Subject Matter "D" Evidence: Unit 3, Nucleic Acids and Proteins—Disease Treatment Innovations

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Executive Summary

Sponsored by Genentech, Futurelab+ brought together a coalition of partners to develop an innovative, modular, 2-year biotechnology curriculum, along with instructional materials, to expose students and educators to the breadth of education and career pathways across biotechnology. To increase adoption and access to such curricula in California and beyond, the modular curriculum was designed to align with the California Career Technical Education Model Curriculum Standards for Biotechnology, meet at least 1 year of the University of California (UC) science (D) subject requirement, and incorporate some of the three-dimensional learning innovations of the Next Generation Science Standards (NGSS). The 2-year biotechnology curriculum has four core units per year; each core unit has nine lessons and a lab that each take approximately 1 week to complete (9–10 weeks for the full unit). In total, the biotechnology curriculum has 72 lessons and eight labs that span 2 full instructional years. Because the Futurelab+ biotechnology curriculum is modular, teachers can select specific units and materials to design biotechnology courses that are relevant and appropriate for their students and teaching environments.

Because teachers and schools can choose which portions of the curriculum to include in their final course designs, this report series provides evidence of where each unit meets specific criteria for the UC science (D) subject requirement and, when incorporated into a full year-long course, where the curriculum could meet at least 1 year of the UC science (D) subject requirement, contingent upon review and approval by UC. Subsequently, the evidence provided herein can be used by teachers for submitting Futurelab+ course materials for UC science (D) subject approval.

The purpose of this report is to provide evidence for alignment of Unit 3 of the Futurelab+ Biotechnology Curriculum with the UC science (D) subject requirement. To help educators submit their final courses for UC science (D) subject review, the American Institutes for Research (AIR) also wrote sample unit and lab summaries, which follow the guidelines for writing a UC science (D) course (March 17, 2021), to provide language to teachers as they write their full course descriptions.

Specifically, AIR reviewed each unit for evidence of the extent to which the unit meets the eight Course Content Guidelines for the UC science (D) subject requirement. This report provides specific examples to demonstrate where and how materials satisfy these criteria. Based on our review, we believe there is a strong body of evidence that will likely translate to Unit 3 meeting the UC science (D) subject matter requirement. **This review was completed on materials received March 2, 2022 and has not been updated to reflect any revisions made to materials since then.**

University of California A–G Course Requirements

To be eligible for admission into the California State University or the University of California (UC) systems, high school students must successfully complete (with a grade of C or better) the UC A through G (A–G) course requirements. The A–G course requirements encompass 15 year-long courses, including (A) 2 years of history/social science, (B) 4 years of English composition and literature, (C) 3 years of mathematics, **(D) 2 years of science**, (E) 2 years of language other than English, (F) 1 year of visual and performing arts, and (G) 1 year of a college preparatory elective. Teachers, parents, and students want high school courses to meet A–G requirements. To increase adoption of the Futurelab+ biotechnology curriculum, the modular curriculum was designed to meet at least 1 year of the UC science (D) subject requirement.

Futurelab+ and UC Science (D) Subject Requirement

The 2-year Futurelab+ biotechnology curriculum was designed to be modular. Teachers can select specific units and materials to design biotechnology courses that are relevant and appropriate for their students and teaching environments. For example, a biotechnology teacher can create a course that consists of four Futurelab+ units—two units from Year 1 of the curriculum and two units from Year 2 of the curriculum. Or a school can create a course that consists of two Futurelab+ units in conjunction with other materials. Each course would have unique course descriptions because the materials are different.

The modular, 2-year Futurelab+ biotechnology curriculum consists of four core units each year. Each unit has nine lessons and a lab. A lesson consists of more than one class period of learning to allow students the opportunity to develop their knowledge and understanding more fully. Lessons and labs take approximately five 45-minute instructional periods to complete. In its entirety, the biotechnology curriculum has 72 lessons and eight labs.

