" experiments in biological physics that are designed to introduce the student to concepts, methods, and biological model systems in biophysics. Most experiments combine experimentation with computer simulations. The list of available experiments includes electrophysiology, human bioelectricity, optical tweezers, ultrasonic imaging, mass spectrometer, and viscosity measurements. Prerequisite: Phys 117A and Phys 118A, or Phys 197 and Phys 198, or permission of instructor. Small class. Credit 3 units. **S. Handley, R. Wessel** (Physics)

Biol 372 Behavioral Ecology (fall 2018 only)

This course examines animal behavior from an evolutionary perspective and explores the relationships between animal behavior, ecology, and evolution. Topics include foraging behavior, mating systems, sexual selection, predator-prey relationships, cooperation and altruism, competition and parental care. Not available to students who have credit for Biol. 472. Prerequisite: Biol 2970 or permission of instructor. Large class. Credit 3 units. **J. Parks**

Biol 373. Laboratory on the Evolution of Animal Behavior (fall)

This course explores the costs, benefits and constraints that drive the evolution of animal behavior. It is divided into four modules: a brief overview of basic statistics, a lab on agonistic behavior, a lab on animal communication, and a lab on sexual selection by female choice. Laboratory modules are hands-on and student driven. They begin with an overview of relevant literature and a discussion of key questions that have been addressed experimentally in that field. Students are then encouraged to apply these concepts into the design, execution, and analysis of a research project aimed at answering a question of their own choosing through the use of house crickets as a study system. A majority of class time is devoted to active learning through the collection and analysis of data (each lab module lasts 4 weeks). In addition, the course includes weekly presentations by the instructor and class discussions on topics that help place the students' work into the broader context of evolutionary theory. Biol 2970 and Psych 100B or permission of instructor. Credit 3 units. **C. Botero**

Biol 381. Introduction to Ecology (spring)

This course explores the science of ecology, including factors that control the distribution and population dynamics of organisms and the structure and function of biological communities. It regularly touches on applications of these principles such as ecological responses to global climate change, consequences of habitat fragmentation, and disease ecology/conservation medicine. Principles of experimental design, quantitative data analysis and interpretation, and mathematical models are critical to the field of ecology and are emphasized throughout the course. The class meetings have an active learning format includes lecture and regular student interaction during small group activities, discussions, and computer simulation labs. Assignments include regular homework reading and occasional problem sets and computer pre- and post-lab activities. Prereq: Bio 2970 or Bio 2950 or permission of instructor. Same as L&E 381. Credit 3 units. **E. Pardini**

Biol 4023. How Plants Work: Physiology, Growth and Metabolism (fall, odd years)

This course introduces students to the fundamentals of how plants grow, metabolize and respond to their environment. Topics to be covered include the conversion of light energy into chemical energy through photosynthesis and carbon fixation, nitrogen assimilation, water and mineral uptake and transport, source-sink relationships and long-distance transport of carbon and nitrogen, cell growth and expansion, hormone physiology and physiological responses to a changing environment. Prerequisite: Biol 2970 or permission of instructors. Small class. Credit 3 units. **B. Kunkel**

Biol 4030. Biological Clocks (spring, odd years)

Biological clocks are the endogenous oscillators that coordinate physiological and behavioral rhythms in nearly all organisms. This course examines how these rhythms are generated and regulated. The material includes molecular, cellular and systems physiology and the relevance of biological timing to ecology and health in everything from protozoans to plants to people. Prerequisites: Biol 2970. Medium-size class. Credit 3 units. **E. Herzog**

Biol 404. Laboratory of Neurophysiology (fall)

Neurophysiology is the study of living neurons. Students record electrical activity of cells to learn principles of the nervous system including sensory transduction and coding, intercellular communication and motor control. The course meets for 8 hours on Tuesdays or Wednesdays. Students may leave the lab for up to 2 hours. Prerequisites: Biol 3411 or Psych 4411, and permission of instructor. One eight-hour lab period a week. Enrollment limited to 18 students per section. Credit 3 units. **E. Herzog, B. Carlson, M. Kundel**

Biol 4071. Developmental Biology (spring, even years)

An introduction to the molecular and cell biology of animal development. The course is divided into three broad sections, which cover 1) an introduction to the major cell-cell signaling systems used during development and their study in model organisms, 2) molecular studies of early vertebrate development, and 3) the biology of stem cells. The focus is on molecular approaches applied to important model systems, but framed in classical concepts. Prereqs.: Principles of Biology II (Biol 2970); Cell Biology (Biol 334) and/or a course in biochemistry recommended. Small Class. Credit 3 units. **I. Duncan, S. Imai (WUMS), S. K. Kornfeld (WUMS), C. Michelli (WUMS), J. Mills (WUMS), D. Ornitz (WUMS), A. Yoo (WUMS)**

