

# BIOLOGY

## Department of Biology

The Biology Department houses both the Biology Major and the Biotechnology Major, which is an interdisciplinary major sponsored by the Biology Department and the Chemistry Department. Within the Biology Department, students may also pursue minors in Ecology (not open to Biology majors) or Cellular & Molecular Biology (not open to Biology or Biotechnology majors). In addition, the Biology Department co-sponsors interdisciplinary minors in Psychobiology together with the Psychology Department and Bioinformatics together with the Computer Science Department; both of these minors can be elected by Biology or Biotechnology majors.

The Biology major program provides students with a broad knowledge in the biological sciences through a core curriculum and upper-level courses in specialized areas of study. A hands-on approach for teaching laboratory techniques and field work is emphasized. Throughout the program, students are encouraged to develop effective communication skills and an awareness of the societal and global implications of biology. Students interested in medical, dental, veterinary, or physician assistant school may complete a Biology major with a Pre-Medicine Concentration. The Biology Major also provides a path to meet most of the prerequisites necessary for other programs in the health professions, such as optometry, physical therapy, and pharmacy, and the Accelerated Pharmacy Program with MCPHS can be completed through the Biology major.

Undergraduate biology majors who have demonstrated academic excellence and an interest in biological research may participate in the Honors in Biology program. The Chi Iota Chapter of the national biological honor society, Beta Beta Beta, provides recognition to outstanding students majoring in Biology and Biotechnology.

- Bioinformatics Minor for Biology/Biotechnology Majors
- Bioinformatics Minor for Chemistry Majors
- Bioinformatics Minor for Computer Science Majors
- Bioinformatics Minor for non-Biology, Biotechnology, Chemistry, or Computer Science Majors
- Biology Major
- Biology Major and Prerequisites for the Accelerated Pharmacy Program with Massachusetts College of Pharmacy and Health Sciences
- Cellular & Molecular Biology Minor
- Ecology Minor
- Honors Program in Biology
- Major in Biology, Concentration in Pre-Medicine
- Psychobiology Minor

## Faculty

Latifeh Amini-Kormi, Professor (1994), B.S., Tehran University; Ph.D., University of Pennsylvania

Daron C. Barnard, Professor (2006), B.A., Middlebury College; Ph.D., Vanderbilt University

Maura Collins, Professor (2001), B.S., Worcester Polytechnic Institute; M.S., Ph.D. Rutgers University

Roger S. Greenwell, Co-Coordinator of the Biotechnology Program, Professor (2014), B.S., Western Kentucky University; Ph.D., University of Wisconsin-Madison

Aleel K. Grennan, Associate Professor (2017), B.S., University of Massachusetts; M.S., Ph.D., University of Illinois

Bradley Harris, Visiting Assistant Professor (2023), B.S., University of California, Berkeley; M.S., Kaplan University; M.D., Tufts University School of Medicine

Jennifer Hood-DeGrenier, Department Chair, Professor (2012), B.A., Williams College; Ph.D., Harvard University

Yan Hu, Associate Professor (2018), B.S., Qufu Normal University ; Ph.D., Wuhan University

Jaime G. Mancilla, Assistant Professor (2023), B.S., University of Maryland; Ph.D., University of Chicago

Steven J. Oliver, Professor (2003), B.A., University of Montana; Ph.D., Boston University

Luis Rosado, Assistant Professor (2020), B.S., Boise State University; M.S., Ph.D., University of Massachusetts Amherst

Randall Tracy, Professor (2003), B.S., M.S., University of Connecticut; Ph.D., Arizona State University

Sebastian Velez, Professor (2012), B.S., University of Puerto Rico; M.S., University of Notre Dame; Ph.D., Harvard University

## Courses

### PB-200 Introduction to Psychobiology

**LASC Categories:** HBS, NSP

**Prerequisites:** PS-101 and BI-116, or BI-140, or BI 103 and BI-104.

Introductory course in Psychobiology that covers topics including neurobiology, evolution, sensory/motor systems, learning and memory, and social behavior.

Fall only and every year. 3 Credits

### PB-400 Capstone in Psychobiology

**LASC Categories:** CAP

Seminar covering selected topics in Psychobiology including primary source material readings, laboratory activities, discussion, oral presentation and written papers.

