

Biology Student Handbook 2018-19

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I. Biology Department Faculty & Staff

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- Evolutionary developmental biology; developmental genetics

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- Physiology, Exercise Physiology, Bioenergetics

Susanne Altermann, Senior Lecturer (Sci 166): 522-4430; altermsm@whitman.edu

- Ecology and evolution, especially symbioses in lichens and plant galls

Heidi Dobson, Professor (Sci 201): 527-5141; dobsonhe@whitman.edu

- Botany, plant ecology

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- Microbiology, cell biology, nutrition

Delbert Hutchison, Associate Professor (Sci 209): 527-5135; hutchidw@whitman.edu

- Evolutionary biology, population genetics, natural history, conservation biology

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- Herpetology, vertebrate anatomy, systematics and biodiversity (on leave Spring semester 2018)

Leena Knight, Associate Professor (Sci 366): 527-4965; knightls@whitman.edu

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- Cognitive neuroscience, systems neurophysiology, biostatistics

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- Plant hormone signaling pathways, cell signaling dynamics, synthetic biology

Tim Parker, Associate Professor & Chair (Sci 210): 526-4777; parkerth@whitman.edu

- Ecology, natural history, avian evolutionary ecology, scientific inference

Dan Vernon, Professor (Sci 311): 527-5326; vernondm@whitman.edu (on leave Spring semester 2018)

- Molecular biology, plant developmental genetics and genomics

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- Neurobiology, developmental biology

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Visiting faculty members, Consult the current college catalog for the full listing of biology faculty for the current year: <http://www.whitman.edu/academics/catalog/courses-of-instruction/biology>

II. Curriculum

Biology Department Learning Goals for Majors:

Upon graduation,

- **Students will understand core biological concepts including:**
 - evolution (the process creating the diversity of life-forms and the phylogenetic relationships among major groups)
 - structure and function (the basic units of biological structures that control the functions of living things)
 - information flow, exchange and storage (the influence of genetics on the control of the development of phenotypes)
 - pathways and transformations of energy and matter (the ways in which chemical transformation pathways and the laws of thermodynamics govern biological systems)
 - the nature of complex systems.
- **Students will be capable of understanding, interpreting, and critically evaluating scientific information presented in multiple forms (e.g., numeric, graphical, written)**
- **Students will be capable of conducting a structured scientific inquiry and thoroughly communicating scientific biological knowledge**

The Biology Major at Whitman College:

Biology courses deal with the science of living organisms in their various forms and their interactions with their environments. The curriculum emphasizes the integration of biological investigation all levels from molecular to ecological, with evolution as a unifying theme. To engage students in the scientific process, we require all seniors to complete a year-long research project that includes lab and/or field work, thesis writing, and scientific communication. The department serves students who expect to work in a biological field or related profession such as medicine, as well as those who elect biology as part of their general education. (See <http://www.whitman.edu/academics/courses-of-study/biology>)

Required courses for the Biology major:

Required Courses Outside the Major:

Chemistry 125, 126, 135, 136, or Chemistry 140; 245; and demonstrated mastery of either two semesters of college calculus (Math 125 and 126) or one semester each of college calculus and statistics (Mathematics 125 or 247, Economics 227, Psychology 210, Sociology 208).

Major Courses:

A minimum of 33 credits in biology, including Biology 111, 112, 205, 206; four credits from each of the three categories of upper-level courses (Molecular/Cell Biology, Organismal Biology, Ecology/Evolution); 489; 490 or 498; 499; and additional courses in biology and/or BBMB courses numbered 200 or above to earn a minimum total of 33 credits in biology and/or BBMB. Departmental policy does not allow a P-D-F grade option for biology or BBMB courses that count toward the major. Course descriptions are given in the College Catalog (<http://www.whitman.edu/content/catalog>).

Senior Year Requirements:

The Senior Assessment consists of oral and written components. Oral component: a one-hour exam administered by a committee of biology faculty. Written component: Students must take the biology MFT and score in the 70th percentile or above (see additional information starting on page 8).

The capstone experience for senior Biology majors involves the research thesis. Seniors must complete a research project, work with their thesis advisors to analyze their data (Bio 489), write a research thesis describing the work and present their findings as a seminar to the department (Biol 490). Seniors are also required to register for and attend seminar (Bio 499). (See Section IV for additional information).

Advice on Curricular Planning:

The department recommends that students considering a major program in biology consult with a biology adviser and begin with Chemistry 125, 126, 135, 136; or 140; Mathematics 125 and 126 or statistics; and Biology 111 or 112; Chemistry 245; Biology 205, 206. For those planning to pursue most graduate programs in biology, a year of physics (with labs), a full year in organic chemistry, a year of foreign language, as well as statistics and competency with computers are highly recommended.

Biology/BBMB Courses

Consult the college catalog (<http://www.whitman.edu/academics/catalog/courses-of-instruction/biology>) and the search for classes link on the Whitman website (<http://www.whitman.edu/students>) to identify available classes.

III. Study Abroad

Biology faculty encourage off-campus studies, which are particularly feasible if all supporting courses (Chemistry and Mathematics/Statistics) and the introductory courses (111, 112, 205) are completed by the end of the sophomore year. We strongly encourage majors considering off-campus study to work their academic advisor in a timely manner to make sure off-campus study in your junior fits into your plans and leaves time for fulfilling all graduation requirements.

Your academic advisor and the staff at the Off-Campus Study Center can help you determine which courses taken abroad may work to satisfy distribution requirements or major requirements. The organization of upper-level course requirements into three categories makes it possible for major courses taken elsewhere to satisfy the requirements for the major. However, such course must be approved before you leave to study off-campus. We recommend strongly against taking courses for the major at sites where instruction takes place in languages other than English, or the primary language of the student (assessed on a case-by-case basis).

Biology majors have a range of options for off-campus study. The Off-Campus Study Center is continually updating approved partner programs, so please see their most current list on their website. Below is a representative list of a few programs that our students have successfully incorporated into their Whitman education.

