Texas Higher Education Coordinating Board

Making Opportunity Affordable in Texas:

A Student-Centered Approach

Tuning of Biology

Texas Higher Education Coordinating Board

Austin, Texas

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Tuning Oversight Council for Engineering and Science

Biology Committee

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Table of Contents

Definition of Tuning

"Tuning" is a faculty-led pilot project designed to define what students must know, understand, and be able to demonstrate after completing a degree in a specific field, and to provide an indication of the knowledge, skills, and abilities students should achieve prior to graduation at different levels along the educational pipeline – in other words, a body of knowledge and skills for an academic discipline in terms of outcomes and levels of achievement of its graduates.

Tuning provides an expected level of competency achievement at each step along the process of becoming a professional: expectations at the beginning of pre-professional study, at the beginning of professional study, and at the transition to practice. It involves seeking input from students, recent graduates, and employers to establish criterion-referenced learning outcomes and competencies by degree level and subject area. Through Tuning, students have a clear "picture" of what is expected and can efficiently plan their educational experience to achieve those expectations. The objective is not to standardize programs offered by different institutions, but to better establish the quality and relevance of degrees in various academic disciplines.

An overview of Lumina Foundation for Education's "Tuning USA" Initiative is available at: http://www.luminafoundation.org/goal_2025.html; an overview of Tuning work to date in Texas is available at: http://www.thecb.state.tx.us/tuningtexas.

Table of Contents

Definition of Biology

Biology is the study of living organisms, living systems, and life processes.

Table of Contents

Biology Expertise Profile

The expertise profile lists types of coursework included in typical baccalaureate degrees in biology. Note: General undergraduate degree requirements (e.g., the core curriculum) are not considered for the purpose of tuning biology and this report.