Spring only and every year. 2 Credits

## Biology Courses (Undergraduate)

See LASC section for information on the Liberal Arts and Sciences Curriculum (LASC).

### BI-101 Concepts of Biology

**LASC Categories:** LAB, NSP

Unifying principles in biology; diversity and evolution of plant and animal life at cellular and organismic levels. Three lecture hours and a two-hour laboratory per week. Not open to Biology Majors.

Fall and Spring and every year. 4 Credits

**BI-103 The Human Animal****LASC Categories:** NSP

A general survey of the structure and function of human body systems from the biochemical and cellular basis of life to evolution of the human body and the organization of organs and organ systems, including the biological basis of selected disease states. Not open to Biology Majors. Every year. 3 Credits

**BI-104 The Human Animal Laboratory****LASC Categories:** NSP, LAB**Prerequisites or Corequisite:** BI-103

This course is the lab to accompany The Human Animal, a general survey of the structure and function of human body systems from the biochemical and cellular basis of life to evolution of the human body and the organization of organs and organ systems, including the biological basis of selected disease states. Every year. 1 Credit

**BI-109 Writing in the Natural Sciences****LASC Categories:** WR2, NSP**Prerequisites:** EN-101.

Builds upon the writing skills gained in EN-101 to introduce students to the various genres of writing in the natural sciences. Students will develop literature research skills, learn how to craft and explain an experimental proposal, and practice written, graphical, and oral presentation of data and scientific concepts to academic and lay audiences. Spring only and every year. 3 Credits

**BI-111 Social Biology****LASC Categories:** HBS, NSP

This course considers the interface between current biological technologies and the social, cultural, legal, and moral postures of modern man. Every 2-3 years. 3 Credits

**BI-112 Diseases and Mankind****LASC Categories:** GP, NSP

Diseases of ancient and modern man; the impact on history, religion, science, art and philosophy. Every 2-3 years. 3 Credits

**BI-114 Plants and Human Affairs****LASC Categories:** GP, NSP

Man's dependence upon plants and their influence on civilization and its art, religions, literature, folklore, medicine, and human behavior. Every 2-3 years. 3 Credits

**BI-116 Animal Biology****LASC Categories:** LAB, NSP

Survey of animal kingdom with emphasis on animal diversity, morphology, life histories, ecological evolutionary relationships. No credit for Biology major. Three lecture hours and two laboratory hours per week. Not open to Biology majors. Every year. 4 Credits

**BI-117 Humans and the Environment****LASC Categories:** LAB, NSP

A survey of Anthropologic environmental impacts and the underlying mechanisms involved. Three lecture hours and three laboratory hours per week. Not open to Biology or Environmental Science majors. Every 2-3 years. 4 Credits

**BI-118 Dinosaurs****LASC Categories:** NSP, LAB

A survey of dinosaurs; their evolution, anatomy, diversity and impact on evolutionary biology. discussions of the changing views of dinosaurs in the media and public consciousness. Three hours lecture and two hours lab. Every 2-3 years. 4 Credits

**BI-125 Women in Science****LASC Categories:** HBS, NSP, DAC

Examines issues related to gender in science and technology. Includes historical and recent contributions to science made by women. Every 2-3 years. 3 Credits

**BI-130 Field Biology****LASC Categories:** GP, NSP, LAB

Study-Abroad Field Biology course for non-Biology majors. Course explores the intersection of human activities and environmental preservation, with a basic introduction to topics in organismal biology, biodiversity and biogeography. Spring only and every year. 4 Credits

**BI-140 Introduction to Organismal Biology****LASC Categories:** LAB, NSP

Evolution, ecology, anatomy, physiology and diversity of organisms. Three hours lecture and three hours lab each week. Intended for STEM Majors. Fall and Spring and every year. 4 Credits

**BI-141 Intro to Cellular and Molecular Biology****LASC Categories:** NSP, LAB

**Prerequisites:** CH-120 or CH-112 with a C- or above. CH-121 is a recommended course that can be completed concurrently or previously. Cellular and molecular concepts in biology. Emphasis on the structures and functions of macromolecules and organelles. Introduction to cellular transport, signaling, metabolism, cell division, and gene expression. Three lecture hours and three laboratory hours per week. Intended for STEM Majors/Minors. Fall and Spring and every year. 4 Credits