School for Field Studies (SFS) See <http://www.fieldstudies.org/>

SFS creates transformative study abroad experiences through field-based learning and research. Their educational programs explore the human and ecological dimensions of the complex environmental problems faced by their local partners, contributing to sustainable solutions in the places where students live and work. The SFS community is part of a growing network of individuals and institutions committed to environmental stewardship. A primary feature of the SFS program are their multi-year Directed Research projects designed to accumulate substantive data and results based on

student research which serve to address local needs. This program is designed for a wide range of majors, but with an over-arching environmental focus. You are able to derive a thesis from the project done in this program. Just make sure the project is biological in focus and not centered on some socio-political aspect of the Direct Research project.

Organization for Tropical Studies (OTS) See ots.ac.cr/

In the early 1960's, scientists from U.S. universities forged working relationships with colleagues at the Universidad de Costa Rica in the interest of strengthening education and research in tropical biology. Intense interest both in the U.S. and Costa Rica led to the founding of OTS in 1963 to provide leadership in education, research and the responsible use of natural resources in the tropics. To address this mission, OTS conducts graduate and undergraduate education, facilitates research, participates in tropical forest conservation, maintains three biological stations in Costa Rica and conducts environmental education programs. OTS owns and operated three biological stations in Costa Rica (La Selva, Palo Verde, and Las Cruces Biological Stations), all of which are affiliated with the Organization of Biological Field Stations to promote interchange of professionals for biological research and education. Studies at OTS are intensely focused on biological study and are meant primarily for biology majors with prior study. You are able to derive a thesis from the project done on this program.

School for International Training (SIT) See <http://www.sit.edu/>

A pioneer in experiential, field-based study abroad, SIT offers semester and summer programs in more than 40 countries in Asia and the Pacific, Africa, Europe, Latin America, and the Middle East, focused on critical global issues with opportunities for undergraduate research. SIT prepares students to be effective intercultural leaders, professionals, and citizens. In so doing, SIT fosters a worldwide network of individuals and organizations committed to responsible global citizenship. This program is designed for a wide range of majors and includes many programs of study. However, at least seven sites offer biologically-related field programs in places such as Madagascar, Tanzania, Australia, Viet Nam, Cambodia, Brazil, and Panama. Primary features of SIT include home stay visits and independent research projects tailored to student interests. You are able to derive a thesis from the project done on this program. Just make sure to coordinate with the faculty abroad to design a biologically-related project.

DIS (Danish Institute for Study Abroad) See <http://www.dis.dk/>

Based in Copenhagen, Denmark, DIS is designed for students exploring career opportunities within Biotechnology & Biomedicine. Students take a core course in a specific area of interest and then electives from a wide range of offerings, all taught in English. The program includes extended study tours to offer insight into biotechnology-based methods for diagnosis and treatment of disease; an understanding of the dynamics of drug discovery and development; and an interdisciplinary perspective on how biotech research and biotech business work together. Students also take a course in Danish language and culture. Thesis projects are not a main focus of this program, although the possibilities exist for independent research or extended stays dedicated to research (ask the program coordinators for more information).

Universities

There are a number of international universities (e.g., University of Otago in New Zealand or University of Edinburgh in Scotland) where our students have elected to complete off-campus studies. These research institutions offer few research opportunities that can serve as thesis projects. Therefore we strongly encourage taking courses that will fulfill distribution requirements or major requirements and/or take courses that expose you to the uniqueness of that area (e.g., ecology with field trips).

IV. Senior Year Requirements

The senior year is a busy time with several requirements and key dates to keep in mind. A **SENIOR-YEAR REQUIREMENTS FOR GRADUATION** document with accurate dates is posted to the Biology Majors' CLEo page each year in the "Senior Folder". **The key to a successful senior experience is organization and time management.**

A. Degree candidacy declaration

This form comes from the Registrar's office and must be completed by all seniors intending to graduate. It is typically due in early November and you will receive the form in the mail from the Registrar. Please consult the registrar's office for the exact due date for your senior year. For December graduation, you must submit this form by the end of the preceding February.

B. Senior Assessment in Biology

1) **Writtens:** The Biology department offers two options for the written exam. Students may take EITHER the MFT (Major Field Test) or the GRE (Graduate Record Exam). The content of these exams is very similar. We allow the GRE primarily so that students wishing to take the GRE in preparation for applying to graduate school do not have to take two similar exams. **THE BIOLOGY DEPARTMENT RECOMMENDS THE MFT** unless you are planning to apply to graduate school.

MFT exam in Biology (recommended option)

The department will hold the MFT exam on the first Saturday after the start of classes in January.

To pass the MFT, the student must score in the 70th percentile* or above

To qualify for distinction on senior exams, the student must score 98th percentile* (if a Biology major) or 96th percentile* (if a Biology combined major) or above

*The percentile is calculated across all college seniors taking the biology MFT across the United States.

GRE subject exam in Biology

The department does NOT hold the GRE exam. Students must register
ETS holds GRE exams in September, October, and April. If you wish to take the GRE as your senior written exam, you must take the exam in September or October. Registration should be done online by mid-August (for the Sept exam) or by mid-September (for the Oct exam) at <http://www.ets.org/gre/subject/register>

If you register for the GRE, be sure to designate that your scores should be released to Whitman College.

Please see **Appendix A** for a list of specific topics covered.

To Pass the GRE, the student must score in the 30th percentile^ or above

To qualify for distinction on senior exams, the student must score 85th percentile^ or above

^ The percentile is calculated across all students taking the biology GRE worldwide. The population of students taking the GRE is much different than the population taking the MFT. The

GRE is taken primarily by students who plan to pursue graduate study. Thus percentile scores on the GRE tend to be much lower than percentile scores on the MFT. The percentile thresholds set by the Whitman Biology Department for the GRE and for the MFT lead to a similar proportion of Whitman Students passing the exam and crossing the distinction threshold.