Biol 4181. Population Genetics and Microevolution (fall)

Introduction to the basic principles of population and ecological genetics; mechanisms of microevolutionary processes; integrated ecological and genetic approach to study the adaptive nature of the evolutionary process. Prerequisite: Biol 2970. Medium-size class. Credit 3 units. **D. Queller**

Biol 4182. Macroevolution (spring, even years)

An advanced introduction to the study of macroevolutionary patterns and processes with emphasis on the systematic methodology employed. Topics: theories of classification, phylogenetic reconstruction, testing of historical hypotheses, hierarchy theory, adaptation, extinction, speciation, developmental mechanisms of organismal evolution, biogeography. Prerequisite: Biol 2970 or permission of instructor. Medium-size class. Credit 3 units. **A. Larson**

Biol 4183. Molecular Evolution (spring, odd years)

A rigorous introduction to the study of evolution at the molecular level, focusing on intraspecific molecular evolution, including the origin, amount, distribution, and significance of genetic variation at the molecular level, and interspecific molecular evolution, including the use of molecular data in

systematics, and in testing macroevolutionary hypotheses. Prerequisite: Biol 2970 or permission of instructor. Small class. Credit 3 units. **A. Larson**

Biol 419. Community Ecology (spring)

Community ecology is an interdisciplinary field that bridges concepts in biodiversity science, biogeography, evolution and conservation. This course provides an introduction to the study of pattern and process in ecological communities with an emphasis on theoretical, statistical and experimental approaches. Topics include: ecological and evolutionary processes that create and maintain patterns of biodiversity; biodiversity and ecosystem function; island biogeography, metacommunity dynamics, niche and neutral theory; species interactions (competition, predation, food webs), species coexistence and environmental change. The class format includes lectures, discussions, and computer labs focused on analysis, modeling and presentation of ecological data using the statistical program R. Prereq: Bio 2970 required, Bio 381 recommended, or permission of instructor. Credit 3 units. **J. Myers**

Biol 4193. Experimental Ecology Laboratory (spring)

The goal of this course is to provide skills in the design, interpretation, and written presentation of results of ecological experiments, with emphasis on hypothesis testing, sampling methodology, and data analysis. Students have opportunities to address a variety of ecological questions using field, greenhouse, or laboratory (microcosm) studies. The course is divided into a 5-hour lab period (generally held at the Tyson Research Station) and a 1.5-hour lecture/discussion period held on campus. Occasional Saturday field trips to local sites (e.g., forests, wetlands, prairies, streams) for in-depth study might be scheduled. This is a writing intensive course and grades are based on written assignments, including final projects, and in-class participation. This course fulfills the upper-level laboratory requirement for the Biology major. Prereq: Permission of instructor and at least one of the following: Bio Bio 3501, Bio 372, Bio 381, Bio 419, or Bio 472. Enrollment is limited to 15 students. Credit 3 units. **S. Mangan**

Biol 424. Immunology (fall and spring)

Basic molecular and cellular aspects of the vertebrate Immune System with emphasis upon the interrelationships of non-specific and specific host defense against disease, the nature of immunological specificity and its underlying molecular biology. Includes complement systems, immunochemistry and immunoassay, systems, the nature of cellular activation and effector generation, immunodeficiency, tolerance, tissue transplantation, hypersensitivity, immune regulation and specific diseases illustrative of the successes and failures of the immune system. Prerequisites: Bio 2970 or permission of instructor, and Chem 262. Credit 4 units. Small-size class. **D. Hanson**

Biol 4241. Immunology Laboratory (fall and spring)

The Immunology Laboratory introduces students to a variety of common, broadly useful immunological techniques and then allows each student to employ most of the learned techniques in addressing a current research question. Experiments employ mouse cells in vitro and emphasize quantitative analysis of the data. Prereq: Bio 424 and permission of instructor. Credit 3 units. Small-size class. **D. Hanson**

Biol 4270. Problem-Based Learning in the Biomedical Sciences (spring)

Groups of five to eight students are presented with medical case studies that are then researched and discussed under faculty guidance. Students take major responsibility for their own learning within their teams. Prerequisite: Biol 2970, some experience in molecular biology, and permission of instructor. Same content as discontinued course Bio 427, but not writing intensive. Not available to students who have credit for Biol 427. Small discussion groups. Credit 3 units. **D. Thotala** (Radiation Oncology, WUMS), **J. Wang** (University College) **and staff**