**BI-161 Human Anatomy and Physiology I****LASC Categories:** NLL

Considers human cellular biology, tissues, integumentary, nervous, endocrine, skeletal, muscular systems. Three hours of lecture and a three-hour laboratory per week. Fall and Spring and every year. 4 Credits

**BI-162 Human Anatomy and Physiology II****LASC Categories:** LAB, NSP**Prerequisites:** BI-161.

Considers digestive, respiratory, cardiovascular, urinary, immune and lymphatic systems; water and electrolyte balance, reproduction and embryology. Three lecture hours and three laboratory hours per week. Fall and Spring and every year. 4 Credits

**BI-193 First Year Seminar Biology****LASC Categories:** FYS

Introductory level course covering topics of special interest to first year students. Offered only as a First Year Seminar. Every year. 3 Credits

**BI-199 Selected Topics: Biological Sciences**

Each topic is a lecture and/or a laboratory course in a selected area of the biological sciences presented by a departmental instructor, Topics will be announced in advance. Every 2-3 years. 1-4 Credits

**BI-200 Human Biology****LASC Categories:** NLL

**Prerequisites:** BI-140 and BI-141 or PB-200 with a grade of C- or above  
 A systemic approach to the study of human biology. The course will emphasize structure/function relationships and homeostatic mechanisms. Three hour lecture and three hour lab.  
 Fall and Spring and every year. 4 Credits

**BI-202 Principles of Ecology****LASC Categories:** NLL

**Prerequisites:** BI-140, EN-102 or BI-109, MA-150, or MA-180, or MA-190, or MA-200, with a grade of C- or above.  
 Basic ecological theory relating to organism-environment interactions; population dynamics, and ecosystems. Three hours of lecture and a three-hour laboratory per week.  
 Fall and Spring and every year. 4 Credits

**BI-203 Genetics****LASC Categories:** NLL, QAC

**Prerequisites:** BI-141 with a grade of C- or above. Must have a minimum math placement exam score of 3.  
 Introductory genetics with examples of human inheritance and recent developments in genetic engineering. Three hours of lecture and a three-hour laboratory per week.  
 Fall and Spring and every year. 4 Credits

**BI-204 Microbiology****LASC Categories:** NLL

**Prerequisites:** BI-141 and CH-121 with a grade of C- or above.  
 The cytology, metabolism, and genetics of bacteria. Immune responses and control of microorganisms are stressed. Three lectures and a three-hour laboratory per week. (Prerequisites: Introductory chemistry and biology courses)  
 Fall and Spring and every year. 4 Credits

**BI-205 Research Techniques and Experimental Design****Prerequisites:** BI-141, and MA-150.

Investigations in experimental design and research methodologies required for the Honors program in Biology (or Biotechnology).  
 Spring only and every year. 2 Credits

**BI-206 Medical Microbiology****LASC Categories:** NSP, LAB

**Prerequisites:** BI-161 and either CH-112 or CH-120 and CH-121.  
 A study of growth and control of pathogenic microorganisms with emphasis on infectious disease transmission, immune responses, prevention and treatment. Three lecture and three laboratory hours per week.  
 Fall and Spring and every year. 4 Credits

**BI-207 Public Health Microbiology****Prerequisites:** BI-161 and CH-112.

Growth and control of pathogenic microorganisms with emphasis on infectious disease transmission, immune responses, prevention and treatment for Public Health Majors.  
 Every year. 3 Credits

**BI-211 Pre-Medical Seminar: Preparing for a Career in Medicine**

A seminar that will introduce pre-medical, pre-dental, and pre-veterinary students to the requirements for admission to graduate programs in these areas. Students will develop personal plans for working toward these requirements, will interact with a variety of healthcare professionals to gain knowledge about different careers and determine which is the best fit for them, and will discuss current ethical and policy issues related to healthcare. Open only to Biology, Biotechnology, and Chemistry students with a declared Pre-Medical Concentration who have an overall GPA of at least 3.2 and a Biology/Chemistry/Math/Physics GPA of at least 3.2.  
 Fall only and every year. 1 Credit

**BI-212 Concepts of Microbiology**

**Prerequisites:** BI-206: Medical Microbiology (with a B- or higher) CH-121: General Chemistry II Only for students who transfer into the Biology or Biotechnology major and have taken BI-206: Medical Microbiology prior to switching their major.