2) Departmental comprehensive oral exam

The department will schedule your oral exam and you will be notified of the date, time, location, and the faculty serving on your examination committee at least two weeks prior to the exam date.

The purpose of the exam is to gauge your overall grasp of fundamental biological principles and concepts by assessing your ability to think on your feet and to discuss biological principles using the vocabulary of the field. Faculty members are looking for basic knowledge and the ability to synthesis concepts. There is NOT a pre-determined set of questions for any exam; questions may come from any area in Biology, but will tend to come from the topics covered in the introductory courses, although some may venture into other well knows areas of biology. You may be asked to draw structures or diagrams on the board. You may ask examiners to clarify questions. We do not expect you to know the answer to all questions. As we explore the boundaries of your knowledge and understanding, you will encounter questions that you cannot answer unaided. The oral exam will last ~ 50 minutes, after which the committee ask you to step outside briefly while they discuss your exam. You will be informed immediately thereafter of the results, which may take the form of pass with distinction, pass, or no-pass. Passing with distinction signals a truly impressive performance. A no-pass necessitates a retake of the exam after a period of not less than two weeks, during which time the student should prepare for the next exam.

Senior oral exams are excused absences. If your scheduled exam conflicts with a class, please inform your professor that you will miss class for your exam.

Approximately half the exams for occur in the fall (Oct – Nov) with the other half beginning in early February. You will be randomly assigned two members of the biology faculty (2-3 faculty members for Bio-ES majors). Should you prefer fall vs spring (or vice versa), please contact Emily Hamada (hamadaeo@whitman.edu) to inform her of your preference. We will attempt to respect your preference, but we reserve the right to override student preference if scheduling requires.

C. Senior Research, Thesis and Seminar (Biology 489, 490, 499)

All Biology students must do a research project in some area of the biological sciences. Theses generally involve testing a hypothesis, but may also take the form of appropriate descriptive work. Projects may involve laboratory or field work, clinical or epidemiologic research, or data analysis of previously collected data. The Whitman Biology Department is flexible with regard to this requirement: there is no predetermined minimum number of hours for an acceptable research project; projects can (hypothetically) be done at any time during a student's last 2-3 years at Whitman, including during an academic year or over a summer; and the work may take place with

a member of the Whitman faculty or under the supervision of a qualified advisor off-campus. The important thing is to take part in a supervised research project for which you obtain and/or analyze data, and then to communicate your results in a written senior thesis and research seminar presentation. Projects do need to be approved in advance by a Biology advisor for use as a thesis project.

You should start thinking about finding a research project NO LATER THAN the fall of your junior year. If you wish to work with a member of the Whitman faculty, you should speak with them early to learn of research opportunities. Talk to faculty members or look at their course offerings and web pages, and contact the professor(s) who have research expertise most closely related to your own. If you are offered a research opportunity off campus, BEFORE you accept the offer, please discuss it with a Whitman faculty member whose areas of expertise most closely fit with the project. The same strategy of researching faculty interests will work to identify those professors who can best help you. For example, if you do research in molecular genetics, Prof. Vernon or Cooley might be the best research advisor; if you work in ecology, it might be Prof. Parker or Dobson. However, if you run into difficulties or change projects, you can finalize advisor arrangements any time before September of your senior year. Once you are in agreement with a member of the faculty, obtain consent and register for that advisor's section of Bio 489 in the fall of your senior year. Ideas for finding research opportunities off-campus are given in **Appendix B**, along with a list of recent senior theses and where or with whom those students did their research.

We strongly recommend against waiting for your senior year to initiate a research project. If you do wait until senior year, you will be assigned a research adviser, and you will work on a thesis project assigned by that adviser. You will NOT have the flexibility to choose your own project.

The department does not endorse student-designed projects conducted independent of expert mentorship. Mentorship from an expert (whether a Whitman professor or off-campus scientist) during the design and data gather stage (as well as the later stages) is essential to the process of developing an effective thesis. There are no funds available for student-designed projects.

Students get credit for research data processing, analysis, and writing (**Bio 489**), continued thesis work and research seminar presentation (**Bio 490**), and attendance at seminar (**Bio 499**) during the spring of the senior year. Typically, Bio 489 is taken in the fall of the senior year, while 490 and 499 are taken in the spring. December graduates, however, should take 499 in the spring of their junior year, with 489 and 490 in the fall of the senior year. Registration for 489 and 490 requires consent from your research/thesis advisor.

D. Honors in Major Study

To qualify for honors at Whitman, seniors must:

- 1) meet the college's GPA requirements, both overall (3.3) and in the major (3.5),
- 2) pass both written and oral exams with distinction, and
- 3) complete an excellent senior research thesis and give a presentation that merit honors distinction.

In biology and biology combined majors, students do NOT apply for admission to candidacy for honors. Students whose thesis earns a grade of at least A-, who pass the Senior Comprehensive Examinations with distinction, and who attain a Cumulative GPA of 3.3 and a major GPA of 3.5, may be granted Honors in Major Study by the biology department faculty. The biology department chair will notify the Registrar of those students attaining Honors in

Major Study not later than the beginning of the third week of April. Two copies of the Honors Thesis must be submitted to Penrose Library no later than Reading Day.

We hope that all students will strive to produce an excellent thesis. To achieve an excellent thesis, work with your thesis advisor to understand her/his criteria for thesis assessment. Many examples of biology honors theses are available in Penrose Library.

For those eligible for honors, when the thesis is almost in final form (early April), the Department Chair will assign two other members of the Biology faculty to read the final draft. You will be notified of the readers and when to distribute copies to them for their input. After you get comments back from the readers, you will discuss suggested revisions with your advisor and finalize your thesis. Mind the format: check with Penrose Library (<https://library.whitman.edu/honors-thesis/>) and the registrar's office to learn about the many institutional rules for Honors theses (e.g., paper requirements, special formatting, exact due date, etc). Submit copies of your properly formatted and printed thesis to your thesis advisor for final signatures and to Penrose library *before the end of classes*. Your thesis advisor will determine your final grade.