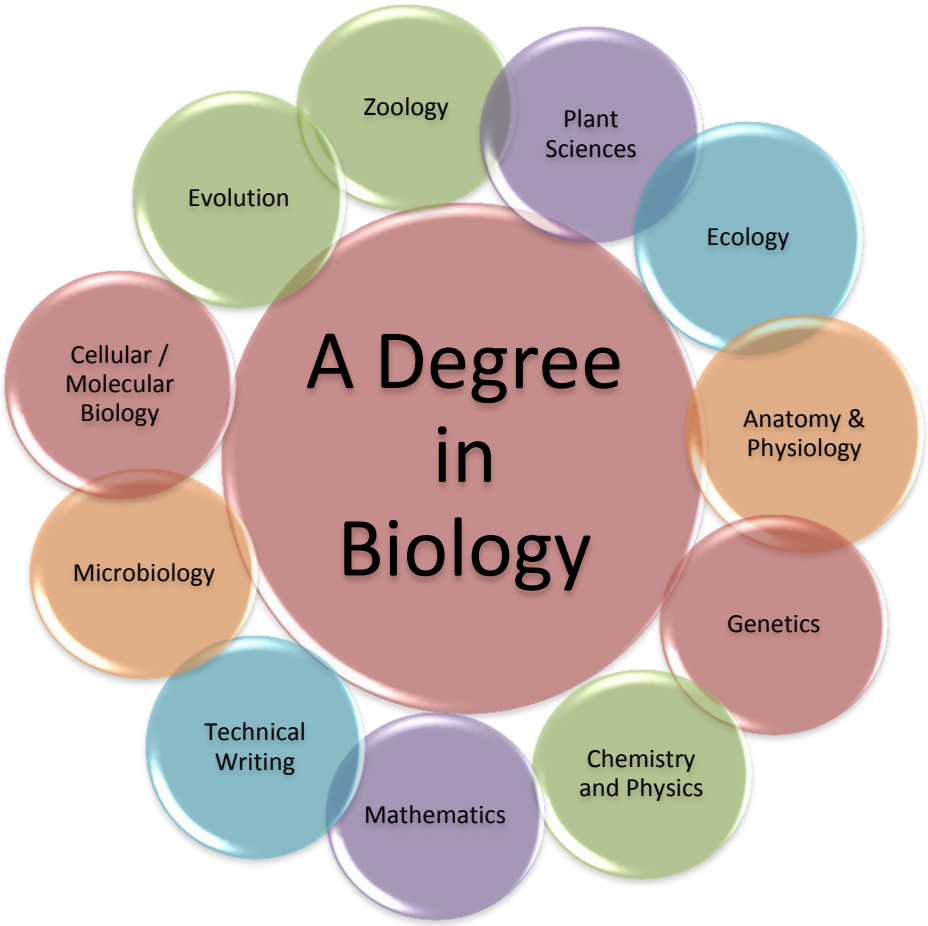

Table of Contents

Biology Employment Profile

The employment profile lists employment opportunities available to Biology graduates.

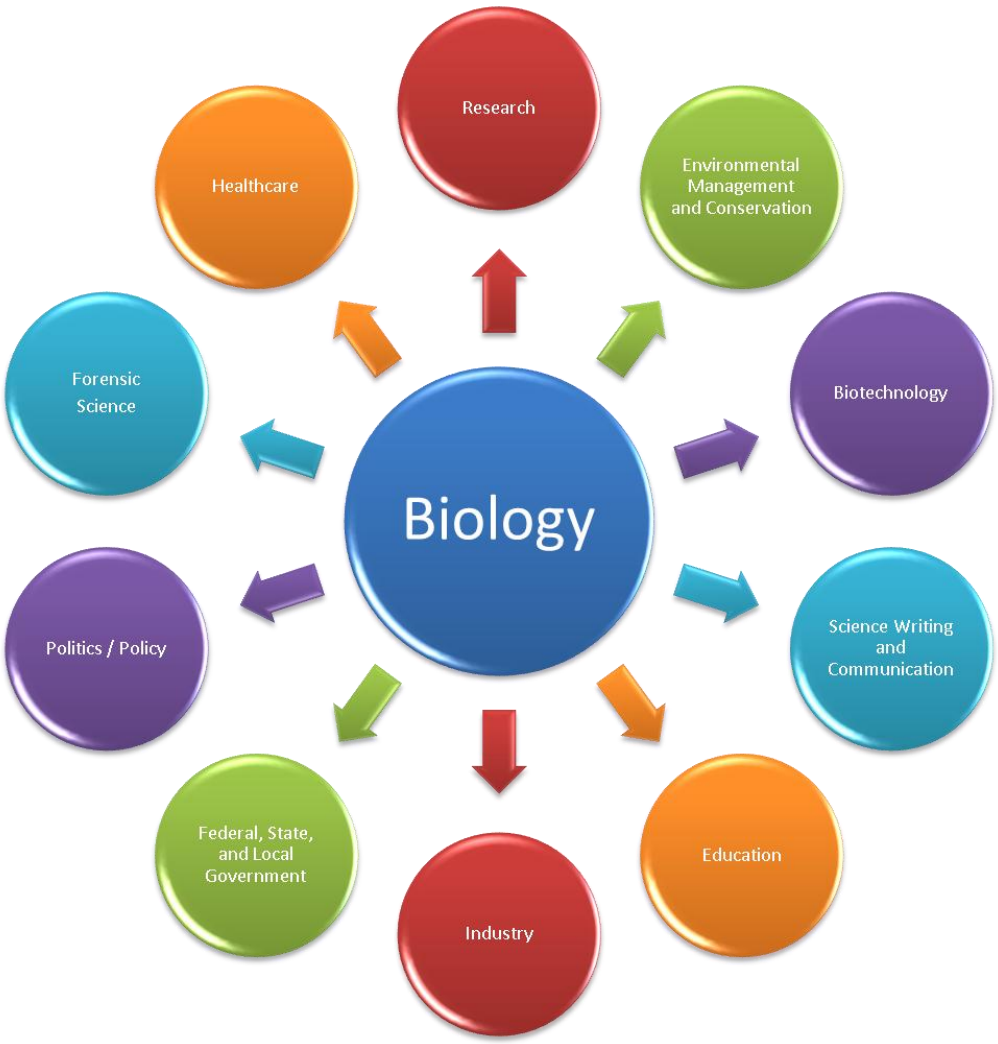

Table of Contents

Biology Key Competency Tables and Learning Outcome Descriptions

The Biology competency table has 11 learning outcome titles, one for each learning outcome description:

1. Evolution
2. Structure/Function
3. Information Flow
4. Transformation of Energy and Matter
5. Systems Biology
6. Physical Sciences
7. Mathematics
8. Experimentation/Problem Solving
9. Laboratory Skills
10. Communication
11. Science and Society

The competency table has four learning outcome categories (columns from left to right):

1. core competencies needed to enter higher education in biology (HS),
2. competencies gained during first two years of biology study (CC),
3. baccalaureate-level biology competencies (BS), and,
4. graduate-level biology competencies (G)

Learning outcome descriptions for each of the outcome titles of the competency table explain the knowledge, skills, and attitudes that should be achieved by the graduates.

Table of Contents

Biology Key Competencies Profile

Lumina Foundation Grant Biology Committee

	Evolution	Structure/Function	Information Flow	Transformations of Energy and Matter	Systems Biology	Physical Sciences	Mathematics	Experimentation/ Problem Solving	Laboratory Skills	Communication	Science and Society
Evaluation	G	G	G		G			G	G	G	G
Synthesis	G	G	BS	G	G			BS	BS	BS	BS
Analysis	BS	BS	BS	G	BS	G	G	BS	BS	BS	BS
Application	BS	BS	BS	BS	CC	BS	BS	CC	CC	CC	CC
Comprehension	CC	CC	CC	CC	HS	CC	CC	CC	CC	HS	CC
Knowledge	HS	HS	HS	HS	HS	HS	HS	HS	HS	HS	HS

G	**graduate-level competencies**
BS	**baccalaureate-level competencies**
CC	**biology fundamental competencies**
HS	**secondary education competencies**

Table of Contents

Evolution:

Evolution, in a broad sense, is the origin of entities possessing different states of one or more characteristics and changes in the proportions of those entities over time (Futuyma, 2009). Organic or biological evolution is a change over time in the proportions of individual organisms differing genetically in one or more traits. Such changes transpire by the origin and subsequent alteration of the frequencies of genotypes from generation to generation within populations, by alteration of the proportions of genetically differentiated populations within a species, or by changes in the numbers of species with different characteristics, thereby altering the frequency of one or more traits within a higher taxonomy.

The biology graduate must know the primary modes of speciation (e.g., allopatric, parapatric, and sympatric) as well as the differences and similarities of micro- and macroevolution. An understanding of these is accomplished by foundational knowledge of the mechanisms of evolution (natural selection, mutation, gene flow, and genetic drift; describing processes, differences, and examples), and evidence for evolution (e.g., antibiotic resistance, fossil record, extinction) as well as how this evidence is used to suggest evolutionary relationships. All skills will enable the biology graduate to interpret evolutionary data and relate evolutionary concepts to their own graduate school and/or job-related research.

EVOLUTION			
Core Competencies needed to enter Higher Education in Biology	**Competencies gained during first two years of Biology study**	**Baccalaureate-Level Biology Competencies**	**Post-Graduate/ Work Experience Biology Competencies**
Knowledge	**Comprehension**	**Application/Analysis**	**Synthesis/Evaluation**
Know multiple categories of evidence for evolutionary change and how this evidence is used to infer evolutionary relationships among organisms.	Describe processes, differences, and examples of evolutionary mechanisms.	Compare and contrast microevolution with macroevolution, and understand the primary modes of speciation.	Critique published evolutionary research, interpret evolutionary data, and relate evolutionary concepts to their work.

Table of Contents

Structure/Function:

At any given level of biological organization, from molecular to ecosystem, structure dictates function. Biological structures are built of subunits, and biological complexity is created through differential use of such subunits.