Given the modular nature of the curriculum and because teachers and schools can choose which units to include in their final course designs, this report series provides evidence of where singular units meet specific criteria for the UC science (D) subject requirement and, when incorporated into a full year-long course, where the curriculum could meet at least 1 year of the UC science (D) subject requirement, contingent upon review and approval by UC. Subsequently, the evidence provided herein can be used by teachers for submitting Futurelab+ course materials for UC science (D) subject approval.

To assist educators in writing and submitting to UC their unique course descriptions that incorporate Futurelab+ materials, each unit report includes a sample unit overview, assignment overview, and laboratory activity summary, as required for A–G course submissions and following the sample provided in the UC Policy Guide. **Appendix A** includes the example UC science (D) subject course description provided by UC. **Appendix B** includes a sample unit overview, assignment overview, and laboratory activity for educators to adapt to their needs.

This summary report provides evidence on how **Unit 3, Nucleic Acids and Proteins—Disease Treatment Innovations** of the Futurelab+ curriculum meets the UC science (D) subject requirement.

Methodology

There is strong overlap between the UC science course content guidelines and the NGSS Lesson Screener criteria (see Exhibit 1). As such, the American Institutes for Research (AIR) staff first conducted an NGSS Lesson Screener review on a randomly sampled lesson from Unit 3.

Exhibit 1. Course Content Guidelines and NGSS Lesson Screener Criteria

There is strong overlap between the UC science (D) subject requirement and the NGSS Lesson Screener criteria. Specific course content guidelines of the A–G Policy Resource Guide are briefly summarized here, with notations about which Lesson Screener criteria include the same or similar requirements.

- Explicitly integrate the eight NGSS Science and Engineering Practices **(Lesson Screener Criteria B and C); this requirement is mentioned multiple times.**
- Draw content generally from the NGSS **(Lesson Screener Criteria B and C)** and Common Core State Standards for Literacy in History/Social Studies, Science, and Technical Subjects.
- Provide opportunities for students to participate in all phases of the scientific process and require students to discuss ideas with other students **(Lesson Screener Criteria B, C, D, and E).**
- Be explicit about formative and summative assessment practices **(Lesson Screener Criteria B, C, and E).**
- Include real-world problems that engage all students in science learning **(Lesson Screener Criteria A, D, and E).**
- Specify minimum mathematics course requirements.
- Reserve at least 20% of class time for teacher-supervised, hands-on laboratory activities.
- Incorporate technology (to the extent possible) to increase access and computer-based skills for students.

Upon completion of the NGSS Lesson Screener deep dive, AIR staff reviewed the remaining Unit 3 materials for further evidence. Specifically, AIR reviewed each unit for evidence of the extent to which the unit meets the following UC science (D) subject matter course criteria, outlined in the Course Content Guidelines:

Criterion 1 Integrate the eight NGSS practices of science and engineering

Criterion 2 Consist of content pulled largely from the California NGSS and the Common Core State Standards for literacy in history/social studies, science, and technical subjects

Criterion 3 Provide opportunities for students to participate in all phases of the scientific process

Criterion 4 Employ quantitative reasoning and methods where appropriate

Criterion 5 Hold at least 20% of class time for teacher-supervised, hands-on laboratory activities

Criterion 6 Include explicit formative and summative assessment practices

Criterion 7 Provide real-world problems and applications

Criterion 8 Include the use of technology if possible

Summary of UC Science (D) Course Content Guidelines

Criterion 1: Integrate the Eight Science and Engineering Practices

Subject "Course Criterion 1 requires students to engage with the eight science and engineering practices outlined in the California NGSS throughout a year-long science course. **The following bulleted list shows examples of students engaging with these eight practices throughout Unit 3 of the Futurelab+ curriculum**. This list is not exhaustive.

Practice 1: Asking questions and defining problems

Students engage in elements of *Practice 1, Asking questions and defining problems*, in the following instructional activity:

- **Define a design problem that can be solved through the development of an object, tool, process, or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions**. In the Mystery Disease Conference Project, students design an innovative drug delivery system or technology that helps to cure or prevent a mystery disease. As the first step in this process, teams must define the problem that justifies a new drug innovation (Mystery Disease Conference Project Design Journal, p. 6).