If you earn honors, the registrar will retroactively change your registration in BIOL 490 to BIOL 498. This is an automatic process and requires no action from you.

Appendix A: MFT information

THE BIOLOGY MFT (Major Field Test) – for the most up-to-date information, go to <https://www.ets.org/mft/about/content/biology>

The Major Field Test in Biology contains about 150 multiple-choice questions, a number of which are grouped in sets and based on descriptions of laboratory and field situations, diagrams or experimental results. The subject matter is organized into four major areas: cell biology; molecular biology and genetics; organismal biology; and population biology, evolution and ecology. Some of the questions within each of the major areas are designed to test examinees' analytical skills. Programs can choose when and where to administer the tests. It is designed to take two hours and may be split into two sessions. This test must be given by a proctor. Mathematical operations do not require the use of a calculator.

The Test Outline

I. Cell Biology (~20%)

A. Biochemistry and cell energetics (~10%): biochemical compounds and macromolecules; first and second laws of thermodynamics; enzyme activity and regulation; ATP and energy-producing pathways; post-translational modification, transmembrane insertion and sorting of proteins; cell-cell communication

B. Cellular structure, organization and function (~10%): organelles and other cellular components; cytoskeleton and cell motility; cell surfaces and membrane function; extracellular space; cell theory and germ theory; distinctions among archaeobacteria, eubacteria and eukaryotic cells; cell growth, cell cycle, mitosis and cytokinesis

II. Molecular Biology and Genetics (~20%)

A. Molecular Genetics (~14%): DNA replication and mutation; gene structure, introns and exons; regulation of gene expression; RNA transcription and modification; translation of mRNA; bacteriophages and viruses; control of normal development; cancer; molecular aspects of immunology; genetic engineering

B. Heredity (~6%): meiosis and chromosomal alterations; modes of inheritance; probability and pedigree analysis; segregation, recombination and chromosome mapping; polyploidy and aneuploidy; sex determination; non-Mendelian inheritance; prokaryote genetics

III. Organismal Biology (~33%)

A. Diversity of organisms (~9%): phylogenetic relationships, classification, morphology, life histories and general biology of bacteria and archaea, protists, fungi, plants and animals; origin of life and endosymbiont theory; fossil record and human evolution; systematic and molecular phylogeny; adaptations of organisms to habitats

B. Animal organ systems (vertebrates and invertebrates) – comparative structure, function and organization (~9%): digestion and nutrition, excretion and osmoregulation, gas exchange and ventilation, circulatory systems, support and movement, nervous and endocrine systems, integument, immune system, metabolic rates and energy

C. Animal reproduction, growth and development (~5%): reproductive structures and gametogenesis; fertilization, cleavage and gastrulation; comparative embryology; reproduction in nonchordate animals

D. Plant organ systems (seed plants and nonseed plants) – comparative structures, function and organization (~7%): roots, stems and leaves; plant energetics; water relations; mineral nutrition; translocation and storage; hormones, photoperiods and tropisms; nonphotosynthetic strategies

E. Plant reproduction, development and growth (~3%): reproductive structures, gametogenesis and sporogenesis; fertilization and alternation of generations; embryogeny and germination; meristems and growth

IV. Population Biology, Evolution and Ecology (~29%)

A. Population genetics and natural selection (~7%): genetic variability and polyploidy; distributions of genetic variability; Hardy-Weinberg equilibrium and genetic drift; heritability, fitness and adaptation; natural selection

B. Patterns of evolution (~7%): modes of speciation; isolating mechanisms; convergence, divergence and adaptive radiation; extinction; evidence for evolution; evolution of higher taxa; evolutionary rates and punctuated equilibrium; molecular evolution; neutral mutations; coevolution

C. Environmental Factors (~2%): biogeographic and temporal patterns, biomes and climates

D. Population ecology (~5%): habitat selection, tolerances, limiting factors and resource acquisition; demography and population dynamics; animal behavior

E. Community Ecology (~4%): competition, predation, parasitism and symbiosis; community structure and niche; species richness and species diversity; change and succession; introduced species

F. Ecosystems (~3%): energy flow, biochemical cycling and decomposition; productivity; food webs
G. Human Impacts (~1%): human demography; resource depletion and pollution; economic botany; habitat modification and effects on organisms; emerging diseases and endemic diseases

V. Analytical Skills (~35%)

A. Science as a way of knowing: understanding quantitative aspects and limitations of science; understanding the place of hypotheses and theories in biology; identification and testing of hypotheses

B. Experimental design: identification of variables and establishing experimental controls; ensuring that measured parameters are affected by phenomenon being studied

C. Interpretation, data analysis, inductive reasoning and drawing conclusions from data: application of information to solve a problem or make a prediction; demonstration of proficiency with quantitative concepts and familiarity with units of measure; demonstration of an understanding of probability theory and statistics; interpretation of data, graphs, tables and statistical analyses

Appendix B: GRE information

THE GRE SUBJECT EXAM IN BIOLOGY – for the most up-to-date information, go to <https://www.ets.org/gre/subject/about/content/biology>

The test contains about 200 multiple-choice questions, a number of which are grouped in sets toward the end of the test and based on descriptions of laboratory and field situations, diagrams, or experimental results.

The content of the test is organized into three major areas: cellular and molecular biology, organismal biology and ecology and evolution (See the list of topics below). Approximately equal weight is given to each of these three areas. In addition to the total score, a subscore in each of these subfield areas is reported. Subject area subdivisions indicated by Arabic numerals may not contain equal numbers of questions.

In developing questions for the test, the committee that develops the test keeps in mind both the content of typical courses taken by undergraduates and the knowledge and abilities required for graduate work in the fields related to the test. Because of the diversity of undergraduate curricula, few examinees will have encountered all of the topics in the content outline. Consequently, no examinee should expect to be able to answer all questions on the edition of the test he or she takes. The committee is aware that the three content areas are interrelated. Because of these interrelationships, individual questions or sets of questions may test more than one content area. Therefore, the relative emphases of the three areas in the following outline should not be considered definitive. Likewise, the topics listed are not intended to be all-inclusive but, rather, representative of the typical undergraduate experience.

