

| <b>PROCESS OF SCIENCE</b>   |   |
|---|---|
| Program-Level Learning Outcomes   | Course-Level Learning Outcomes  |
| <b>SCIENTIFIC THINKING</b><br>Explain how science generates knowledge of the natural world.         | Explain how scientists use inference and evidence-based reasoning to generate knowledge.  |
|   | Describe the iterative nature of science and how new evidence can lead to the revision of scientific knowledge.                               |
| <b>INFORMATION LITERACY</b><br>Locate, interpret, and evaluate scientific information.              | Find and evaluate the credibility of a variety of sources of scientific information, including popular science media and scientific journals. |
|   | Interpret, summarize, and evaluate evidence in primary literature.  |
|   | Evaluate claims in scientific papers, popular science media, and other sources using evidence-based reasoning.                                |
| <b>QUESTION FORMULATION</b><br>Pose testable questions and hypotheses to address gaps in knowledge. | Recognize gaps in our current understanding of a biological system or process and identify what specific information is missing.              |
|   | Develop research questions based on your own or others' observations.   |
|   | Formulate testable hypotheses and state their predictions.  |
| <b>STUDY DESIGN</b><br>Plan, evaluate, and implement scientific investigations.                     | Compare the strengths and limitations of various study designs.   |
|   | Design controlled experiments, including plans for analyzing the data.  |
|   | Execute protocols and accurately record measurements and observations.  |
|   | Identify methodological problems and suggest how to troubleshoot them.  |
|   | Evaluate and suggest best practices for responsible research conduct (e.g., lab safety, record keeping, proper citation of sources).          |

*Process of Science continued on next page...*

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| <b>DATA INTERPRETATION &amp; EVALUATION</b><br>Interpret, evaluate, and draw conclusions from data in order to make evidence-based arguments about the natural world. | Analyze data, summarize resulting patterns, and draw appropriate conclusions.   |
|   | Describe sources of error and uncertainty in data.  |
|   | Make evidence-based arguments using your own and others' findings.  |
|   | Relate conclusions to original hypothesis, consider alternative hypotheses, and suggest future research directions based on findings. |
| <b>DOING RESEARCH</b><br>Apply science process skills to address a research question in a course-based or independent research experience.                            |   |

Pre-Publication

## QUANTITATIVE REASONING

| Program-Level Learning Outcomes  | Course-Level Learning Outcomes   |
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| <b>NUMERACY</b><br>Use basic mathematics (e.g., algebra, probability, unit conversions) in biological contexts.                                | Perform basic calculations (e.g., percentages, frequencies, rates, means).   |
|  | Select and apply appropriate equations (e.g., Hardy-Weinberg, Nernst, Gibbs free energy) to solve problems.                |
|  | Interpret and manipulate mathematical relationships (e.g., scale, ratios, units) to make quantitative comparisons.         |
|  | Use probability and understanding of biological variability to reason about biological processes and statistical analyses. |
|  | Use rough estimates informed by biological knowledge to check quantitative work.   |
|  | Describe how quantitative reasoning helps biologists understand the natural world.   |
| <b>QUANTITATIVE &amp; COMPUTATIONAL DATA ANALYSIS</b><br>Apply the tools of graphing, statistics, and data science to analyze biological data. | Record, organize, and annotate simple data sets.   |
|  | Create and interpret informative graphs and other data visualizations.   |
|  | Select, carry out, and interpret statistical analyses.   |
|  | Describe how biologists answer research questions using databases, large data sets, and data science tools.                |
|  | Interpret the biological meaning of quantitative results.  |

## MODELING & SIMULATION

| Program-Level Learning Outcomes  | Course-Level Learning Outcomes  |
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| <b>PURPOSE OF MODELS</b><br>Recognize the important roles that scientific models, of many different types (conceptual, mathematical, physical, etc.), play in predicting and communicating biological phenomena. | Describe why biologists use simplified representations (models) when solving problems and communicating ideas.                      |
|  | Given two models of the same biological process or system, compare their strengths, limitations, and assumptions.                   |
| <b>MODEL APPLICATION</b><br>Make inferences and solve problems using models and simulations.   | Summarize relationships and trends that can be inferred from a given model or simulation.   |
|  | Use models and simulations to make predictions and refine hypotheses.   |
| <b>MODELING</b><br>Build and evaluate models of biological systems.  | Build and revise conceptual models (e.g., diagrams, concept maps, flow charts) to propose how a biological system or process works. |
|  | Identify important components of a system and describe how they influence each other (e.g., positively or negatively).              |
|  | Evaluate conceptual, mathematical, or computational models by comparing their predictions with empirical data.                      |