This course introduces students to fundamental concepts in microbiology that are not emphasized in a medically-focused microbiology course, including the myriad positive and negative ways that microorganisms affect our lives and impact the world around us, microbial physiology and genetics, microbial contributions to biotechnology, microbial diversity, and evolutionary relationships and genetic exchange between microbes.  
 Other or on demand and other or on demand. 2 Credits

**BI-215 Neuroscience****LASC Categories:** NLL

**Prerequisites:** BI-161 and BI-162  
 Structural and functional organization of the human nervous system with a focus on clinical applications. Three lecture hours and three laboratory hours per week.  
 Fall only and every year. 4 Credits

**BI-240 Research Experience**

Lab and/or field based research on a specific research topic under the supervision of a faculty member. Permission of instructor required.  
 Fall and Spring. 1-6 Credits

**BI-271 Basic Kinesiology****LASC Categories:** NSP

**Prerequisites:** BI-161.  
 Structure and function of human skeletal muscles in relation to motion and general body mechanics under normal and stress conditions.  
 Spring only and every year. 3 Credits

**BI-301 Topics in Invertebrate Zoology****LASC Categories:** NLL

**Prerequisites:** BI-140 and BI-202 with a grade of C- or above.  
 Considers anatomy, taxonomy (including selected articles of the international code of zoological nomenclature), natural history, and evolutionary relationships of selected invertebrate phyla. Three hours of lecture and a three-hour laboratory per week.  
 Every 2-3 years. 4 Credits

**BI-303 Parasitology****LASC Categories:** NLL

**Prerequisites:** BI-140 and either BI-200 or BI-161 and BI-162 with a grade of C- or above.  
 Basic concepts in symbiology, life cycles, epidemiology, disease development, control and prevention of selected human parasites. Three hours of lecture and a three-hour laboratory per week.  
 Every 2-3 years. 4 Credits

**BI-304 Comparative Vertebrate Anatomy****LASC Categories:** NLL**Prerequisites:** BI-140 and either BI-200 or BI-161 and BI-162 with a grade of C- or above.

Considers prochordate and chordate taxonomy and phylogeny; systematic morphological comparison of representative chordates to establish homology, analogy, and evolution. Three lecture hours and a three-hour laboratory per week.

Every 2-3 years. 4 Credits

**BI-306 Developmental Biology****LASC Categories:** NLL**Prerequisites:** BI-141 and BI-203 with a grade of C- or above.

Study of developmental patterns, cellular differentiation and cell interactions resulting in cellular diversity, organization, and perpetuation of the germ line. Three lecture hours and three laboratory hours per week.

Every 2-3 years. 4 Credits

**BI-307 Human Movement and Perception****Prerequisites:** either BI-161 and BI-162, or BI-200 or BI-271.

This course is an introduction to the ecological perspective of human movement (action) and perception in which we will explore the philosophical roots for our contemporary views of human perception, the evolution/development of our sensory/perceptive mechanisms and compare-contrast humans with other perceptive organisms in the Animal Kingdom.

Every 2-3 years. 4 Credits

**BI-315 Comparative Neurobiology****LASC Categories:** NLL**Prerequisites:** BI-161 and BI-162 or BI-200 or PB-200 with a grade of C- or above.

Structural and functional organization of the central and peripheral nervous system. Principles of normal and abnormal transmission, integration, and storage of information in neuronal pathways. Three hours of lecture and a three-hour laboratory per week.

Every 2-3 years. 4 Credits

**BI-321 Comparative Physiology****LASC Categories:** NLL**Prerequisites:** BI-140, BI-141, and either BI-200 or BI-161 and BI-162 with a grade of C- or above.

A comparison of select physiological functions of different animal taxa with mammals used as a reference. Three lecture hours and a three-hour laboratory per week.

Every 2-3 years. 4 Credits

**BI-324 Endocrinology****LASC Categories:** NLL**Prerequisites:** BI-140, BI-141, and BI-200 or BI-161/162 with a grade of C- or above.

The role of endocrine glands in the normal integration of animals; mechanisms of hormone action, function, and interrelationships. Three hours of lecture and a three-hour laboratory per week.