Practice 2: Developing and using models

Students engage in several elements of *Practice 2, Developing and using models*, including the following:

- **Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.** In the Genetic Engineering for Protein Production Laboratory Investigation, students develop a model to explain what has occurred inside transformed bacterial cells that cause them to produce new proteins (Student Section, p. 34).

Practice 3: Planning and carrying out investigations

Students engage in elements of *Practice 3: Planning and carrying out investigations*, in the following instructional activity:

- **Select appropriate tools to collect, record, analyze, and evaluate data.** During Lesson 7, Protein Assays, students are given the opportunity to conduct a virtual lab to complete an ELISA assay with minimal guidance, providing them an opportunity to select the appropriate virtual tools needed (Teacher Section, p. 15).

Practice 4: Analyzing and interpreting data

Students engage in elements of *Practice 4, Analyzing and interpreting data*, in the following instructional activity:

- **Analyze and interpret data to provide evidence for phenomena.** As noted for Practice 3, Lesson 7, Protein Assays, provides students with the opportunity to conduct a virtual lab to complete an ELISA assay with minimal guidance. Students then analyze their results to diagnose a disease (Teacher Section, p. 15).

Practice 5: Using mathematics and computational thinking

Students engage in elements of *Practice 5, Using mathematics and computational thinking*, in the following instructional activity:

- **Use mathematical representations to describe and/or support scientific conclusions and design solutions.** In Lesson 6, Nucleic Acid Assays, students are presented with two pie charts that show the representation of different ethnic groups through genome-wide research and are asked to draw conclusions from the charts, based on the information displayed (Student Section, p. 9).

Practice 6: Constructing explanations and designing solutions

Students engage in elements of *Practice 6, Constructing explanations and designing solutions*, in the following instructional activity:

- **Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion**. During the Genetic Engineering for Protein Production Laboratory Investigation, students use evidence from the lab they just completed to make a claim about whether their model can reliably predict how to modify the DNA of any organism to create and isolate a useful protein product. As the final part of this task, students use scientific principles to explain how their claim is supported by the data they collected (Student Section, p. 35).

Practice 7: Engaging in argument from evidence

Students engage in elements of *Practice 7, Engaging in argument from evidence*, in the following instructional activity:

- **Construct and/or support an argument with evidence, data, and/or a model**. During the Genetic Engineering for Protein Production Laboratory Investigation, students use evidence from the lab they just completed to make a claim about whether their model can reliably predict how to modify the DNA of any organism to create and isolate a useful protein product (Student Section, p. 35).

Practice 8: Obtaining, evaluating, and communicating information

Students engage in elements of *Practice 8, Obtaining, evaluating, and communicating information,* in the following instructional activity:

- **Communicate scientific and/or technical information or ideas in multiple formats.** For their final project, student groups present a Pecha Kucha style presentation that introduces an innovative drug delivery system to cure or prevent a disease, along with a model of how the drug works and clinical trial plans for approval by the U.S. Food and Drug Administration (Social Awareness Campaign Project Design Journal, p. 3).

Criterion 2: Content Largely From the California NGSS

As previously noted, the Futurelab+ curriculum was designed to be aligned to the California Career Technical Education Model Curriculum Standards for Biotechnology. These standards, adopted in 2013, include an Academic Alignment Matrix (p. 32) that explicitly indicates content overlap with the NGSS and the Common Core State Standards for Literacy in History/Social Studies, Science, and Technical Subjects. For feedback about incorporation of specific three-dimensional learning and instructional shifts, see the accompanying **NGSS Innovations and Design Principles: Summative Review, Unit 3, Laboratory Investigation** report.