Biol 4331. Algae: Cell Biology and Molecular Evolution (spring, discontinued after 2017)

Algae are ubiquitous and highly diverse photosynthetic organisms: they are prokaryotic (cyanobacteria) and eukaryotic, unicellular and multicellular, and central to soil, fresh water, and marine ecosystems. This course will consider their molecular taxonomy and evolution, specific lineage adaptations (e.g. silicon in diatoms), life cycles, cell cycle and cell-division mechanisms, light and nutrient acquisition, storage products, cell and cell-wall organization, ecological habitats and symbioses (e.g. lichens), and commercial applications (e.g. carotene, omega-3 fatty acids and other nutraceuticals; biodiesel). A course for upper-level biology and bioengineering undergraduates and graduate students. Tu Th 2:00 - 4:00 until spring break, where a second course, Biol 4830, is highly recommended as a sequel. Assigned readings of research literature pertaining to each lecture topic; final take-home exam covering lecture and reading material. Prerequisite: Biol 334 or Biol 4810 or instructor's permission. Small class. Credit 2 units. **U. Goodenough**

Biol 4342. Research Explorations in Genomics (spring)

A collaborative laboratory investigation of a problem in comparative genomics, utilizing a variety of bioinformatics tools to manage and investigate large data sets (currently including genomic sequences, gene predictions, sequence conservation, gene expression). In spring '18 the research problem involves improving the sequence of a region of the *Drosophila eugracilis* genome, and working with one of these sequences to examine patterns of genome organization, gene structure and gene regulation. Prerequisites: Bio 2970, Chemistry 111A/112A, 151/152, and permission of instructor. While Bio 3371 or Bio 437, and some familiarity with computers would be advantageous, this is NOT required. Combined enrollment in Biol 4342 and Biol 434W limited to 12 students. Credit 4 units. **S. Elgin, C. Shaffer, J. Buhler** (Computer Science and Engineering)

Biol 434W. Research Explorations in Genomics (Writing Intensive) (spring)

Course covers the same material as Biol 4342 in a writing-intensive format. Prerequisites: Biol 2970, Chem 111A/112A, Chem 151/152 and permission of instructor. Biol 3371 or Biol 437 and some familiarity with computers would be advantageous, but are not required. Combined enrollment in Biol 4342 and Biol 434W limited to 12 students. Credit 4 units. **S. Elgin, C. Shaffer, J. Buhler** (Computer Science and Engineering), **A. E. Bednarski**

Biol 437. Laboratory on DNA Manipulation (fall)

This course provides investigation-driven research on experimental manipulation of DNA and RNA molecules. This includes the construction, isolation and analysis of plasmids, RNA, PCR products and DNA sequencing. Molecular cloning (genetic engineering), gene knockouts (mutants), RNA isolation, RT-PCR and microarray projects are performed. Prerequisites: Biol 2960 and Biol 2970. One hour of lecture and eight hours of laboratory each week. Enrollment limited to 12 students. Credit 4 units. **R. Kranz**

Biol 4492. Infectious Diseases: History, Pathology, and Prevention (fall)

Leveraging the primary research literature, this course examines the history and pathology of infectious disease, the development of antibiotics and vaccines, the rise of antibiotic resistance, and the emergence and reemergence of diseases including Zika virus, Ebola, and Tuberculosis. In addition to gaining insights into the underlying causes and treatment of infectious disease, students will hone their ability to identify important biological questions, develop testable hypotheses, design experiments tailored to particular questions, and evaluate results. Through a series of written and oral assignments, students develop the skills to communicate about science effectively to both the research community and the general public. Prerequisites: Biol 2960, Biol 2970; Chem 261, 262, and Biol 500 or permission of the instructor. Small Class. Credit 3 units. **P. Levin**

Biol 451. General Biochemistry (fall, summer)

A study of structure-function relationships as applied to carbohydrates, proteins, and lipids; intermediary metabolism of principal cellular components; and general aspects of regulation. Prereqs: Biol 2970 and Chem 262 and permission of department. Recommended for students who have achieved grades of B or better in the prerequisites. Students may not receive credit for both Biol 451 and Biol 4810/4820 (Chem 481/482). Large class. Credit 4 units. **H. Zaher** (fall), **D. Hoover** (summer, Summer School)

Biol 4520. Protein Function in Model Cellular Systems (fall)

