ED I Lab: Flow of Matter, Energy and…^{137}Cesium?

This lab combines Disciplinary Core Ideas from the physical, life, and earth and space sciences as well as engineering design. The core ideas include how energy flows through ecosystems; biomagnification and bioaccumulation and how they can threaten the health of humans and ecosystems alike; and biodiversity, including the negative impact that humans have had on biodiversity and how people are thinking about decreasing the negative impact. In studying these phenomena, students have the opportunity to understand them in relation to 6 Crosscutting Concepts – patterns; cause and effect; scale, proportion, and quantity; systems and systemic models; energy and matter; and stability and change (indicated by color below). Students learn about these ideas and concepts through engaging in a variety of scientific practices. They model both biomagnification and sustainable fishing and use what they have learned as a basis for their first formal debate. Each of three groups will take a position on which of the following is the most significant threat to Pacific seafood over the next five years – radioactivity, mercury poisoning or overfishing. Groups will be competing for funding to be used over a five-year timeframe, two of the most critical constraints faced by any research team. To support their position, students must use what they have learned in the lab as well as conduct internet research on human consumption of Pacific seafood, biodiversity, and existing conservation efforts using secondary sources and relevant databases. Preparing for and engaging in the debate gives students the opportunity to work on a variety of skills, particularly analyzing and interpreting data; constructing explanations; engaging in argumentation; evaluating or proposing solutions, and obtaining, evaluating, and communicating information.

This lab also addresses the following understandings about the *Nature of Science* as described in Appendix H of NGSS:

- Scientific Investigations Use a Variety of Methods (MS&HS)
- Scientific Knowledge is Based on Empirical Evidence (MS&HS)
- Scientific Knowledge is Open to Revision in Light of New Evidence (MS&HS)
- Science, Models, Laws, Mechanisms, and Theories Explain Natural Phenomena (HS)
- Science is a Way of Knowing (MS&HS)
- Scientific Knowledge Assumes an Order and Consistency in Natural Systems (MS&HS)
- Science is a Human Endeavor (MS&HS)
- Science Addresses Questions About the Natural and Material World (MS&HS)

NRC Framework Disciplinary Core Ideas (DCI) and Crosscutting Concepts Related to the Lab

Crosscutting Concepts Color Key	
■ = Patterns	■ = Energy and matter
■ = Cause and effect	■ = Structure and function
■ = Scale, proportion, and quantity	■ = Stability and change
■ = Systems and systemic models	Brackets [ ] denote additional cross-cutting concepts

NOTE: Where the NGSS Performance Expectations align to both our lab and the Framework DCI, we include the Performance Expectations parenthetically [i.e., (MS-PS1-1)]. This follows the same convention that Achieve follows in their documents.

Physical Sciences	**Life Sciences**	**Earth and Space Sciences**	**Engineering, Technology, and the Application of Science**
Matter and Its Interactions: Structure and Properties of Matter (PS1.A) Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS) [This lab also connects this DCI to Patterns.] Each atom has a charged substructure consisting of a nucleus, which is made of	**From Molecules to Organisms: Organization for Matter and Energy Flow in Organisms (LS1.C)** Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use. (MS-LS1-6) [This lab also connects this DCI to Systems and Systemic Models.]	**Earth's Systems: Earth's Materials and Systems (ESS2.A)** All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms. (MS)	**Engineering Design: Defining and Delimiting Engineering Problems (ETS1.A)** The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be

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protons and neutrons, surrounded by electrons. (HS) The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (HS) **Matter and Its Interactions: Chemical Reactions (PS1.B)** Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS) **Energy: Definitions of Energy (PS3.A)** Energy is a quantitative property of a system that	Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy. (MS) The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. (HS) [This lab also connects this DCI to Systems and Systemic Models.] **Ecosystems: Interactions, Energy, and Dynamics: Interdependent Relationships in Ecosystems (LS2.A)** Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. (MS) **Ecosystems: Interactions, Energy, and Dynamics: Cycle of Matter and Energy Transfer in Ecosystems (LS2.B)** Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter	The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future. (MS) **Earth and Human Activity: Natural Resources (ESS3.A)** Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes. (MS-ESS3-1) Resource availability has guided the development of human society. (HS)	successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. (MS-ETS1-1) Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design

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depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (HS) [This lab also connects this DCI to Systems and Systemic Models.] At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS) [This lab also connects this DCI to Scale, Proportion, and Quantity.] **Energy: Conservation of Energy and Energy Transfer (PS3.B)** Energy cannot be created or destroyed, but it can be transported from one place to another and transferred	into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. (MS-LS2-3) [This lab also connects this DCI to Systems and Systemic Models.] Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. (HS)* * We have not yet considered cellular respiration but have included this DCI because we do consider the relationship between photosynthesis and energy that sustains living systems. Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels	All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. (HS) [This lab also connects this DCI to Cause and Effect.] **Earth and Human Activity: Human Impacts on Earth Systems (ESS3.C)** Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things. (MS-ESS3-3) Typically as human populations and per-capita consumption of natural resources increase, so do the	meets them. (HS-ETS1-1) Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1) **Engineering Design: Developing Possible**

