

Unit SUMMARY**Storyline Narrative:**

In this Unit, students will be exploring the dynamics of ecosystems including energy flow, homeostasis, and populations. Students will investigate the factors affecting systems from the micro to the macro level. The anchoring phenomenon of this Unit is “How Do Wolves Change Rivers” which is based upon the reintroduction of wolves into Yellowstone National Park.

In sequence 1, students will view a short clip of the video “How Do Wolves Change Rivers?” After viewing the clip, students will generate questions via the instructional strategy known as QFT (Question Formulation Technique) about how wolves can change rivers. They will also create a driving question board that will be revisited throughout the subsequent Learning Sequences. The question “How Do Wolves Change Rivers?” will be the anchoring phenomenon for this Unit.

In Learning Sequence 2, students will explore feedback loops and their effect on systems. Students will begin by watching a short video clip: “How to Outrun a Cheetah” and generate ideas about why the cheetah could not catch the gazelle using a discussion diamond. They will create models to apply their understanding of systems to how the stability of a living system depends on self regulating (feedback) mechanisms; lastly, students will describe how the structures of a system function independently, yet come together for the functioning of the system as a whole.

In Learning Sequence 3, students will explore the cycling of energy and carbon in systems when sunlight and oxygen are not present. Students will conclude that different forms of energy can be used to drive the cycling of matter in different systems. Students will be challenged to explain how organisms can convert chemical energy to ATP in the absence of oxygen. They will use these concepts to develop a model of a deep sea vent ecosystem.

In Learning Sequence 4, students will draw upon their knowledge of energy transfer and conversion to explore the factors that determine population size. Students will identify trends of population sizes within an ecosystem, describe how a limited amount of resources will affect the interactions across all levels of an ecosystem and mathematically represent how carrying capacity limits the number of organisms and populations within an ecosystem. They will begin by analyzing a predator/prey graph, looking for patterns and trends. Students will simulate a predator prey relationship to identify the interdependence of the species. Students will perform a computer simulation to “build their own ecosystem”, describing how a limited amount of resources will affect the interactions across all levels of an ecosystem. Students will then apply this new knowledge to a real-world scenario, using data and evidence to predict why the population of reindeer died off on St. Matthew Island in the mid-1960s.

In Learning Sequence 5, students will modify their original model, showing how the reintroduction of wolves into Yellowstone National Park changed the park’s ecosystem. This sequence adapts lesson plans from [The Nature Conservancy](#). Students will analyze mathematical representations of factors that determine population changes and their effects on the biodiversity of an ecosystem; lastly, students will revise their model of a system showing how the parts work together to contribute to fluctuations or stability in biodiversity.

Suggested time frame:

28 hours or 37 days (Based on 45 min blocks)

Anchoring Phenomenon/Design Problem:

- Reintroduction of Wolves into Yellowstone National Park

NGSS Performance Expectation(s): (Hyperlinks will bring reader to NGSS Evidence Statements)

- [HS-LS1-2](#). Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. [Clarification Statement: Emphasis is on functions at the organism system level such as nutrient uptake, water delivery, and organism movement in response to neural stimuli. An example of an interacting system could be an artery depending on the proper function of elastic tissue and smooth muscle to regulate and deliver the proper amount of blood within the circulatory system.] [Assessment Boundary: Assessment does not include interactions and functions at the molecular or chemical reaction level.]
- [HS-LS1-3](#). Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis. [Clarification Statement: Examples of investigations could include heart rate response to exercise, stomate response to moisture and temperature, and root development in response to water levels.] [Assessment Boundary: Assessment does not include the cellular processes involved in the feedback mechanism.]
- [HS-LS2-1](#). Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales. [Clarification Statement: Emphasis is on quantitative analysis and comparison of the relationships among interdependent factors including boundaries, resources, climate, and competition. Examples of mathematical comparisons could include graphs, charts, histograms, and population changes gathered from simulations or historical data sets.] [Assessment Boundary: Assessment does not include deriving mathematical equations to make comparisons.]
- [HS-LS2-2](#). Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. [Clarification Statement: Examples of

mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.] [Assessment Boundary: Assessment is limited to provided data.]

- [HS-LS2-3](#). Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.[Clarification Statement: Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration in different environments.] [Assessment Boundary: Assessment does not include the specific chemical processes of either aerobic or anaerobic respiration.]
- [HS-ETS1-2](#). Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

Three Dimensions that form the Foundation for these NGSS Performance Expectations:

Science & Engineering Practices:

Planning and Carrying Out Investigations

- Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. HS-LS1-3

Developing and Using Models

- Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. HS-LS1-2

Constructing Explanations and

Designing Solutions

- 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 do so in the future. HS-LS2-3
- Design a solution to a complex real-world problem based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade off considerations.HS-ETS1-2

Using Mathematics and Computational Thinking

- Use mathematical and/or computational representations of phenomena or design solutions to support explanations.HS-LS2-1
- Use mathematical representations of phenomena or design solutions to support and revise explanations. HS-LS2-2

Disciplinary Core Ideas:

LS1.A: Structure and Function

- Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system. HS-LS1-3
- Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. HS-LS1-2

LS2.A: Interdependent Relationships in Ecosystems

- Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. HS-LS2-1,HS-LS2-2

LS2.B: Cycles of Matter and Energy Transfer in Ecosystems

- Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.HS-LS2-3

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

- 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

Crosscutting Concepts:

Systems and System Models

- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. HS-LS1-2

Energy and Matter

- Energy drives the cycling of matter within and between systems. HS-LS2-3

Stability and Change

- Feedback (negative or positive) can stabilize or destabilize a system. HS-LS1-3

Scale, Proportion, and Quantity

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. HS-LS2-1
- Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. HS-LS2-2

	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-LS2-2 ETS1.C: Optimizing the Design Solution Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. HS-ETS1-2	
Possible Common Core State Standards Connections: ELA/Literacy - - RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-LS2-3)(HS-LS2-1)(HS-LS2-2) - WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-LS2-1)(HS-LS2-2) - WHST.9-12.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-LS2-3) - WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-LS1-3) - WHST.11-12.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and over reliance on any one source and following a standard format for citation. (HS-LS1-3) - SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-LS1-2) Mathematics - - MP.2 Reason abstractly and quantitatively. (HS-LS2-1)(HS-LS2-2) - MP.4 Model with mathematics. (HS-LS2-1)(HS-LS2-2)(HS-ETS1-2) - HSN.Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-LS2-1)(HS-LS2-2) - HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-LS2-1)(HS-LS2-2) - HSN.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-LS2-1)(HS-LS2-2) Prior Student Knowledge: MS.LS1.A All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular). - Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. - In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions. (HS-LS1-2, HS-LS1-3) MS.LS2.A Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. - In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. - Growth of organisms and population increases are limited by access to resources. - Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually		

beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared. ([HS-LS2-1](#), [HS-LS2-2](#))

- [MS.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. Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health. ([HS-LS2-1](#), [HS-LS2-2](#))
- [MS.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. ([HS-LS2-1](#))
- [MS.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.
- Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise. ([HS-LS2-1](#), [HS-LS2-2](#))
- [MS.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.
- The total number of each type of atom is conserved, and thus the mass does not change.
- Some chemical reactions release energy, others store energy. ([HS-LS2-3](#))
- [MS.PS3.D](#) [HS-LS2-3](#)
- [MS.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.
- 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. ([HS-LS2-3](#))
- [MS.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 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. ([HS-LS2-3](#))
- [MS.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 successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. ([HS-ETS1-2](#))
- [MS.ETS1.B](#) A solution needs to be tested, and then modified on the basis of the test results, in order to improve it.
- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.
- Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.
- Models of all kinds are important for testing solutions. [HS-ETS1-2](#)
- [MS.ETS1.C](#) Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design.
- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. [HS-ETS1-2](#)

Possible Misconceptions:

- Changes in a population do not affect populations that are not directly connected by a feeding relationship.
- Organisms higher in a food web eat everything that is lower in the food web.
- If the size of one population in a food web is altered, all other populations in the web will be altered in the same way.
- Plants do not compete for resources.
- Different kinds of organisms (species) do not compete for resources.
- Plants do not compete for light.
- Competition between organisms always involves direct, aggressive interaction. Exploitative competition (e.g., getting to the resource before other organisms) is not competition.
- Air is distributed through the body in air tubes.
- Molecules from food are distributed by way of special tubes, not by way of the circulatory system, to the rest of the body.
- The heart is the mixing place for air and blood.
- Anything can pass through the walls of capillaries.
- Carbon dioxide is absorbed through the roots of plants.

- Food is a source of energy but not a source of building materials.
- Carbon dioxide is food for plants.
- Substances in soil are food for plant.
- Plants have multiple food sources, not just the sugars that they make from water and carbon dioxide.
- Plants cannot store molecules from food in their body structure.

PROGRESSION OF LEARNING

Learning Sequence 1: Student Engagement with the Anchoring Phenomenon

- Essential Question: How can biotic (wolves) components of an ecosystem alter the abiotic (river course, flow) components of the ecosystem?
- [Learning Sequence 1](#)
- Relationship to Anchoring Phenomena/Design Problem: This is the introduction to the anchoring phenomenon.
- Student Expected Outcomes:
 - Students will create an initial model of changes across many dimensions in an ecosystem in response to a change at one trophic level.
 - Students will ask questions about what else they need to understand in order to make predictions about changes in an ecosystem.

Learning Sequence 2

- Essential Question: Why are component systems necessary for complex organisms to function?
- [Learning Sequence 2](#)
- Relationship to Anchoring Phenomena/Design Problem:
 - Students will develop understanding of dynamic interactions in systems of individual organisms in order to apply to the complex interactions affecting the wolves/river ecosystem.
- Student Expected Outcomes:
 - Students will create models to apply their understanding of systems to how the stability of a living system depends on self regulating (feedback) mechanisms
 - Students will describe how the structures of a system function independently, yet come together for the functioning of the system as a whole.