The goal of this 3-credit laboratory course is to train students in the scientific method. Throughout this course, they study a protein involved in a cellular process. Students, working in small groups, use bioinformatics to identify this protein in a number of species, then use this information to hypothesize which residues of the protein are important for its function. Over the course of the semester, students test their hypotheses in two model systems for studying cellular function—the unicellular eukaryote *Saccharomyces cerevisiae* and the multicellular eukaryote *Physcomitrella patens*. The weekly lecture gives students the background necessary to understand and perform their experiments, including information on a variety of bioinformatics tools, phylogeny, protein structure, molecular techniques, cell biology, and microscopy. In addition, students use primary literature to understand the role their assigned protein plays in their cellular process. Prereq: Biol 2960 and Biol 2970. Small class. Credit 3 units. **L. Strader**

Biol 4522. Laboratory in Protein Analysis, Proteomics, and Protein Structure (spring)

The majority of the laboratory work focuses on a research question using biochemical methods. The course consists of three sections: protein biochemistry, mass spectrometry, and structural biology. In the first section of the course, students learn principles and methods for heterologous expression of proteins in bacteria, protein quantitation, protein purification, SDS-PAGE, and kinetic analysis of enzyme activity. The second part focuses on using mass spectrometry to identify and to characterize proteins. The final part of the course introduces students to concepts of structural

biology including protein crystallization, x-ray diffraction, and computer modeling of protein structures. Fulfills the upper-level laboratory requirement for the Biology major. Prereqs: Chem 252 and either Biol 451 or Biol 4810/Chem 481. Suggested to be taken concurrently with Biol 4820/Chem 482. Enrollment is limited and requires the permission of Dr. Jez. Small class. Credit 3 units. **J. Jez, W. Cruz**

Biol 4523. Molecular Methods in Enzyme Analysis (fall)

Understanding enzyme structure and function is essential in many important drug design projects. This course focuses on common methods used to investigate enzyme active sites to elucidate binding interactions between small molecules and enzymes. Students use 3D protein viewing software to design and model modifications to an enzyme active site, then perform those modifications using recombinant DNA technology and site-directed mutagenesis. This course also introduces other commonly used methods to assay active-site metals, characterize inhibitors, over-express and purify proteins, and use UV spectroscopy to analyze enzyme activity. This is an investigative course in which students perform collaborative research projects in small groups. Fulfills the upper-level laboratory requirement for the generic biology major and the biochemistry track; intended for students who have no other courses that fulfill these requirements. Prerequisites: Biol 2970; Limit 12. Credit 4 units. **A. Bednarski**

Biol 4524. Structural Bioinformatics of Proteins (fall)

In this investigative laboratory course, students are given high-quality, experimentally determined, three-dimensional structural coordinates and will use cutting-edge bioinformatics tools and methods to evaluate and analyze these datasets. Some topics include: structural validation, protein-structure prediction, domain and motif recognition, secondary structure prediction, protein-protein and protein-ligand interactions, protein and structure-based sequence alignments, inferring protein function from structure, electrostatic interactions, and threading and homology modeling. Upon completing their analyses, students are responsible for writing a manuscript that will be submitted to a scientific journal for publication. Prerequisites: Bio 2960 and Chem 262. Fulfills upper-level laboratory requirement for the biology major. Prerequisites: Biol 2970; Limit 12. Credit 4 units. **C. Smith**

Biol 4580. Principles of Human Anatomy and Development (fall)

Same as Anthro 4581. This course is designed for both undergraduate and graduate students in the anthropological, biological, and/or pre-medical sciences who wish to learn about human anatomy from various evolutionary, functional, developmental, and clinical perspectives. Lectures will emphasize the organizational and developmental principles of various organ systems of the human body. The course will also make use of our extensive anatomy museum of labeled dissected human specimens as well as our cast collections of numerous specimens from the human fossil record where appropriate. Frequent use of X-rays, CT, and MRI scans will also be used to help students visualize human anatomy from a number of different imaging modalities. Prerequisites: Undergraduate or graduate students in the anthropological, biological, and/or pre-medical sciences who have had at least one course in physical anthropology and/or biology, or consent of instructor. Credit 3 units. **D. Strait (Anthropology)**

Biol 472 Behavioral Ecology (fall, not offered 2018)

This course examines animal behavior from an evolutionary perspective and explores the relationships between animal behavior, ecology, and evolution. Topics include mating systems, sexual selection, parental care, kin selection, and cooperation. There is a strong active - learning component. Not available to students who have credit for Biol 372. Prerequisite: Biol 2970 or permission of instructor. Medium-size class. Credit 4 units. **J. Strassmann**