A biology graduate should be able to examine how characteristics of specific subunits influence biological structures and predict how changes will alter structure and function.

STRUCTURE/FUNCTION			
Core Competencies needed to enter Higher Education in Biology	**Competencies gained during first two years of Biology study**	**Baccalaureate-Level Biology Competencies**	**Post-Graduate/ Work Experience Biology Competencies**
Knowledge	**Comprehension**	**Application/ Analysis**	**Synthesis/ Evaluation**
Define major biological structures and their corresponding function(s), identify their basic subunits at different levels of biological organization, and recognize that changes in the composition and arrangement of subunits can result in changes in function.	Identify specific biological structures; relate their functions to their structures, and associate changes in the composition and arrangement with changes in function.	Discuss the characteristics of specific subunits and how those characteristics influence biological structures. Predict how changes will alter structure and function.	Create predictive hypotheses regarding biological structure and function, and manipulate biological structures to evaluate such hypotheses.

Table of Contents

Information Flow in Molecular Biology:

Biology students should understand how information flows in a cell and how cellular activities are regulated. These activities and processes are driven by a network of interacting macromolecules and metabolites. They should be able to describe the mechanisms and processes of DNA replication, transcription, RNA processing, and translation. In addition, the student should recognize that genetic information may not always flow in one direction (retroviruses). Therefore, the biology student must understand gene expression, epigenetics, signal transduction mechanisms, and gene splicing.

The biology student should be able to discuss gene regulation (e.g. development, cell signaling, metabolism, aging, etc).

INFORMATION FLOW			
Core Competencies needed to enter Higher Education in Biology	**Competencies gained during first two years of Biology study**	**Baccalaureate-Level Biology Competencies**	**Post-Graduate/ Work Experience Biology Competencies**
Knowledge	**Comprehension and Application**	**Analysis/Synthesis**	**Evaluation**
Describe the molecular structure of DNA and RNA, DNA replication, and protein synthesis.	Demonstrate and explain the basic processes of gene expression.	Compare and contrast molecular structure of DNA, RNA, and proteins. Integrate the mechanisms of gene expression and genomic signaling processing to various techniques and tools.	Justify mechanisms of gene signaling and regulation, relating those mechanisms to biotechnology and scientific advancements.

Table of Contents

Transformation of Energy and Matter:

Processes involving Transformations of Energy and Matter are fundamental to life. Biology students should be well-versed in mechanisms by which living organisms transform energy and matter from one form to another, including the roles of gradients, enzymes, energy pyramids, and trophic levels. They should also be able to explain how these processes are regulated (e.g., negative feedback) and how perturbations of these mechanisms affect the rate of transformations and impact the viability of the organism.

A biology graduate should be able to predict the outcome(s) of perturbations of the events of energy transformation reactions under a set of given circumstances.

TRANSFORMATION OF ENERGY AND MATTER			
Core Competencies needed to enter Higher Education in Biology	**Competencies gained during first two years of Biology study**	**Baccalaureate-Level Biology Competencies**	**Post-Graduate/ Work Experience Biology Competencies**
Knowledge	**Comprehension**	**Application**	**Analysis/Synthesis**
Describe the interdependence of organisms to one another and the flow of energy and matter within an ecosystem.	Explain the events that make up the processes of energy transformation reactions in general terms.	Predict the outcome(s) of perturbations of the events of energy transformation reactions under a set of given circumstances.	Design an experiment and/or analyze results of experiments involving energy transformation reactions or flow of energy and matter within an ecosystem.

Table of Contents

Systems Biology:

Life exists at several interactive and interdependent levels of organization. Systems biology is the quantitative analysis of the interactions between components within and between biological levels, with the aim of constructing predictive models of the dynamic behavior of biological systems. The systems strategy begins with traditional reductionist biology: the identification of the components of a biological system. Systems biologists then determine the specific relationships between each component within that system. Finally, the network of interactions within a biological system can be mapped and visualized using mathematical models and computer software, and possible outcomes of disturbances of component interactions on a biological system can be predicted. Through such analysis, systems biologists seek to relate the outcomes of component interactions at one biological level to the emerging properties at higher biological levels.