Learning Sequence 3

- Essential Question: How does energy drives the cycling of matter in an ecosystem?
- [Learning Sequence 3](#)
- Relationship to Anchoring Phenomena/Design Problem:
 - Students will consider the sources of energy that drive the cycling of matter in an ecosystem.
- Student Expected Outcomes:
 - Students will identify forms of energy and sources of carbon that life requires within and between systems.
 - Students will propose ways that energy can be converted from one form to another and transferred within a system.
 - Students will evaluate and refine their proposals based on evidence to demonstrate how changes in energy availability will affect the system.
 - Students will describe how changes to energy availability at different levels of a system will affect that system.

Learning Sequence 4

- Essential Question: What determines population size of different organisms?
- [Learning Sequence 4](#)
- Relationship to Anchoring Phenomena/Design Problem:
 - Students will explain feedback mechanisms that control populations and and the consequences of changes in populations.
- Student Expected Outcomes:
 - Students will identify trends of population sizes within an ecosystem.
 - Students will describe how a limited amount of resources will affect the interactions across all levels of an ecosystem.
 - Students will mathematically represent how carrying capacity limits the number of organisms and populations within an ecosystem.

Learning Sequence 5

- Essential Question: How do ecosystems respond to change?
- [Learning Sequence 5](#)
- Relationship to Anchoring Phenomena/Design Problem:
 - Students complete their model of the anchoring phenomenon, explaining how the components of an ecosystem interact.
- Student Expected Outcomes:
 - Students will analyze mathematical representations of factors that determine population size and their effect on the biodiversity of an ecosystem.
 - Students will develop a model of a changing ecosystem and identify the interactions of its parts.
 - Students will develop a model of a system showing how the parts work together to respond to fluctuations or maintain stability and biodiversity.

Special thanks to all of the individuals that contributed to this unit:

Unit developed by: Keith Syrett, Angie Kumm, Michelle Desrochers, Matthew DeBacco, Dave Capozzi, Beth Sugden

Edited by: Anne Puzzo

Materials Required for this Unit**List Number required for a class of 24 students**

Quantity	Description	Potential Supplier (item #)	Estimated Price
Learning Sequence 1			
1	newsprint 24x36 500 sheets	WB Mason PAC3414	34.95
24	assorted markers	WB Mason CYO587708	5.09 ea
	Computer with YouTube access and way to project video		
1	Sticky Notes 12 pack	WB Mason MMM65412SST	26.09
Learning Sequence 2			
1	Projector for video		
1	newsprint 24x36 500 sheets	WB Mason PAC3414	34.95
24	assorted markers (set 8)	WB Mason CYO587708	5.09 ea
12	Stopwatches(2 set/12, \$45 ea)	Carolina 962108	45.00ea
12	garbage bags	grocery store	8.00
Learning Sequence 3			
1	Empty 500 mL water bottles or 1000 ml graduated cylinders (box/6)	Flinn AP6408	120.24
6	Knife or scissors	WB Mason BOS10065	7.39 ea
1	sharpie box/12	wb mason SAN30001	11.98
2	Utility Buckets	Flinn AP6009	4.19 ea
100 g	Newspaper or calcium carbonate or sodium bicarbonate (baking soda)	Flinn C0347	7.30
500 g	Boiled egg yolk or calcium sulfate	Flinn C0032	6.55
1	Gloves (pkg 500)	Flinn SE1032	36.20
6	Large mixing bowls or containers	walmart or similiar	6.50 ea
1	Parafilm (roll)	Flinn AP1501	25.50
4	lamps or grow lights	Carolina 974254	21.95ea
12	Stopwatches(2 set/12, \$45 ea)	Carolina 962108	45.00ea

1	jar yeast	grocery store	7.50
4	bottles karo syrup	grocery store	2.50 ea
12	test tube rack	Flinn AP4417	9.25 ea
36	test tubes (18x150mm) .85	Flinn GP6025	.85 ea
36	test tubes (25 mm x 150 mm)	Flinn GP6035	1.55 ea
1	dropping pipette box/500	Flinn AP1516	25.50
12	metric rulers	wb Mason UNV59022	1.99 ea
12	graduated cylinders (100 mL)	Flinn AP2297	11.50 ea
	Assorted teacher prepared solutions (soda, juice, ect)		
	Learning Sequence 4		
1	newsprint 24x36 500 sheets	WB Mason PAC3414	34.95
24	assorted markers	WB Mason CYO587708	5.09 ea
	Access to computers/internet		
1	paper (hares) 5000 sheet	WB Mason BLZ41200	8.99
1	card stock (lynx) pk 100 sheet	WB Mason PAC101169	14.69
	Access to paper cutter		
	Learning Sequence 5		
1	newsprint 24x36 500 sheets	WB Mason PAC3414	34.95
24	assorted markers	WB Mason CYO587708	5.09 ea
	Computer with YouTube access and way to project video		
1	Sticky Notes 12 pack	WB Mason MMM65412SST	26.09
1	newsprint 24x36 500 sheets	WB Mason PAC3414	34.95