Biol 4810 General Biochemistry I (fall)

Same as Chem 481. The first part of a two-semester survey of biochemistry. This course covers biological structures, enzymes, membranes, energy production and an introduction to metabolism. Prereqs: Biol 2960 and Chem 262. Large class. Credit 3 units. **R. Blankenship, A. Krezel (WUMS)**

Biol 4820 General Biochemistry II (spring)

Same as Chem 482. Topics include carbohydrate, lipid and amino acid metabolism, signal transduction, transport across membranes, DNA replication and repair, transcription and translation, molecular motors, mechanisms of drug action, and the biosynthesis of natural products, biofuels, and biomaterials. Prereq: Biol 2960 and Chem 262. Large class. Credit 3 units. **R. Blankenship, A. Krezel (WUMS)**

Biol 4830 Bioenergy (spring, discontinued after 2017)

A broad overview of the flow of energy, captured from sunlight during photosynthesis, in biological systems, and current approaches to utilize the metabolic potentials of microbes and plants to produce biofuels and other valuable chemical products. An overall emphasis is placed on the use of large-scale genomic, transcriptomic and metabolomic datasets in biochemistry. The topics covered include photosynthesis, central metabolism, structure and degradation of plant lignocellulose, and microbial production of liquid alcohol, biodiesel, hydrogen & other advanced fuels. Course meets during the second half of the spring semester. Prerequisites: Biol 4810 or permission of instructor. Small class. Credit 2 units. **H. Pakrasi**

Biol 4832 Molecular Mechanisms of Photosynthesis and Respiration (fall even years)

Photosynthesis is a biological process whereby the Sun's energy is captured and stored by a series of events that convert the pure energy of light into the free energy needed to power life. Respiration is a biological process that extracts energy in a useable form from high-energy compounds produced by photosynthesis. This course examines these essential biological processes at the molecular level in both bacterial and eukaryotic organisms. Emphasis is on chemiosmotic principles as well as the structure and mechanism of action of the protein complexes that carry out photosynthesis and respiration. Additional topics include the assembly and regulation of these protein complexes and the origin and evolution of these processes. Prerequisite: Chem 482, Biol 4820 or Biol 451 or permission of instructor. Small Class. Credit 3 units. **R. Blankenship**

Biol 4833 Protein Biochemistry (spring)

Same as Chem 483. The focus of this course is protein biochemistry, and is intended to build upon General Biochemistry (Biol 4810). In this course we will focus on protein structure, folding, and techniques to purify and characterize protein activity. We will progress from initial studies to first understand protein fold and function to current efforts to better characterize protein structure-function relationships. We will also highlight human diseases that are underpinned by protein misfolding. This course will focus on reading and understanding primary literature, including landmark papers along with more recent work. During the second half of the semester, each student will select a paper and prepare a written analysis of that paper. The student will then present the paper and lead a journal club style discussion of the paper. Prerequisite: Biol 4810. Small Class. Credit 3 units. **M. Jackrel** (Chemistry)

Biol 493. Seminar in Advanced Biology (spring/fall)

In special cases credit may be given for individual study. Topics and credit must be arranged with a faculty sponsor and approved by the department. Credit 1-3 units.

Biol 4933 Molecular Biology on the Cutting Edge (spring)

Recent biomedical discoveries have been greatly advanced through the development of innovative, state-of-the-art techniques. For example, Nuclear Magnetic Resonance (NMR) has proved to be an invaluable tool in both efforts to determine the atomic structure of proteins and small molecules as well as in clinical settings, as MRI to identify tumors that would otherwise go unnoticed. This course introduces students to a variety of cutting-edge laboratory techniques, and discusses the impact of these techniques on biology and medicine. Students have the unique opportunity to learn from graduate students employing these approaches in their doctoral studies. Topics include: high-throughput sequencing of genetic disorders, x-ray crystallography, and single molecule force spectroscopy by AFM. Weekly classes consist of a 30-45 minute presentation on a particular technique, followed by 60-minute discussion of the assigned readings. Prerequisites: Biol 2960 and Biol 2970 and at least one semester of Biol 500 or equivalent research experience approved by the course master. Credit 2 units. **P. Levin and graduate students**

Biol 4934 Neuroscience Futures 2 (fall/spring)