Criterion 3: All Phases of the Scientific Process

Throughout Unit 3, students complete learning activities to develop the content knowledge and skills needed for the unit's final project, for which they serve as part of a drug research and development team working to cure or prevent a mystery disease, and they then present their design solution and clinical trial plan at a mock conference (Design Journal, p. 3). Learning activities that work toward addressing this final project include the following:

- Identifying a problem through research that justifies the need for a new drug innovation or technology
- Researching the disease description and details; background information; available treatments, including benefits and limitations; and other questions they identify through the unit's activities
- Communicating the problem and proposed solution by creating their choice of a model or animation that demonstrates their proposed solution, along with a Pecha Kucha slideshow they present to their peers
- Student groups are guided through a 12-step engineering design process during the final project, as identified throughout the Mystery Disease Conference Project Design Journal (pp. 6–35).

Criterion 4: Employ Quantitative Reasoning and Methods Where Appropriate

Unit 3 has several opportunities for students to use quantitative reasoning, particularly in making sense of graphical displays of data, such as in the Nucleic Acid–Based Drugs Model Assignment in the Nucleic Acid Assays lab (Student Section, p. 9). Additionally, students calculate serial dilutions and a standard curve during Lesson 7, Protein Assays (Student Section, p. 2).

Criterion 5: At Least 20% Class Time for Teacher-Supervised, Hands-On Laboratory Activities

This criterion specifically recommends that at least one scientific investigation be a student-designed project involving a tested hypothesis and that "teacher supervision may be synchronous or asynchronous, depending on whether the learning environment is classroom-based, fully online, or a hybrid."

Names of specific laboratory activities are noted in the Unit 3 Flow Chart and are listed, along with their timings, below:

- LAB: Genetic Engineering for Protein Production—6 Days
- Lesson 3: DNA Virtual Extraction Lab; Gel Electrophoresis Virtual Lab—2 Days
- Lesson 6: Gel Electrophoresis Simulation—1 Day
- Lesson 7: Purifying Proteins Virtual Lab—1 Day

Unit 3 includes 10 days, or roughly 19% of unit time, of teacher-supervised, hands-on laboratory activities throughout 53 days of instruction. Although this specific unit does not meet the 20% requirement, the full year of curriculum a student encounters should be taken into consideration for this criterion.

Criterion 6: Explicit Formative and Summative Assessment Practices

AIR found evidence of several opportunities for teachers to gauge student learning, with both formative and summative assessment practices, and students are often provided the opportunity to demonstrate their learning of a specific topic in multiple ways.

The [Protocols for Culturally Responsive Learning and Increased Student Engagement] include multiple protocols for gathering *formative* assessment information, in a culturally responsive way, about student prior knowledge. Specific protocols and their purposes are often identified within the teaching section, with notes to teachers about what to look for in student responses. An example can be found in Lesson 7, Protein Assays, where teachers use the *silent appointment* strategy for students to summarize and share key information with each other as a formative assessment of student understanding (Teacher Section, p. 10).

The Unit 3 Flow Chart provides an overview for teachers about specific instructional activities and resulting student artifacts generated to demonstrate student learning, including student-created posters, presentations, videos, concept maps, activities, and letters. Each lesson includes several graphic organizers and worksheets for students as well.

Finally, the overall summative assessment is a unit-long, project-based learning opportunity in which students apply what they have learned throughout the unit to solve a real-world problem by designing an innovative drug delivery system or technology that helps to cure or prevent a mystery disease.

Criterion 7: Real-World Problems and Applications

Unit 3 of the Futurelab+ biotechnology curriculum excels at providing real-world problem and application connections for students.

As noted in several prior criteria, the Unit 3 final activity is a project-based learning opportunity in which students are tasked with designing an innovative drug delivery system or technology that helps to cure or prevent a mystery disease.

Additionally, lessons within the unit are explicitly tied to real-world problems and scenarios. Some examples of real-world problem and application activities in Unit 3 lessons include the following:

- *Protein Assays*, in which students learn how protein assays are used to diagnose diseases and then create a public service announcement to share how a selected disease or condition can lead to kidney disease
- *How are Drugs Tested*, in which students review case studies and ethical issues that guide biomedical research.