- The test consists of approximately 200 five-choice questions, a number of which are grouped in sets toward the end of the test and are based on descriptions of laboratory and field situations, diagrams or experimental results.
- The content of the test is organized into three major areas: cellular and molecular biology, organismal biology and ecology and evolution. Approximately equal weight is given to each of these three areas. In addition to the total score, a subscore in each of these subfield areas is reported. Subject area subdivisions indicated by Arabic numerals may not contain equal numbers of questions.

The approximate distribution of questions by content category is shown below.

I. CELLULAR AND MOLECULAR BIOLOGY (33–34%)

- Fundamentals of cellular biology, genetics and molecular biology are addressed.
 - Major topics in cellular structure and function include metabolic pathways and their regulation, membrane dynamics and cell surfaces, organelles, cytoskeleton, and cell cycle.
 - Major areas in genetics and molecular biology include chromatin and chromosomal structure, genomic organization and maintenance, and the regulation of gene expression.
 - The cellular basis of immunity and the mechanisms of antigen-antibody interactions are included. Distinctions between prokaryotic and eukaryotic cells are considered where appropriate.
 - Attention is also given to experimental methodology.
1. Cellular Structure and Function (16–17%)
 1. Biological compounds
 - Macromolecular structure and bonding
 - Abiotic origin of biological molecules
 2. Enzyme activity, receptor binding and regulation
 3. Major metabolic pathways and regulation
 - Respiration, fermentation and photosynthesis
 - Synthesis and degradation of macromolecules

- Hormonal control and intracellular messengers
 - 4. Membrane dynamics and cell surfaces
 - Transport, endocytosis and exocytosis
 - Electrical potentials and transmitter substances
 - Mechanisms of cell recognition, cell junctions and plasmodesmata
 - Cell wall and extracellular matrix
 - 5. Organelles: structure, function, synthesis and targeting
 - Nucleus, mitochondria and plastids
 - Endoplasmic reticulum and ribosomes
 - Golgi apparatus and secretory vesicles
 - Lysosomes, peroxisomes and vacuoles
 - 6. Cytoskeleton, motility and shape
 - Actin-based systems
 - Microtubule-based systems
 - Intermediate filaments
 - Bacterial flagella and movement
 - 7. Cell cycle, growth, division and regulation (including signal transduction)
 - 8. Methods
 - Microscopy (e.g., electron, light, fluorescence)
 - Separation (e.g., centrifugation, gel filtration, PAGE, fluorescence-activated cell sorting [FACS])
 - Immunological (e.g., Western Blotting, immunohistochemistry, immunofluorescence)
2. Genetics and Molecular Biology (16–17%)
1. Genetic foundations
 - Mendelian inheritance
 - Pedigree analysis
 - Prokaryotic genetics (transformation, transduction and conjugation)
 - Genetic mapping
 2. Chromatin and chromosomes
 - Nucleosomes
 - Karyotypes
 - Chromosomal aberrations
 - Polytene chromosomes
 3. Genome sequence organization
 - Introns and exons
 - Single-copy and repetitive DNA
 - Transposable elements
 4. Genome maintenance
 - DNA replication
 - DNA mutation and repair
 5. Gene expression and regulation in prokaryotes and eukaryotes: mechanisms
 - The operon
 - Promoters and enhancers
 - Transcription factors
 - RNA and protein synthesis
 - Processing and modifications of both RNA and protein
 6. Gene expression and regulation: effects
 - Control of normal development
 - Cancer and oncogenes
 - Whole genome expression (e.g., microarrays)
 - Regulation of gene expression by RNAi (e.g., siRNA)
 - Epigenetics

7. Immunobiology
 - Cellular basis of immunity
 - Antibody diversity and synthesis
 - Antigen-antibody interactions
8. Bacteriophages, animal viruses and plant viruses
 - Viral genomes, replication, and assembly
 - Virus-host cell interactions
9. Recombinant DNA methodology
 - Restriction endonucleases
 - Blotting and hybridization
 - Restriction fragment length polymorphisms
 - DNA cloning, sequencing and analysis
 - Polymerase chain reaction

II. ORGANISMAL BIOLOGY (33–34%)

- The structure, physiology, behavior and development of plants and animals are addressed.
 - Topics covered include nutrient procurement and processing, gas exchange, internal transport, regulation of fluids, control mechanisms and effectors, and reproduction in autotrophic and heterotrophic organisms.
 - Examples of developmental phenomena range from fertilization through differentiation and morphogenesis.
 - Perceptions and responses to environmental stimuli are examined as they pertain to both plants and animals.
 - Major distinguishing characteristics and phylogenetic relationships of selected groups from the various kingdoms are also covered.
1. Animal Structure, Function and Organization (10%)
 1. Exchange with environment
 - Nutrient, salt and water exchange
 - Gas exchange
 - Energy
 2. Internal transport and exchange
 - Circulatory and digestive systems
 3. Support and movement
 - Support systems (external, internal and hydrostatic)
 - Movement systems (flagellar, ciliary and muscular)
 4. Integration and control mechanisms
 - Nervous and endocrine systems
 5. Behavior (communication, orientation, learning and instinct)
 6. Metabolic rates (temperature, body size and activity)
 2. Animal Reproduction and Development (6%)
 1. Reproductive structures
 2. Meiosis, gametogenesis and fertilization
 3. Early development (e.g., polarity, cleavage and gastrulation)
 4. Developmental processes (e.g., induction, determination, differentiation, morphogenesis and metamorphosis)
 5. External control mechanisms (e.g., photoperiod)
 3. Plant Structure, Function and Organization, with Emphasis on Flowering Plants (7%)
 1. Organs, tissue systems, and tissues
 2. Water transport, including absorption and transpiration
 3. Phloem transport and storage
 4. Mineral nutrition