Students in this course engage with the neuroscience community both at WUSTL and beyond by attending, summarizing, and discussing neuroscience seminars on campus throughout the semester. Specifically, students are expected to attend three neuroscience seminars over the course of the semester, and submit summaries of each seminar. Students meet twice during the semester, in week 5 and week 11, for guided discussion of the science in the seminars they attended. Additionally, students in this seminar attend two combined classes with Neuroscience Futures 1 during the first and last weeks of the semester. In both meetings, students have an opportunity to give brief presentations on their own research. The last class combines short student presentations with a keynote address from an invited speaker from within or outside the WUSTL neuroscience community. Credit 1 unit. **M. Kundel**

Biol 4935 Undergraduate Research Perspectives (fall/spring)

The purpose of this course is for undergraduates to acquire a broad perspective on their hands-on research. What are your big questions? How will you communicate your discoveries? How do your results fit with what has gone before? Each semester will have a focus, which might be science communication, statistics, or critical reading, for example. Required activities may include weekly writing, participation in the undergraduate poster session, research, presentations, and attendance. Enrollment is by permission only from Joan Strassmann. This course is required for undergraduates conducting research in the Queller/Strassmann laboratories and is open to other students involved in research. Credit 1-3 unit. **D. Queller, J. Strassmann**

Biol 4936 Seminars in Ecology and Evolution (fall/spring)

What: At least once a week there are seminars from researchers in ecology or evolution. These seminars are given by local people and by visitors. This semester there are also a number of presentations by job candidates. The point of these seminars is to learn about exciting research. What questions are they asking? What are they discovering? What new scientific stories can we hear about ecology or evolution? What makes up these fields anyway? The seminars are often followed by receptions, which are a chance to get to know each other better and to ask questions. This course invites undergraduates to listen to these presentations and write about them. After all, this is a major part of the ideas climate at Wash U. It would be a great idea to get in the habit of going to seminars, with this course, or without. In addition to attending seminars, we will meet three times during the semester, early on and a couple of times later. When: Most seminars are 4:00 on Thursdays, though some are on other days. The three meetings will be arranged at a time that works for the students in the course. Small class. Pre-requisites: Biol 2960 and Biol 2970. No final. Credit 1.0 unit. **C. Botero**

Biol 500/500A Independent Research (spring/fall)

Research under the supervision of a faculty sponsor. Prerequisites: junior or senior standing and permission of sponsor and the department. Credit/No Credit or Audit grade options; credit to be determined in each case, usually 3 units/semester and not to exceed 3 units/semester; may be repeated for credit. Because this course has a large number of sections, some sections are listed and enrolled as Biol 500A. If work is to be submitted for Latin honors, see p. 3 of this handbook. Arrangements for registration should be completed during the preregistration period through the Biol 500 course website: <http://www.nslc.wustl.edu/courses/bio500/bio500.html>. Credit 2-3 units per semester. **K. Olsen**

Biol 500S/500T Independent Research (summer)

Summer research under the supervision of a faculty sponsor. Prerequisites: junior or senior standing and permission of sponsor and the department. Credit to be determined in each case, usually 3 units/summer; may be repeated for credit in different summers. Because this course has a large number of sections, some sections are listed and enrolled as Biol 500T. Credits are received in the fall semester following the summer research. If work is to be submitted for Latin honors, see p. 3 of this handbook. Arrangements for registration should be completed no later than the end of Summer Session I through the Bio 500 website: <http://www.nslc.wustl.edu/courses/bio500/bio500.html>. Credit/No Credit or Audit grade options. Course may not be taken for a letter grade. Credit usually 3 units per summer. **K. Olsen**

SUMMER SCHOOL AT WASHINGTON UNIVERSITY

Most first-year science courses (Biol 2960-2970, Chem 111A-112A, Chem 151-152, Phys 117A-118A) are offered during the summer at WU, as are organic chemistry (Chem 261-262) and calculus (Math 131, 132, and 233). A student who has withdrawn from or had a difficult time in freshman chemistry or calculus should consider retaking that course during the summer. Students interested in biophysics/biochemistry also should consider taking Phys 117A-118A in the summer after the freshman year, as should students interested in studying overseas during junior year. Upper-level courses that are usually (but not always) given in the summer include Microbiology Laboratory (Biol 3491) and General Biochemistry (Biol 451). Biol 3491 is given in an all-day lab format during the three-week May-June session (Summer Session 1). This course can be a very useful prelude to summer research. Consult the Summer School catalogue (which usually is available in March) or check with the relevant faculty to determine whether an upper-level course of interest is going to be available in a particular summer.

HELP IN BIOLOGY

The first rule for doing well in a biology course is to keep up with the lectures and assignments. Lectures almost always cover material not in the text; regular attendance is important.