Every 2-3 years. 4 Credits

**BI-331 Marine Biology****LASC Categories:** NLL**Prerequisites:** BI-140 and BI-202 with a grade of C- or above.

Considers the marine environment, its flora and fauna, distribution and production of plankton-nekton-benthos, zoogeography, bioeconomic factors and potential. Three lecture hours and a three-hour laboratory per week.

Every 2-3 years. 4 Credits

**BI-333 Topics in Vertebrate Zoology****LASC Categories:** NLL**Prerequisites:** BI-140 and BI-202 with a grade of C- or above.

Life histories, adaptations, distribution, systematics, and economic importance of selected vertebrates taxa. Each semester will focus on a particular taxon. Three hours of lecture and a three-hour laboratory per week.

Every 2-3 years. 4 Credits

**BI-334 Wildlife Biology****Prerequisites:** BI-140 and BI-202 with a grade of C- or above.

Theory and Practice of wildlife management. Considers procedures for collection and analysis of field and laboratory data on vertebrate game populations useful to wildlife biologists. Three hours of lecture and a three-hour laboratory per week.

Every 2-3 years. 4 Credits

**BI-340 Plant Sciences****LASC Categories:** NLL**Prerequisites:** BI-140 and BI-202 with a grade of C- or above.

Morphology, anatomy, physiology of flowering plants with studies on life cycles, ecological relationships, biochemical processes and evolution of plant diversity. Three lecture hours and three laboratory hours per week.

Every 2-3 years. 4 Credits

**BI-341 Mycology****LASC Categories:** NLL**Prerequisites:** BI-141 and either BI-204, or BI-206 and BI-212, with grades of C- or higher.

The morphology, cytology, and evolution and classification of the fungi. Three hours of lecture and a three-hour laboratory per week.

Every 2-3 years. 4 Credits

**BI-342 Plant Physiology****Prerequisites:** BI-141 and either BI-204, or BI-206 and BI-212, with grades of C- or higher.

Fundamentals of plant processes: nutrition, metabolism, growth, development and responses. Three hours of lecture and a three-hour laboratory per week.

Every 2-3 years. 4 Credits

**BI-354 Systematics and Evolution****LASC Categories:** LAB, NLL**Prerequisites:** BI-140 and BI-203.

Introduction to the use of morphological and molecular data to trace the evolutionary history of living things. Historical overview of the fields of taxonomy and systematics. Evolution of genes and genomes. Algorithmic and criteria-based methods for the development of phylogenetic hypotheses. Course includes lectures and projects based on computer applications. Lecture and computer laboratory.

Every 2-3 years. 4 Credits

**BI-360 Animal Behavior****LASC Categories:** NLL**Prerequisites:** BI-202 or PB-200 with a grade of C- or above.

Survey of ethology and behavioral ecology from an historical and evolutionary perspective. Laboratory involves observation, recording and analysis of animal behavior. Three lecture hours and three laboratory hours per week.

Every 2-3 years. 4 Credits

**BI-370 Lakes & Environmental Change****LASC Categories:** LAB, NSP**Prerequisites:** GS-140 Take one earth science course at the 200-level or above.

Modern Physical, ecological, and sedimentary processes in lakes. Lake sediments as archives of past climate and environmental change.

Includes fieldwork. [Cross-listed with GS-370 and EV-370]

Every 2-3 years. 4 Credits

**BI-371 Advanced Topics in Cell and Molecular Biology****LASC Categories:** NLL**Prerequisites:** BI-141 and BI-203 or BI/CH-410 with a grade of C- or above.

Examination of current topics in cell and molecular biology, including mechanisms that regulate gene expression and protein function, organization of cellular components into functional pathways, and modern experimental techniques.

Every 2-3 years. 4 Credits

**BI-372 Immunology****LASC Categories:** NLL**Prerequisites:** BI-141 and either BI-204, or BI-206 and BI-212, with grades of C- or higher.

Introduction to cellular defense mechanisms in health and disease; antigen-antibody reactions, human immune responses. Three lecture hours and three laboratory hours per week.

Every 2-3 years. 4 Credits

**BI-375 Virology****LASC Categories:** NLL**Prerequisites:** BI-141 and either BI-204, or BI-206 and BI-212, with grades of C- or higher.

Physical structure and replication schemes of viruses; role of viruses in human disease, research and commercial applications. Three lecture hours and three laboratory hours per week.