5. Plant energetics (e.g., respiration and photosynthesis)
4. Plant Reproduction, Growth and Development, with Emphasis on Flowering Plants (5%)
 1. Reproductive structures
 2. Meiosis and sporogenesis
 3. Gametogenesis and fertilization
 4. Embryogeny and seed development
 5. Meristems, growth, morphogenesis and differentiation
 6. Control mechanisms (e.g., hormones, photoperiod and tropisms)
5. Diversity of Life (6%)
 1. Archaea
 - Morphology, physiology and identification
 2. Bacteria (including cyanobacteria)
 - Morphology, physiology, pathology and identification
 3. Protista
 - Protozoa, other heterotrophic Protista (slime molds and Oomycota) and autotrophic Protista
 - Major distinguishing characteristics
 - Phylogenetic relationships
 - Importance (e.g., eutrophication, disease)
 4. Fungi
 - Distinctive features of major phyla (vegetative, asexual and sexual reproduction)
 - Generalized life cycles
 - Importance (e.g., decomposition, biodegradation, antibiotics and pathogenicity)
 - Lichens
 5. Animalia with emphasis on major phyla
 - Major distinguishing characteristics
 - Phylogenetic relationships
 6. Plantae with emphasis on major phyla
 - Alternation of generations
 - Major distinguishing characteristics
 - Phylogenetic relationships

III. ECOLOGY AND EVOLUTION (33–34%)

- This section deals with the interactions of organisms and their environment, emphasizing biological principles at levels above the individual.
 - Ecological and evolutionary topics are given equal weight.
 - Ecological questions range from physiological adaptations to the functioning of ecosystems.
 - Although principles are emphasized, some questions may consider applications to current environmental problems.
 - Questions in evolution range from its genetic foundations through evolutionary processes to their consequences.
 - Evolution is considered at the molecular, individual, population and higher levels.
 - Principles of ecology, genetics and evolution are interrelated in many questions.
 - Some questions may require quantitative skills, including the interpretation of simple mathematical models.
1. Ecology (16–17%)
 1. Environment/organism interaction
 - Biogeographic patterns
 - Physiological ecology
 - Temporal patterns (e.g., seasonal fluctuations)
 2. Behavioral ecology

- Habitat selection
 - Mating systems
 - Social systems
 - Resource acquisition
3. Population Structure and Function
 - Population dynamics/regulation
 - Demography and life history strategies
 4. Communities
 - Direct and indirect interspecific interactions
 - Community structure and diversity
 - Change and succession
 5. Ecosystems
 - Productivity and energy flow
 - Chemical cycling
-
2. Evolution (16–17%)
 1. Genetic variability
 - Origins (mutations, linkage, recombination and chromosomal alterations)
 - Levels (e.g., polymorphism and heritability)
 - Spatial patterns (e.g., clines and ecotypes)
 - Hardy-Weinberg equilibrium
 2. Evolutionary processes
 - Gene flow and genetic drift
 - Natural selection and its dynamics
 - Levels of selection (e.g., individual and group)
 - Trade-offs and genetic correlations
 - Natural selection and genome evolution
 - Synonymous vs. nonsynonymous nucleotide ratios
 3. Evolutionary consequences
 - Fitness and adaptation
 - Speciation
 - Systematics and phylogeny
 - Convergence, divergence and extinction
 - Coevolution
 4. History of life
 - Origin of prokaryotic and eukaryotic cells
 - Fossil record
 - Paleontology and paleoecology
 - Lateral transfer of genetic sequences

Appendix C: Research Internships- Information and Examples

A. Projects at Whitman...

Many professors in Biology and BBMB secure funds to support students during the summer and sometimes during the school year. There is also a Whitman Internship Program that provides stipends to students for summer work, on a competitive basis (contact the Student Engagement Center for info on that program; deadline is in March). Environmental Studies also might procure funding from the ES program; contact Amy Molitor for more information.

B. Projects elsewhere...

You can Google "undergraduate research opportunities biology" and find lots of sites. Many of these are posted by specific universities or labs looking for undergraduates. Others sites are dedicated sites for helping you in your search:

- **Institute for Biology Education**
<http://biology.wisc.edu/Undergraduates-GettingInvolvedBeyondtheClassroom-UndergraduateResearch>
- **National Science Foundation** The biggest and most diverse collection of undergraduate research opportunities in the U.S. is the NSF's REU (Research Experience for Undergraduates) program. REU internships are full-time, paid summer research internships at numerous universities and research institutions, offered to provide opportunities for undergrads from other institutions (like Whitman). You can get info on REUs opportunities from individual universities (or university departments that host REU students), or go directly to the NSF website to get more info:
http://www.nsf.gov/crssprgm/reu/reu_search.cfm You can search for opportunities by geographic location, research topic, etc. There are REU programs are all over the U.S., including the Northwest.
- **NIH Summer Research Program** (any of the National Institutes of Health)
<http://www.training.nih.gov/student/internship/internship.asp>
- **Institute for Broadening Participation (Science, Technology, Engineering, Medicine)**
<http://www.pathwaystoscience.org/>
- **HHMI (Howard Hughes Medical Institute)**
<http://www.hhmi.org/grants/office/undergrad/#undergrad>

For some other sites that sometimes post summer opportunities, see below: **Appendix C: Post-Graduation Plans- section A. JOB SEARCHING**

The department also receives many email announcements of research opportunities throughout the year. These are forwarded to the biology student list-serve, so pay attention for those announcements as well.

You may also wish to contact researchers at universities, government agencies, or other institutions in your home town or in some location you would like to spend the summer. Some of these people may have money to hire summer researchers, and others may at least be willing to have volunteers work in their labs.