If you miss a lecture or wish to review a lecture, video recordings of lectures from Biol 2960, 2970 and some of the other large courses are available at course websites. Completing your reading and problem sets in a timely fashion will make lecture and lab much more meaningful.

If you have difficulty with a course, your first resources are your friends who are also enrolled in the course and the TA. Be sure to attend all discussion and review sessions with the TA, and be prepared to ask questions about aspects you do not understand. Working in small groups is an effective way to tackle problem sets, but only if every group member participates. Tutorial help for individuals and small groups is available from the Department for Biol 2960 and Biol 2970; contact Kathy Hafer (x5-4424; hafer@biology.wustl.edu) for more information. Tutorial rooms are available in the Natural Sciences Learning Center (schedule with Patrick Clark, x5-6881; pclark@biology2.wustl.edu). Note that all TA's hold office hours and they will be happy to work with you. In more advanced classes, problems should be discussed with the TA and then with the instructor. Tutorial assistance is available on a needs-based fee schedule through the Student Education Service (x5-5970).

Hints in Taking Exams

In university science courses you will be asked not simply to remember information, but to use new information and new experimental tools to solve problems. Some students have difficulty on exams that require problem solving. The following techniques may eliminate sources of error:

1. Scan the test at the start. Do the easy questions first.
2. Write down something for every question, even if just to indicate the line of reasoning one would pursue. Most math/science graders give partial credit.
3. Read the question carefully. After you have completed your answer, go back and read the question again to be sure that you have covered all components requested.
4. Show your work. Even if you can work the problem in your head, write down the general principle or relationship you are using. Then indicate how the input numbers get your numerical answer. This information usually will get some points even if you make an arithmetic error.
5. Check your answer in the following ways: does it make sense in the real world? (i.e., the number of DNA copies of a gene can never be less than one); is a numerical answer in the right ballpark - right order of magnitude? Does it have the correct physical units?
6. Do not leave a test early until you have done all of the above and have carefully reread the questions and your answers.

Biology Student Affairs Office

Erin Gerrity and Patrick Clark operate the Biology Student Affairs Office in Jeanette Goldfarb 105. Erin Gerrity is the person to see to declare a major in biology and to obtain a Biology advisor. She also edits BIORhythms (<http://wubio.wustl.edu/BIORhythms>), the undergraduate biology newsletter, which includes items submitted by students. Patrick Clark checks students' records for completion of graduation requirements for the biology major and minor and determines eligibility for Latin honors. To register for a class that requires "permission of the department," you must see Mr. Clark. Lab courses are limited by the size of our teaching labs, and some upper-level courses are limited in size to encourage discussion.

Natural Sciences Learning Center

The NSLC is a study center for undergraduates located close to the teaching laboratories and classrooms. It includes a student lounge, a computer classroom, a conference room, eight multipurpose rooms for TA's office hours and study groups. The Center is a "home base" for our freshman and sophomore students taking Bio 2960 and Bio 2970 (Principles of Biology I & II).

A second use of NSLC is to bring together information on careers, internships and research programs of interest to biology majors. This information is displayed and kept on file in the NSLC.

The NSLC is located in Room 104-117 on the ground floor of the Life Sciences Building. Hours are Monday - Thursday 9 am - midnight, Friday 9 am -6 pm, and Sunday 4 PM - midnight (closed on Saturday). Visit our homepage at <http://www.nslc.wustl.edu> for more information about NSLC, Biology Courses, Student Research Opportunities, Biology Majors and the Biology Department; the WWW version of this Handbook can also be found at the NSLC homepage.

Biology Library

Most of our library materials, including access to most journals, are available electronically at Olin Library's Life Sciences web page: <https://library.wustl.edu/category/biology-news>. For help

in using these resources, contact biology librarian Ruth Lewis at Olin Library: 935-4819, e-mail rlewis@wustl.edu.

BIOLOGY CLUB

The activity level of the undergraduate Biology Club at Washington University varies from year to year, depending on the interests and energy of the students. Past activities have included career seminars, local field trips, and volunteer science demonstrations in local schools. Students interested in the Biology Club should contact Dr. Wilhelm Cruz (x5-5436 or cruzws@biology.wustl.edu). For information on science-outreach activities, contact Vicki May (x5-6846; may@biology.wustl.edu).