The biology graduate is able to predict possible outcomes of disturbances in one system level at higher biological levels. The systems biology required for biology practice must be learned at the undergraduate level and should prepare students for subsequent courses in biology and biology practice.

SYSTEMS BIOLOGY			
Core Competencies needed to enter Higher Education in Biology	**Competencies gained during first two years of Biology study**	**Baccalaureate-Level Biology Competencies**	**Post-Graduate/ Work Experience Biology Competencies**
Knowledge/ Comprehension	**Application**	**Analysis**	**Synthesis/Evaluation**
Identify and explain basic strategies and key concepts of systems biology.	Apply the strategies of systems biology and interpret the results of basic systems models.	Infer possible outcomes of disturbances in one system level at higher biological levels.	Develop and justify predictive models to examine complex biological problems.

Table of Contents

Physical Sciences:

A biology graduate must acquire a broad education within the physical sciences to support their understanding of biology. Depending on the student's area of focus, some of the physical sciences may include, but are not limited to: physics, chemistry, earth science, and environmental science. Concepts in physics involve: basic understanding of matter, forces, thermodynamics, electromagnetism, and optics. Concepts in chemistry involve: matter and its properties, atomic structure, chemical bonding and reactions, thermochemistry, properties and behavior of gases and liquids and solids, and basic structure and function of biological molecules (proteins, carbohydrates, lipids, and nucleic acids). Concepts in environmental science include: understanding earth systems, energy, populations, economics and politics, and human practices and their impacts.

A biology graduate should apply these concepts to biological problem solving.

PHYSICAL SCIENCES			
Core Competencies needed to enter Higher Education in Biology	**Competencies gained during first two years of Biology study**	**Baccalaureate-Level Biology Competencies**	**Post-Graduate/ Work Experience Biology Competencies**
Knowledge	**Comprehension**	**Application**	**Analysis**
Describe key concepts of physical sciences: physics, chemistry, earth science, and environmental sciences. Solve basic problems for each concept.	Explain key concepts of basic physics, chemistry, earth science, and environmental sciences. Apply knowledge to solve basic biological problems.	Use and summarize concepts of physical science related to their field of study.	Analyze key concepts of physical sciences: physics, chemistry, earth science, and environmental sciences. Debate proposed solutions to problems for each concept.

Table of Contents

Mathematics:

Mathematics is often called the "language of science". Competency in mathematics provides a foundation for evaluating scientific concepts. Mathematics is fundamental to mastering physical sciences that support biology, and is used to analyze and describe experimental data.

The biology graduate uses basic algebraic expressions and mathematical approaches to solve problems. The graduate applies statistical analysis to data and selecting appropriate mathematical strategies to analyze such data in post-graduate or work environments.

MATHEMATICS			
Core Competencies needed to enter Higher Education in Biology	**Competencies gained during first two years of Biology study**	**Baccalaureate-Level Biology Competencies**	**Post-Graduate/ Work Experience Biology Competencies**
Knowledge	**Comprehension**	**Application**	**Analysis**
Solve, describe, and simplify algebraic expressions and equations. Read and interpret descriptive statistical output.	Explain, compute, and interpret descriptive and inferential statistical output.	Apply mathematical reasoning to solve problems. Generate and interpret statistical output.	Select the appropriate mathematical techniques to analyze biological problems.

Table of Contents

Experimentation:

Problem solving and the use of experimental methods to study the living world is a cornerstone of the biological sciences. Biologists must be able to synthesize content knowledge, laboratory skills, and mathematical analysis in order to identify biological problems to study and in order to determine the appropriate methods to apply.

The biology graduate uses a comprehensive base of technical laboratory skills to develop, test, and evaluate hypotheses in regard to biological problems.