## INTERDISCIPLINARY NATURE OF SCIENCE

| Program-Level Learning Outcomes   | Course-Level Learning Outcomes   |
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| <b>CONNECTING SCIENTIFIC KNOWLEDGE</b><br>Integrate concepts across other STEM disciplines (e.g., chemistry, physics) and multiple fields of biology (e.g., cell biology, ecology). | Given a biological problem, identify relevant concepts from other STEM disciplines or fields of biology.   |
|   | Build models or explanations of simple biological processes that include concepts from other STEM disciplines or multiple fields of biology.                 |
| <b>INTERDISCIPLINARY PROBLEM SOLVING</b><br>Consider interdisciplinary solutions to real-world problems.  | Describe examples of real-world problems that are too complex to be solved by applying biological approaches alone.  |
|   | Suggest how collaborators in STEM and non-STEM disciplines could contribute to solutions of real-world problems.   |
|   | Be able to explain biological concepts, data, and methods, including their limitations, using language understandable by collaborators in other disciplines. |

## COMMUNICATION & COLLABORATION

| Program-Level Learning Outcomes  | Course-Level Learning Outcomes  |
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| <b>COMMUNICATION</b><br>Share ideas, data, and findings with others clearly and accurately.                                | Use appropriate language and style to communicate science effectively to targeted audiences (e.g., general public, biology experts, collaborators in other disciplines).                      |
|  | Use a variety of modes to communicate science (e.g., oral, written, visual).  |
| <b>COLLABORATION</b><br>Work productively in teams with people who have diverse backgrounds, skill sets, and perspectives. | Work with teammates to establish and periodically update group plans and expectations (e.g., team goals, project timeline, rules for group interactions, individual and collaborative tasks). |
|  | Elicit, listen to, and incorporate ideas from teammates with different perspectives and backgrounds.  |
|  | Work effectively with teammates to complete projects.   |
| <b>COLLEGIAL REVIEW</b><br>Provide and respond to constructive feedback in order to improve individual and team work.      | Evaluate feedback from others and revise work or behavior appropriately.  |
|  | Critique others' work and ideas constructively and respectfully.  |
| <b>METACOGNITION</b><br>Reflect on your own learning, performance, and achievements.                                       | Evaluate your own understanding and skill level.  |
|  | Assess personal progress and contributions to your team and generate a plan to change your behavior as needed.  |

| <b>SCIENCE &amp; SOCIETY</b>   |   |
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| Program-Level Learning Outcomes  | Course-Level Learning Outcomes  |
| <b>ETHICS</b><br>Demonstrate the ability to critically analyze ethical issues in the conduct of science.   | Identify and evaluate ethical considerations (e.g., use of animal or human subjects, conflicts of interest, confirmation bias) in a given research study. |
|  | Critique how ethical controversies in biological research have been and can continue to be addressed by the scientific community.                         |
| <b>SOCIETAL INFLUENCES</b><br>Consider the potential impacts of outside influences (historical, cultural, political, technological) on how science is practiced. | Describe examples of how scientists' backgrounds and biases can influence science and how science is enhanced through diversity.                          |
|  | Identify and describe how systemic factors (e.g., socioeconomic, political) affect how and by whom science is conducted.                                  |
| <b>SCIENCE'S IMPACT ON SOCIETY</b><br>Apply scientific reasoning in daily life and recognize the impacts of science on a local and global scale.                 | Apply evidence-based reasoning and biological knowledge in daily life (e.g., consuming popular media, deciding how to vote).                              |
|  | Use examples to describe the relevance of science in everyday experiences.  |
|  | Identify and describe the broader societal impacts of biological research on different stakeholders.  |
|  | Describe the roles scientists have in facilitating public understanding of science.   |