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between systems. (HS) [This lab also connects this DCI to Energy and Matter.] The availability of energy limits what can occur in any system. (HS) [This lab also connects this DCI to Energy and Matter.] Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). (HS) [This lab also connects this DCI to Energy and Matter.] [This lab also connects this DCI to Stability and Change.] **Energy: Energy in Chemical Processes and Everyday Life (PS3.D)** The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction,	of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved. (HS)* * We have not yet considered cellular respiration but have included this DCI because we do cover trophic levels and energy availability. **Ecosystems: Interactions, Energy, and Dynamics: Ecosystem Dynamics, Functioning, and Resilience (LS2.C)** Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. (MS-LS2-4) [This lab also connects this DCI to Cause and Effect.] Biodiversity describes the variety of species found in Earth's terrestrial and	negative impacts on Earth unless the activities and technologies involved are engineered otherwise. (MS-ESS3-3) (MS-ESS3-4) The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. (HS) [This lab also connects this DCI to Cause and Effect.] Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (HS) **Earth and Human Activity: Global Climate Change (ESS3.D)** Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage	**Solutions (ETS1.B)** When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)

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carbon dioxide and water combine to form carbon-based organic molecules and release oxygen. (MS) Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (HS) [This lab also connects this DCI to Systems and Systemic Models.] The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. (HS)	oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health. (MS-LS2-5) A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. (HS-LS2-6) [This lab also connects this DCI to Scale, Proportion, and Quantity.] Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species. (HS)	current and future impacts. (HS) Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities. (HS) [This lab also connects this DCI to Cause and Effect.]	

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	Biological Evolution: Unity and Diversity: Biodiversity and Humans (LS4.D) Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling. (MS) Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. (HS-LS2-7)		

NRC Framework Science and Engineering Practices Related to the Lab

Asking questions and defining problems	Developing and using models	Planning and carrying out investigations	Analyzing and interpreting data
Ask questions • that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information. (MS) • to identify and/or clarify evidence and/or the premise(s) of an argument. (MS) • to clarify and/or refine a model, an explanation, or an engineering problem. (MS) • that require sufficient and appropriate empirical evidence to answer. (MS) • that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, appropriate, frame a hypothesis based on observations and scientific principles. (MS) • that challenge the premise(s) of an argument or the interpretation of a data set. (MS) • that arise from examining models or a theory, to clarify and/or seek additional information and relationships. (HS) • to clarify and refine a model, an explanation, or an engineering problem. (HS) • that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor	Develop and/or use a model to predict and/or describe phenomena. (MS) Develop a model to describe unobservable mechanisms. (MS) Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. (MS)	Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation. (MS) Select appropriate tools to collect, record, analyze, and evaluate data. (HS)	Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships. (MS) Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships. (MS) Analyze and interpret data to provide evidence for phenomena. (MS) Analyze and interpret data to determine similarities and differences in findings. (MS) Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of

Asking questions and defining problems	**Developing and using models**	**Planning and carrying out investigations**	**Analyzing and interpreting data**
environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory. (HS) Ask and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design. (HS)			measurements and observations. (HS)

NRC Framework Science and Engineering Practices Related to the Lab

Using mathematics and computational thinking	**Constructing explanations and designing solutions**	**Engaging in argument from evidence**	**Obtaining, evaluating, and communicating information**
	Construct an explanation using models or representations. (MS) Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real- world phenomena, examples, or events. (MS) Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion. (MS) Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to	Respectfully provide and receive critiques about one's explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail. (MS) Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. (MS) Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. (HS) Evaluate the claims, evidence, and/or reasoning	Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s). (MS) Integrate qualitative and/or quantitative scientific and/or technical information in written text with that contained in media and visual displays to clarify claims and findings. (MS) Communicate scientific and/or technical information (e.g. about a proposed object, tool, process, system) in writing and/or through oral presentations. (MS) Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. (HS) Compare, integrate and evaluate sources

Using mathematics and computational thinking	Constructing explanations and designing solutions	Engaging in argument from evidence	Obtaining, evaluating, and communicating information
	do so in the future. (HS) 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. (HS)	behind currently accepted explanations or solutions to determine the merits of arguments. (HS) Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence, challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining additional information required to resolve contradictions. (HS) Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence. (HS) Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence. (HS)	of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. (HS) Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. (HS) Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically). (HS)