EXPERIMENTATION/PROBLEM SOLVING			
Core Competencies needed to enter Higher Education in Biology	**Competencies gained during first two years of Biology study**	**Baccalaureate-Level Biology Competencies**	**Post-Graduate/ Work Experience Biology Competencies**
Knowledge	**Comprehension/ Application**	**Analysis/Synthesis**	**Evaluation**
Interpret and outline key components of problem detection, configuration, and problem solving including identification of a hypothesis/null hypothesis related to biological applications.	Apply scientific reasoning as a primary form of problem solving; compose a working hypothesis, distinguish between independent and dependent variables, and analyze basic biological concepts within problems.	Design and conduct experiments using appropriate methodology, and analyze data to test working hypotheses.	Appraise and/or defend proposed solutions to advanced biological problems.

Table of Contents

Laboratory Skills:

Biology is a hands-on science in which observation, collection, and interpretation of the data are critical in order to answer a problem. Students must be proficient in certain laboratory skills in order to conduct investigations. There are basic laboratory techniques that all biologists must know and other skills are "selective" to a certain field of biology.

All biology graduates must know how to maintain a safe laboratory environment, demonstrate an understanding of standard operation procedures, and be knowledgeable in the use of equipment and instrumentation. Biology graduates that specialize in specific areas must be knowledgeable in the proper techniques for that area.

LABORATORY SKILLS			
Core Competencies needed to enter Higher Education in Biology	**Competencies gained during first two years of Biology study**	**Baccalaureate-Level Biology Competencies**	**Post-Graduate/ Work Experience Biology Competencies**
Knowledge	**Comprehension/ Application**	**Analysis/ Synthesis**	**Evaluation**
Understand basic laboratory safety rules and precautions. Describe the proper use of basic biology equipment and protocols, and data presentation.	Demonstrate the proper use and care of research equipment. Collect data following proper laboratory protocols. Troubleshoot experimental failures.	Demonstrate the use of advanced research equipment and proper techniques utilized within specific research areas. Collect data following proper laboratory protocols and analyze results. Troubleshoot and perform quality checks of equipment.	Design experiments utilizing advanced laboratory skills appropriate for a research-specific discipline. Evaluate research-specific methodologies. Collect data, analyze, and evaluate the results. Demonstrate effective time management. Acquire, allocate, and utilize resources efficiently.

Table of Contents

Communication:

Biology students must master written communication skills to effectively produce funding proposals, experimental data, and scientific articles, and demonstrate the visual communication skills to generate graphs, images, and videos that are necessary for conveying scientific information. Communication skills also involve the ability to communicate in an oral format, such as for meetings and conferences.

The biology graduate must possess clear and effective written, visual, and oral communication skills.

COMMUNICATION			
Core Competencies needed to enter Higher Education in Biology	**Competencies gained during first two years of Biology study**	**Baccalaureate-Level Biology Competencies**	**Post-Graduate/ Work Experience Biology Competencies**
Knowledge/ Comprehension	**Application**	**Analysis/Synthesis**	**Evaluation**
Understand the proper use of punctuation and grammar in oral, written, and visual presentations. Demonstrate a basic understanding of commonly used scientific terms.	Properly cite scientific sources; apply the proper use of punctuation and grammar in oral, written, and visual presentations. Apply commonly used technical and scientific terms. Restate biological concepts in own words.	Create and deliver effective oral presentations. Define and explain commonly used technical and scientific terms. Produce written material using appropriate technical styles. Read technical and scientific articles.	Evaluate scientific information and convey in a manner appropriate to audience. Effectively present material at conferences and by way of scientific journals. Organize and convey instructions leading to obtaining research goals.

Table of Contents

Science and Society:

To appreciate the interaction of science (biology), technology, and society, it is essential that students recognize these important connections. It is crucial that the distinction between science and technology be clearly seen and the impact of applying technology to the sciences be easily seen. Next, the interplay of societal issues and biology (sciences) are a critical part of this large area. Lastly, the history of science provides both a view of how science is done and how knowledge in science grows. At first, it may be just identifying potential issues and key figures in biology. As this knowledge grows, then an understanding of influences and a true distinction between science and technology can be developed. At increasingly higher levels, the student begins to access, analyze, and devise solutions for these societal scientifically based problems.