Criterion 8: Include the Use of Technology

The Futurelab+ curriculum was designed to be flexible for teachers who may have to alternate between in-person learning, virtual learning, or a hybrid environment. As such, the curriculum includes multiple opportunities for students to use a variety of programs that are open source and provides students with opportunities to manipulate data; run simulations; record videos and commercials; and, in Unit 3, prepare a mock conference presentation in which student groups introduce a patient, a “mystery” disease, and an innovative drug delivery system or technology that could help cure or prevent the disease. Students present their work during a Pecha Kucha style presentation, using models, animations, and flow charts.

Resources

Achieve & National Science Teachers Association. (2016). *NGSS lesson screener*. https://www.nextgenscience.org/screener

California Department of Education. (2007). *Career technical education framework for California public schools: Grades seven through twelve*. https://www.cde.ca.gov/ci/ct/sf/documents/cteframework.pdf

California Department of Education. (2017). *California career technical education model curriculum standards*. https://www.cde.ca.gov/ci/ct/sf/documents/healthmedical.pdf

Sacramento City Unified School District. (n.d.). *Protocols for culturally responsive learning and increased student engagement*. Retrieved October 11, 2021, from https://www.scusd.edu/sites/main/files/file-attachments/protocols_0.pdf?1445031253.

University of California. (n.d.). *Writing A–G Courses* [UC A–G Course Management Portal]. https://hs-articulation.ucop.edu/guide/update-your-a-g-list/writing-a-g-courses/

Appendix A. Example Science (D) Subject Course Description

The following sample course description was shared by the University of California to “give course authors a model for how to construct course overviews, unit overviews, and sample assignments” (University of California, “Sample course descriptions.”). The course description below can be found here.

Subject Area “D” Sample

Included in this sample is a single course overview, unit, and assignment; this is not a sample of a complete course, nor are all disciplines/courses represented in this sample. The purpose of these pieces is to give course authors a basic sample of how to construct strong course overviews, units, and assignments. Often, when a course is not approved by the UC High School Articulation Team, it is because the UC A-G Subject Area Specific Criteria is not explicitly written into a course submission. We encourage all course authors to consistently review the criteria specific to the subject/discipline under which they are submitting their courses.

Course Title: Biology / **Subject:** Laboratory Science / **Discipline:** Biology

Sample Course Overview:

In this course, students develop an in-depth understanding of the living world by studying structure, function and processes. Students recognize and understand the interactions of chemistry, physics, and earth sciences in the study of biology. Laboratory investigations incorporate procedures and develop the ability to analyze complex information. The main content areas of focus are cell biology, ecology, genetics, evolution, and physiology. Students will continue to develop their skills of reading, writing, discussion, technology, and analysis through lab reports, essays, and individual and group research projects. The ultimate course goal is to demonstrate scientific knowledge and skills as students work toward the school-wide goals of becoming self-directed learners who can identify a task and complete it, complex thinkers who can determine solutions to problems, and community contributors who can work collaboratively.

This course overview demonstrates the following strengths:

- Uses concise language which gives a global view of the course without sacrificing meaning
- Includes a balance of skills and content (merely listing standards to be covered is not sufficient)
- Previews how the course will integrate the following UC laboratory science “D” subject area requirements:
  - All courses approved in the laboratory science subject area should be designed with the explicit intention of developing and encouraging scientific habits of mind important for university-level studies and aligned with the eight practices of science and engineering identified by the National Research Council Framework and detailed within the Next Generation Science Standards

Sample Unit: *Cells*

This unit builds upon key lessons introduced in the previous unit, the scientific process, data analysis, investigation and experimentation, by unifying the themes of biology. This unit covers chemical concepts, the differences between carbon-based molecules and proteins, the differences between aerobic and anaerobic respiration, and cell theories related to all living things and how they function. Students begin by understanding basic cellular functions and then move on to compare and contrast different cell types to develop mastery of the processes essential to homeostasis and the proper function of all living cells. Explanation of the properties of water will be applied to diffusion and osmosis across cell membranes. The concepts of chemical energy production and usage, photosynthesis and cellular respiration, will build a foundation for understanding the processes of cell growth and regulation. Enzymatic activity will be connected to the essential cellular processes as they apply to all living organisms. In total, this unit provides students with an inquiry-based approach to applying their knowledge of energy dynamics within cellular organelles while utilizing investigation and experimentation skills mastered in a previous unit.