Every 2-3 years. 4 Credits

**BI-380 Biodiversity and Conservation Biology****LASC Categories:** LAB, NLL**Prerequisites:** BI-140, BI-141, BI-202, and BI-203 with a grade of C- or above.

A theoretical and quantitative approach to species, genetic, ecosystem and community diversity in the context of modern conservation biology principles. Three lecture hours and three laboratory hours per week.

Every 2-3 years. 4 Credits

**BI-398 Cancer Biology****Prerequisites:** BI-141 and BI-203 with a grade of C- or above.

Cellular and molecular basis of cancer, including cancer genetics, biochemical pathways related to cancer, and modern treatment approaches.

Every 2-3 years. 4 Credits

**BI-401 Selected Topics: Biological Sciences**

Each topic is a lecture and/or laboratory course in a selected area of the biological sciences presented by a departmental instructor and/or guest lecturers when appropriate. Topic to be announced in advance.

Every 2-3 years. 1-4 Credits

**BI-402 Independent Study: Biology**

Advanced semi-independent study (by qualified upper-level biology majors) of an approved biological problem. Faculty supervision required. (May not be used for major requirements.) Consent of department and instructor. Junior/Senior standing required.

Fall and Spring. 1-6 Credits

**BI-403 Internship: Biology**

Intended for qualified, upper-level biology majors. Faculty advisor required. (May not be used for major requirements.) Consent of department. Junior/Senior standing required.

Fall and Spring. 1-6 Credits

**BI-404 Biology Seminar****LASC Categories:** CAP**Prerequisites:** BI-202, BI-203, BI-204, BI-200 or BI-161 BI-162 with a grade of C- or above. Senior Standing also required

Preparation and presentation of biological topics, chosen with the advice and consent of a faculty advisor.

Fall and Spring and every year. 2 Credits

**BI-408 Directed Study: Biology**

Directed study offers students, who because of unusual circumstances may be unable to register for a course when offered, the opportunity to complete an existing course with an established syllabus under the direction and with agreement from a faculty member.

Other or on demand. 1-3 Credits

**BI-410 Biochemistry I****LASC Categories:** NLL**Prerequisites:** CH 201 with a grade of C- or above.

The chemistry of proteins, nucleic acids, carbohydrates, and lipids; enzymes, biological oxidations; and correlations in intermediary metabolism. Three hours of lecture and a three-hour laboratory per week. [Cross listed as CH410.]

Fall and Spring and every year. 4 Credits

**BI-411 Biochemistry II****LASC Categories:** NLL**Prerequisites:** BI-410 with a grade of C- or above.

The generation and storage of metabolic energy; biosynthesis of macromolecular precursors, DNA, RNA, and protein; and biochemical regulation. Three hours of lecture and a three-hour laboratory per week. [Cross listed as CH411.]

Every 2-3 years. 4 Credits

**BI-430 Field Biology for Majors****Prerequisites:** BI-202 with a minimum grade of C-.

Study-Abroad Field Biology course for Biology majors. Course explores the intersection of human activities and environmental preservation, with an in-depth discussion of topics in organismal biology, ecology, biodiversity and biogeography.

Spring only and every year. 4 Credits

**BI-440 Advanced Research Experience for Undergraduates****Prerequisites:** BI-205 along with 3 Biology courses at WSU. Consent of instructor required. Junior/Senior standing required.

Advanced lab and/or field based research on a specific research topic under the supervision of a faculty member.

Fall and Spring. 1-6 Credits

**Program Learning Outcomes**

- Demonstrate a working knowledge of the following core content areas:
  - Cell and molecular biology;
  - Characteristics of organisms, including human biology;
  - Principles of heredity and the evolution of life;
  - Interactions among species within ecosystems.
- Demonstrate competence in processes and practices used by professionals in the field of biology, including:

- Proper use of tools, equipment, materials, and safety procedures to execute laboratory and other experimental techniques;
  - Application of analytical skills to gather, organize, interpret and evaluate scientific data;
  - Application of critical thinking skills to design appropriate experiments to answer scientific questions and solve problems.
- Be able to effectively communicate biological observations and concepts to both lay and scientific audiences through written scientific genres (e.g. lab report/research report, literature review, poster presentation) and oral presentations.
  - Be able to discuss the historical and contemporary social implications of biology, including:
    - The effects of human activities on the environment;
    - Ethical issues that influence decisions related to biology.