The biology graduate recognizes the importance of the interaction between science, technology, and society.

SCIENCE AND SOCIETY			
Core Competencies needed to enter Higher Education in Biology	**Competencies gained during first two years of Biology study**	**Baccalaureate-Level Biology Competencies**	**Post-Graduate/ Work Experience Biology Competencies**
Knowledge	**Comprehension/ Application**	**Analysis/ Synthesis**	**Evaluation**
Identify an example of the impact of technology, a controversial issue, and an historical figure in the biological sciences.	Describe how technology impacts biology. Relate biology as a social enterprise and identify the impact of humans on all other organisms. Identify the ways of knowing in biology, such as empirical requirements, logical arguments, and the requirement of evidence.	Experiment with different proposed solutions. Analyze solutions to complicated interactions between biology and society. Compare and contrast the impact of individuals on key advances in biology. Interpret proposed empirical data and reasoning patterns involved in biological research.	Formulate designs, applicability, and tests for technological applications in biology. Compose proposals for funding for biological research. Evaluate the impact of societal decisions on the health and well-being of humans and other organisms. Formulate scientific explanations based on empirical measures, logical arguments, and a standard of intellectual questioning.

Table of Contents

Community College Program of Study for Transfer to a Biology Program

FRESHMAN YEAR

First Semester (Fall)				Second Semester (Spring)			
		Course	**SCH**			**Course**	**SCH**
BIOL	1306 or 1311	Biology for Science Majors I or General Botany[1]	3	BIOL	1307 or 1313	Biology for Science Majors II or General Zoology[1]	3
BIOL	1106 or 1111	Biology for Science Majors I lab or General Botany lab[1]	1	BIOL	1107 or 1113	Biology for Science Majors II lab or General Zoology lab[1]	1
CHEM	1311	General Chemistry I	3	CHEM	1312	General Chemistry II	3
CHEM	1111	General Chemistry I lab	1	CHEM	1112	General Chemistry II lab	1
MATH	####	Mathematics Option[2]	3-5	MATH	####	Mathematics Option[2] or Texas Core Requirement (if math complete)	3
XXXX	####	Texas Core Curriculum Requirement	3	XXXX	####	Texas Core Curriculum Requirement	3
		Semester Credit Hours	**14-16**			**Semester Credit Hours**	**14**

SOPHOMORE YEAR

First Semester (Fall)				Second Semester (Spring)			
		Course	**SCH**			**Course**	**SCH**
CHEM	2323	Organic Chemistry I	3	BIOL	2321	Microbiology for Science Majors	3
CHEM	2123	Organic Chemistry I lab	1	BIOL	2121	Microbiology for Science Majors lab	1
MATH	####	Mathematics Option[2] or Texas Core Requirement (if math complete)	3	CHEM	2325	Organic Chemistry II	3
XXXX	####	Texas Core Curriculum Requirement	3	CHEM	2125	Organic Chemistry II lab	1
PHYS	1301	College Physics I	3	PHYS	1302	College Physics II	3
PHYS	1101	College Physics I lab	1	PHYS	1102	College Physics II lab	1
		Semester Credit Hours	**14**	XXXX	####	Texas Core Curriculum Requirement	3
						Semester Credit Hours	**15**

NOTES:

[1]Students must complete either the BIOL 1306/1106 and 1307/1107 sequence or the BIOL 1311/1111 and 1313/1113 sequences. Courses from these sequences may not be combined.

[2]Begin mathematics coursework according to placement by initial institution. Maintain continuous enrollment until final mathematics level is achieved. Complete through MATH 1342 or 1442 or 2342 or 2442 Elementary Statistical Methods, or MATH 2313 or 2413 or 2513 Calculus I as determined by four-year degree program. The student is advised to check with the school to which he or she intends to transfer for specific requirements and applicability of the mathematics course to the biology major at that institution.