Sample Unit Assignment: *Cells*

Supervised by course teacher, each student will explore how the sugar content of a banana changes as it ripens. Students will formulate a hypothesis as to the amount of sugar and starch content that are contained in samples of green, ripe and overripe bananas. After determining the sugar and starch concentrations of various samples, students will demonstrate their understanding of the process of fruit ripening by comparing their predictions to the data generated. Students will use the data collected from the lab to confirm whether their hypothesis was valid or disproved. Their conclusions regarding the relationship between sugar content, starch content, and the ripening process will be based on these comparisons. After predicting concentrations of sugar and starch in various banana samples, students will perform a test with Benedict's reagent to determine the presence of sugar and a test for the presence of starch using an iodine solution. Students will then use their predictions and collected quantitative data to demonstrate an understanding of the fruit ripening process. Students will be writing a 2 to 3 page lab report that includes that clearly states the hypothesis, experimental methods, collected data, analysis of the data, and conclusion of their findings.

While these single unit and assignment samples do not, nor are designed to, demonstrate all of the UC subject area "d" course criteria, they clearly and concisely exhibit the components of the criteria listed below, are well-written, and ultimately answer the question: ***How do this single unit and assignment meet the UC criteria for a college-preparatory laboratory science course?***

This sample course unit and assignment demonstrate the following strengths & course criteria:

- provides rigorous, in-depth treatments of the conceptual foundations of the scientific subject studied based on the appropriate underlying biological, chemical and physical principles
- affords students opportunities to participate in all phases of the scientific process, including formulation of well-posed scientific questions and hypotheses, design of experiments and/or data collection strategies, analysis of data, and drawing of conclusions; they will also require students to discuss scientific ideas with other students, differentiate observations from interpretations, engage in critical thinking and write clearly and coherently on scientific topics
- employs quantitative reasoning and methods wherever appropriate
- includes a teacher-supervised, hands-on laboratory activities that are directly related to, and support, the other class work, and that involve inquiry, observation, analysis and write-up

Appendix B. Sample Unit Overview, Assignment Overview, and Lab Activity

Example Unit Overview: *Nucleic Acids and Proteins: Disease Treatment Innovations*

Throughout this unit, students focus on the concept of diagnosing and treating diseases. They explore the role medical devices play in treating patients. For the unit's final project, students create a drug delivery innovation for patients who have been diagnosed with or who are at risk for a disease that does not yet have a cure. Students use the information and skills acquired throughout the lessons in this unit to successfully complete the culminating project. They apply the knowledge gained from initial lessons on how DNA, RNA, and proteins are modified and isolated. Students also apply their understanding of the mechanisms of nucleic acids and proteins in the phases of drug testing and drug delivery.

Example Unit Assignment: *Mystery Disease Conference*

Students work as part of a drug research and development team that has been invited to present at a Mystery Disease Conference. Students research a disease that has no cure and design and present an innovative drug delivery system or technology designed to cure or prevent the disease. Students engage in the full engineering design cycle as they define the problem, brainstorm ideas to research, identify success criteria and constraints of their design, explore existing solutions, select an approach, develop their design proposal, make a model or prototype of their solution, design a test to evaluate their prototype, and then refine their design. Student teams then create and present a Pecha Kucha presentation that includes their 2-D model or animation and outlines a detailed clinical trial plan that gives important data about their drug's effectiveness while addressing a pathway to approval by the U.S. Food and Drug Administration.

Lab Activity: *Genetic Engineering for Protein Production*

In this teacher-supervised lab, students genetically engineer E. coli bacteria to produce a fluorescent green protein, resulting in glowing bacterial colonies via bacterial transformation to introduce a GFP (green fluorescent protein) gene originally from jellyfish into the bacteria. This gene is inducible, meaning that it can be "turned on or off," illustrating the role of gene regulation in protein expression. Then, students isolate GFP from successfully transformed E. coli colonies, using nickel affinity chromatography.

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