Examples of Biology Senior Research Projects from recent years:

** Parenthetic text indicates with whom or where research was conducted.

Addis, B. 2009. Potential association between leaf functional traits and frost resistance in woody tropical plants. (School for Field Studies, Queensland, Australia; Heidi Dobson)

Aegerter, E.R. 2010. Mapping gaze-related cortical projections in the mouse using microstimulation and anterograde tract tracing. (Knight Lab)

Ballinger, K. 2011. The influence of site fidelity on avian vocal culture. (Tim Parker)

Chock, T. 2012. Osmolyte Composition and Skeletal Matrix Structure of Salinity- and pH-resistant Yucatan Corals. (w/ Paul Yancey at the Hawaiian Institute of Marine Biology)

Conner, E. 2009. Na-APR-1 Protein Folding Dynamics and a Potential Human Hookworm Vaccine. (Kansas University Med. Center; Ginger Withers)

Dethier, L. 2010. Conservation concerns for *Elysa stirlingi* populations in the North Johnstone River. (School for Field Studies in Queensland, Australia; Tim Parker)

Gerringer, M. 2012. Proximate chemistry of buoyant gel tissues in demersal and benthic deep-sea fishes [poster presented at SICB conference Charleston 2012]. (w/ Paul Yancey at University of Hawaii)

Guggenheim, J. 2011. The contact mediated role of astrocytes in dendritic growth and development. (Ginger Withers)

Gurche, P. 2011. In search of desert beaver: An assessment of *Castor canadensis* in the Lower Escalante River Watershed. (Utah Division of Wildlife Resources; Delbert Hutchison)

Hart, D.G. Identifying genes required for germ cell rearrangement in the *C. elegans* gonad. (Fred Hutchinson Cancer Institute; Kendra Golden)

Hennessey, S. 2011. Phylogenetic analysis of the collared lizard (*Crotaphytus collaris*) in the eastern portion of its range. (Delbert Hutchison)

Hodges, J.E. 2011. *Manduca sexta* morbidity and mortality in response to infections of live *E. coli* and *B. cereus*, heat-inactivated bacteria, specific bacteriophages, and bacterial cell wall components. (Kendra Golden)

Judkins, S, 2010. Spore germination delay in *Botrytis cinerea* by sunflower pollenkitt through volatile exposure and direct contact. (Heidi Dobson)

Klaassen, J. 2011. Optimal newborn screening for cystic fibrosis using the immunoreactive test. (Washington State Department of Newborn Screening; Delbert Hutchison)

Knox, A. 2010. Ecological and phylogenetic influences on maxillary dentition in snakes. [Published in *Phyllomedusa* 9(2):121-131]. (Kate Jackson)

Korsmo, E. 2011. The Effects of a phage treatment on the immune response of *Manduca sexta* infected with *E. coli*. (Kendra Golden)

Last, M. 2010. Transcriptional Regulation by TBP, TBPL1, TBPL2 and RNA pol II in Zebrafish (*Danio Rerio*) Embryogenesis. (University of Utah; Dan Vernon)

- Laxson, C. 2010. Increasing TMAO:Urea Ratios with Depth in Chondrichthyes: A Physiological Depth Limit? [Talk at international deep-sea Bio conf. Iceland 2010; Published 2011] (University of Hawaii; Paul Yancey)
- Mai, D. 2011. The role of UbpA, a deubiquitinating enzyme, in *Dictyostelium discoideum* development. (Walla Walla University; Kendra Golden)
- Mantilla, B. 2010. Assessing neuronal loss in fetuses after recovery from binge exposure to alcohol. (University of Otago, New Zealand; Leena Knight)
- Momany, C. 2011. Relative expression and cloning of the Pate gene family in *Mus musculus*. (WSU-Riverside, Spokane; Dan Vernon)
- Montminy, T. 2011. Neural activity within in anterior cingulate cortex: encoding of recent outcome/reward ratios, and learning the correct behavior decision. (The Neuroscience Institute; Tom Knight)
- Moore, K. 2010. A quantitative analysis of two scale characteristics in snakes. [Published in *Amphibia-Reptilia* 31:175-182]. (w/ Kate Jackson at Royal Museum of Africa in Belgium)
- Moyer, K. 2010. Phylogenetic relationships among the Stiletto Snakes (genus *Atractaspis*) based on external morphology. [Published in the *African Journal of Herpetology*]. (w/ Kate Jackson at Royal Museum of Africa in Belgium)
- Peterson, J. 2011. Cryopreservation of *Fungia scutaria* coral larvae with the use of Trehalose liposomes. (w/ Paul Yancey at Hawaiian Institute of Marine Biology)
- Reinhart, C. 2011. Unravelling the complex roles of genes in the PIRL family of Arabidopsis pollen Development. (Dan Vernon)
- Richards, K. 2010. Investigating interactions with the SCREAM gene of the stomatal development pathway in Arabidopsis. (University of Washington; Dan Vernon)
- Rosenthal, E. 2010. Examining the effects of flowering synchrony on gene dispersal distance in a common Midwest prairie plant. (NSF-funded REU at the Chicago Botanic Garden; Tim Parker)
- Sampson, H. 2011. Defining the borders of the mouse M2 using microstimulation and anterograde tract tracing. (Knight Lab)
- Wakefield, B. 2011. Optimized pharmacotherapy in the treatment of pancreatic ductal carcinoma. (Fred Hutchinson Cancer Research Center in Seattle, WA; Leena Knight)

Appendix D: Post-Graduation Plans

Immediately after graduation, Biology majors choose many different paths to future careers: immediate employment in academic, governmental, biotech labs, or non-governmental organizations; assignments in the Peace Corps, Teach for America, Americorps or other volunteer/service organizations; post-graduate fellowships or internships; and graduate or professional education.