Table of Contents

Community College Prerequisite Flowchart for Biology

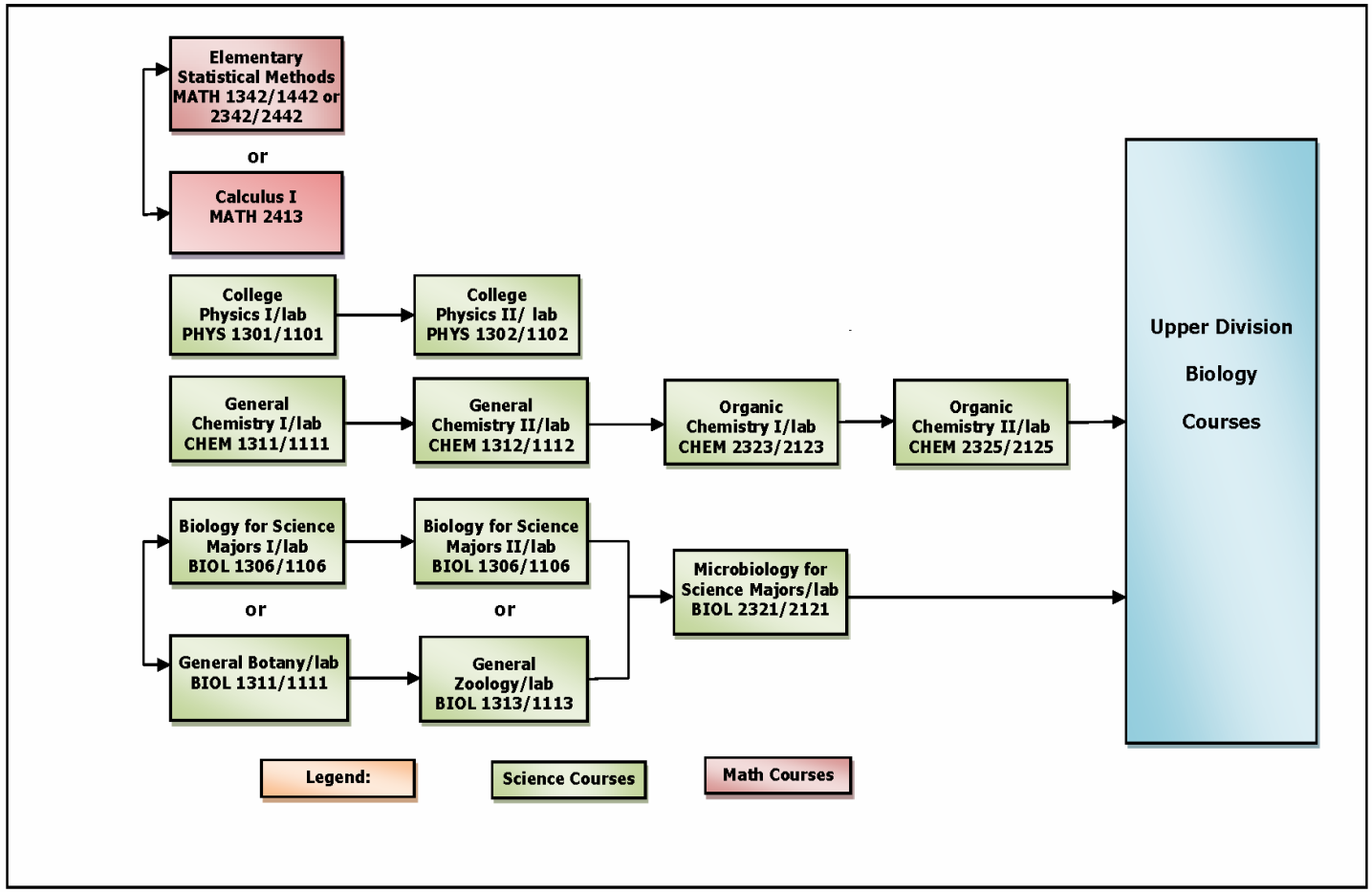

Table of Contents

Resources

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Table of Contents