Learning Goals and Outcomes in Biology

Overview
Biology is the study of organic life, from the structure and function of biomolecules through the complex evolutionary and regulatory processes of cells, organisms, populations, communities, and ecosystems. Biology students must be comfortable considering the fundamental concepts that weave through these levels of organization. In addition, our students should have the depth and breadth of knowledge to facilitate an integrative understanding of the interconnectedness and unity that make biology a cohesive discipline.

We outline the learning goals for Biology students in two parts that roughly represent differences in learning stages and pedagogical approaches. First, we stress the acquisition of areas of knowledge and the integration of fundamental concepts. These goals are achieved by the core course requirements at the 100 and 200 levels. Second, we emphasize skills of inquiry, analysis, and process in science. Opportunities for these higher learning goals are offered in the investigative labs associated with the majority of our courses, seminars that are based on primary literature, off-campus programs, and faculty-guided laboratory or field research. It is our goal to provide our students with the tools to be life-long learners in the explosively growing field of biology.

Areas of knowledge and Integration of Fundamental Concepts
Biology graduates should have solid understanding in these general areas:
- Energy and information flow in living systems
- Form and function of cells
- Heredity, molecular genetics from individuals to populations
- Evolution, genetics and the mechanisms of evolution
- Mechanisms of growth, reproduction, and development
- Physiology and behavior of organisms
- Ecological relationships among organisms, populations, communities, and their physical environment

More specifically, Biology graduates should know that:
- All living things have evolved from a common ancestor, through processes that include natural selection and genetic drift acting on mutable and heritable genetic variation.
- Understanding biological systems requires both reductionistic and broad-based, integrative perspectives.
- Enzymes mediate most regulated biochemical reactions.
- Information encoded as nucleotide sequences in DNA is organized into genes. These heritable units are transcribed into RNA templates for translation into protein sequences, which become functional on folding into distinctive three-dimensional structures. RNA exhibits catalytic activity under certain conditions.
- Most living systems use energy stored in high-energy bonds or ionic concentration gradients. The release of this energy is coupled to thermodynamically unfavorable reactions to drive biological processes.
- Fundamental molecular and cellular processes are conserved across most biological systems, reflecting biological unity, even though organisms, communities, and ecosystems can be incredibly variable and diverse.
- Specific aliphatic lipids combine with proteins to form membranes. These surround cells to separate the intracellular environment from the extracellular environment. Membranes also form distinct compartments within eukaryotic cells.
- Cells are fundamental units of life.
- Biological systems are maintained by complex regulatory mechanisms. Homeostasis acts to buffer internal systems in the face of external environmental changes.
- Cells organize into epithelial layers to separate internal and external environments in multicellular organisms.
- Chemical communication among cells is mediated by protein receptors and facilitates development, defense, and physiological functions in multicellular organisms.
- In multicellular organisms, cells divide and differentiate to form tissues, organs, and organ systems with distinct functions. These differences arise primarily from changes in gene expression.
- Groups of potentially interbreeding organisms form populations of a species.
- Populations of different species interact with one another to form communities.
- Communities interact with the environment to form ecosystems with flow of energy and nutrients among multiple levels.

Skills of Inquiry, Analysis, and Process

*Biology graduates should be able to:*
- Read and interpret biological literature relevant to specific research questions.
- Extend classroom knowledge to other learning contexts including seminars, faculty-guided research, and the Senior Integrative Exercise.
- Generate and state testable scientific hypotheses concerning biological systems.
- Design appropriate hypothesis-driven experiments or measurements to test the predictions of their hypotheses.
- Carry out proposed studies or experiments using basic and advanced laboratory and field techniques.
- Analyze and interpret the results of scientific investigations, including use of quantitative and statistical methods.
- Communicate ideas and arguments effectively both orally and in writing.
- Write scientific reports that are correct in style and follow a logical organization with clear and concise analysis and conclusions.
- Deliver oral presentations with logical organization and clear and concise analysis and conclusions.
- Work effectively as a member of a research team.

Our Approach: The Major

Our Introductory Biology courses are designed to illustrate the connections between levels of organization. One course, BIO 125, examines information flow from genetics through evolution and development, while BIO 126 looks at energy flow from
thermodynamics and photosynthesis through organismic and ecosystem energetics. From these two courses students move to the 200-level courses where we require each major to take at least one course from each of three areas: a) cell, molecular, genetics; b) physiology, development, organismal; and c) ecology, evolution. This means that students primarily interested in molecular biology will also be exposed to organismal and ecological perspectives, while students interested in ecological relationships will gain exposure to cellular or molecular mechanisms. The 300-level courses offer further, more focused exploration into specific subfields (e.g. immunology, neurobiology, molecular biology, behavioral endocrinology, developmental genetics, oncogenes) and are centered on primary literature.

Research is a vital piece of our learning environment. Two important types of research are essential to becoming a scholar in biology. The first is academic research, where we use the library or online databases to efficiently search primary literature in order to access the published results of biological research. In addition, if our students are asking questions that require molecular analysis, then they must be fluent in the use of software that scours through the immense collection of genetic and protein sequence databases, which are growing at an astronomical rate. The second component of research is the actual hands-on process of doing biology. Whether in the field or in the laboratory, measurement and experimentation, designed to generate new and previously unknown information, is essential to becoming a biologist. Though our laboratory courses and off-campus programs offer good research experiences, we encourage students interested in graduate school to gain additional research opportunities during the summer either at Carleton or another institution.

Finally, the Senior Integrative Exercise (“comps”) requires each student to research a specific question using recent primary literature. This affords the student an opportunity to work one-on-one with a faculty member, pull together their knowledge from their coursework, and write a concise review article that synthesizes relevant information regarding a particular biological question. In our current system, two faculty members examine each comps paper, which the student writes during the fall or winter term. The following term, each student gives a public presentation of his or her research. This is followed by an oral examination by the two faculty readers. The experience is intense and, according to feedback from our graduates, prepares our students for the high expectations of graduate school seminars and exams.

Assessment of Learning Outcomes
The department’s assessment of the learning goals for areas of knowledge and concepts is conducted at the individual course level. This is executed in a number of different ways reflecting the specific pedagogical techniques used by each instructor or the skills that are required for the specific course or subdiscipline. Higher-level skills of analysis are assessed through careful monitoring and feedback of laboratory work and faculty-guided research. Many of our courses require writing assignments with opportunity to prepare more than one draft using faculty feedback. Similarly, a student’s ability to critically read and present primary literature is assessed in our seminars. Students receive individual feedback following oral presentations and are
encouraged and expected to improve the quality of subsequent presentations. There is ongoing assessment by many of us involved in several interdisciplinary learning programs (e.g. Neuroscience, Biochemistry, Cognitive Studies, ENTS, and Women’s and Gender Studies concentrations, Carleton Interdisciplinary Science and Math Initiative, interdisciplinary comps, Triad/Dyad).

**Conclusion**

The biggest challenge facing Biologists today is the successful navigation through the rapidly growing body of information generated by researchers in the discipline. The charge of our department is to design the most accurate compass for our students to use as they try to make sense of the depth and breadth of newly emerging biological information. This educational task is directed at a moving target and requires constant assessment and reflection. If the main mission of a liberal arts education is to provide students with the tools to become life-long learners, then the field of Biology, accompanied by a vigilant faculty, fits nicely into the educational goals of our institution.