FACULTY AND STAFF

Biology Department Faculty

For research interests of biology faculty, see <http://www.biology.wustl.edu/faculty/index.php>

- Roger N. Beachy, Professor, Ph.D., Michigan State University, 1973. Gene expression and genetic transformation in plants. Office: Busch Laboratory 254; x5-8529; e-mail: RBeachy@wustl.edu
- April E. Bednarski, Lecturer, Ph.D., University of Michigan, 2001. Enzyme mechanisms. Office: Life Sciences 305; x5-9117; e-mail: aprilb@wustl.edu
- Yehuda Ben-Shahar, Associate Professor, Ph.D., University of Illinois, 2002. Behavioral genetics of *Drosophila melanogaster*. Office: Monsanto 411; x5-3484; e-mail: benshahary@wustl.edu
- Robert E. Blankenship, Professor, Ph.D., University of California at Berkeley, 1975. Biochemistry and evolution of photosynthesis and nitrogen fixation in bacteria. Office: McDonnell 232; x5-7971; e-mail: blankenship@wustl.edu
- Joshua A. V. D. Blodgett, Assistant Professor, Ph.D., University of Illinois, 2007. Microbiology. Office: Rebstock 220; x5-6233; e-mail: jblodgett@wustl.edu
- Arpita Bose, Assistant Professor, Ph.D., University of Illinois, 2008. Microbiology. Office: Rebstock 313; x5-6236; e-mail: abose@wustl.edu
- Carlos A. Botero, Assistant Professor, Ph.D., Cornell University, 2007. Ecology and evolution of adaptation to changing environments. Office: McDonnell 334; x5-4711; e-mail: cbotero@wustl.edu
- Stanton Braude, Professor of Practice, Ph.D., University of Michigan, 1991. Behavioral ecology. Office: McDonnell 306; x5-7352; e-mail: braude@biology.wustl.edu
- Bruce Carlson, Associate Professor, Ph.D., Cornell University, 2003. Electrophysiology and neuroanatomy of electrosensory systems in fish. Office: Monsanto 415; x5-3486; e-mail: carlson.bruce@gmail.com
- Douglas L. Chalker, Professor, Ph.D., University of California at Irvine, 1992. Developmentally regulated genomic rearrangements in ciliated protozoa. Office: Monsanto 304; x5-8838; e-mail: dchalker@biology2.wustl.edu
- Wilhelm S. Cruz, Lecturer, Ph.D., St. Louis University, 1999. Biochemistry and molecular biology. Office: Rebstock 130; x5-5436; e-mail: cruzws@biology.wustl.edu
- Ram Dixit, Associate Professor, Ph.D., Cornell University, 1999. Cytoskeletal control of plant cell form and function. Office: McDonnell 216; x5-8823; e-mail: ramdixit@biology2.wustl.edu
- Ian Duncan, Professor, Ph.D., University of Washington, 1978. Genetics: genes controlling segmentation in *Drosophila*. Office: McDonnell 122; x5-6719; e-mail: duncan@biology.wustl.edu
- Sarah C.R. Elgin, Professor, Ph.D., Caltech, 1971. Chromatin structure and gene expression in *Drosophila*. Office: McDonnell 131; x5-5348; e-mail: selgin@biology.wustl.edu
- Kathleen Hafer, Professor of Practice, Ph.D., Washington University, 1990. Microbial genetics. Office: Life Sciences 102; x5-4424; e-mail: hafer@biology.wustl.edu
- Kathleen Hanes, Lecturer, Ph.D., University of Florida, 2003. Marine ecology. Office: Life Sciences 303; x5-4586; e-mail: khanes@wustl.edu
- Daniel F. Hanson, Lecturer, Ph.D., Johns Hopkins University, 1982. Immunology. Office: McDonnell 116; x5-7306; e-mail: hanson@biology2.wustl.edu
- Elizabeth Haswell, Associate Professor, Ph.D., University of California at San Francisco, 2000. Mechanical signal transduction in plants. Office: McDonnell 221; x5-9223; e-mail: ehaswell@biology2.wustl.edu
- Keith Hengen, Assistant Professor, Ph.D., University of Wisconsin, 2010. Self-organization of intact neural networks that support sensation, perception, and cognition. Office: Monsanto 211; x5-4711; e-mail: khengen@wustl.edu
- Erik D. Herzog, Professor, Ph.D., Syracuse University, 1994. Neural basis of visually guided and circadian behaviors. Office: Monsanto 204; x5-8635; e-mail: herzog@biology.wustl.edu

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 Hani Zaher, Associate Professor, Ph.D. Simon Fraser University, 2007. Molecular biology and biochemistry. Office: Monsanto 508A; x5-7662; e-mail: hzaher@biology2.wustl.edu

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