A. JOB SEARCHING

For positions in academic research labs or biotech companies, you may find positions via direct inquiry to the institution or company (either specific lab/dept or to the HR dept). Also, job placement ads are available in professional journals, such as *Science*. Some websites on which jobs are posted include:

Society for Conservation Biology: <http://www.conbio.org/jobs/>

Texas A&M Dept. of Wildlife and Fisheries Sciences job board (wildlife positions from across the US are advertised here): <http://wfscjobs.tamu.edu/job-board/>

Botanical Society of America: <http://jobs.botany.org/>

Ecological Society of America: <https://listserv.umd.edu/archives/ecolog-1.html>

Animal Behavior Society: <http://www.animalbehaviorsociety.org/web/news-members.php>

Ornithological Societies of North America: <http://www.osnabirds.org/jobs.aspx>

B. APPLYING TO GRADUATE SCHOOLS

Graduate school can lead to a Master's or Ph.D., and provide opportunities for advanced coursework and immersion in research. Students interested in pursuing graduate study in the life sciences or related fields should plan to submit applications by Dec. 1 for admission the following fall. A number of resources are available to help you with selecting and getting accepted into a graduate program. Early in the process you should talk with your adviser or another faculty member about your plans. This conversation can help sort out your interests and identify the types of program you may wish to consider. Talk with at least one faculty member whose expertise is in that area; he or she will be able to help you identify graduate programs that are strong in your area of interest and often can supplement written sources with personal knowledge about institutions and individual researchers. Faculty members also may be acquainted with the experiences of recent Whitman graduates at institutions you are considering.

There are several valuable references available on graduate programs. Keep in mind, however, that your graduate school experience is more a function of your laboratory, your graduate advisor, and your individual accomplishments, rather than the university, department, or program.

One particularly useful source is *Peterson's Guide to Graduate Programs*, issued in several volumes. Each two-page listing describes such things as programs of study, facilities, costs, financial aid, community, application procedure, and faculty. Departments offering only a masters degree are included. All of these are available on-line at

<http://www.petersons.com/GradChannel/code/search.asp?path=gr.fas.grad>

Each year we receive numerous flyers and pamphlets and some catalogs from graduate programs. This information is placed in a few places:

- On the bulletin board outside the Biol111 lab
- Botany-related announcements are placed in the bulleting board outside the office of Heidi Dobson (Sci 201)

- Other professors may post some on their office doors or bulletin boards

Of course, online resources may be most important in your search for programs.

As you search, keep in mind that different sub-disciplines and different universities organize graduate programs and admission to these programs differently. In some cases, students apply to a department, and if accepted, they rotate among labs for a pre-determined period before selecting a lab in which to work. In other cases, students first contact advisers via email and seek admission to a lab prior to completing the formal application to the program. In this latter case, programs do not admit students who have not been endorsed by a faculty member. Thus you need to make strong impressions on the faculty members you contact. This includes demonstrating knowledge of and sincere interest in the faculty member's research, showing commitment to working in that field, and explaining how your previous experiences prepared you for graduate study in that adviser's lab. A good way to find labs is to search for research that interests you in Web of Science, journals in your areas of interest, and other web sources.

Graduate school advisors are always on the lookout for excellent graduate students. They need students for their research work, but they also need to find students that can contribute and who have the skills and talents needed for productive research work. Make sure you turn yourself into one of those people. Create a quality CV (contact your advisor and/or the Student Engagement Center for help), give poster presentation or talks (i.e., bring your present research work to a successful conclusion), gain the trust and respect of your Whitman advisor (you'll need good letters of recommendation), and get as much research experience as you can. All these steps will make you more attractive to potential graduate advisors.

When it comes time to apply, you will need to consider the following:

- Graduate Record Examination (GRE)

Many graduate schools and most fellowship programs require that applicants take BOTH GRE general and subject tests. For some programs, only the general test is required. The general tests are computer-based and offered year round at regional centers (not in Walla Walla). The subject test is the same exam you are required to take for your Biology senior assessment.

- Letters of evaluation:

Usually three evaluations will be required for each application from faculty members or research mentors who know your work well and, if possible, have taught you in recent or upper level courses. Many programs have evaluators submit letters electronically. Writing good evaluations is a demanding task. Consequently you should give those persons who will write on your behalf as much lead time as possible, but at LEAST 2-3 weeks for the first letter. Make sure they have accurate information about the program, names and addresses to whom the letters will be written, dates for submission, a copy of your CV, and a statement from you telling them why you want this opportunity, etc. Writers need good ammunition to write good letters and it is your job to give it to them. A visit with your writer can facilitate this transfer of information.

- Visit the university:

Most programs which invite you to interview will pay for your entire visit (airfare, lodging, meals). Scheduling visits during the academic year can be challenging, but it's important.

If you are fortunate enough to get an invitation, then go prepared; show up in respectful attire, have an interested and positive demeanor, and come with questions and knowledge of the program and the faculty research going on. This is your opportunity to show them how much they want you.

- Financial considerations:

You should NOT pay for graduate school in the sciences. Nearly all programs pay you and cover all or most of your tuition and related expense. Stipends vary but can exceed \$25,000 depending on the program. You WILL have to pay for graduate programs not designed to train scientific researchers (for instance professional programs such as medical schools).

C. POST-GRADUATE FELLOWSHIPS

National Science Foundation (NSF) graduate fellowships

NSF fellowships provide full support for three years of graduate study at any U.S. university. At the time of application, you must designate your first choice institution, but you are not obligated to attend that institution. These are very prestigious and therefore competitive awards. Whitman are regularly awarded these NSF fellowships, but many more students apply than are selected. Consult with your academic advisor early in your senior year.

Fellowships for International Study

Most fellowship programs for graduate study abroad require that applicants be nominated by their undergraduate institution. These include the Churchill, Fulbright, Marshall, Rhodes and Watson Fellowships. Generally these programs carry certain restrictions such as location of study and career goals. Further details may be obtained from the Post-graduate Fellowships and Grants Office in RCC.

D. HEALTH PROFESSIONS SCHOOLS

If you are considering a career in the health professions (medicine, nursing, public health pharmacy, dentistry, veterinary medicine, etc...), contact Jim Russo, Health Professions Advisor, early in your junior year. russo@whitman.edu