SREB Readiness Courses

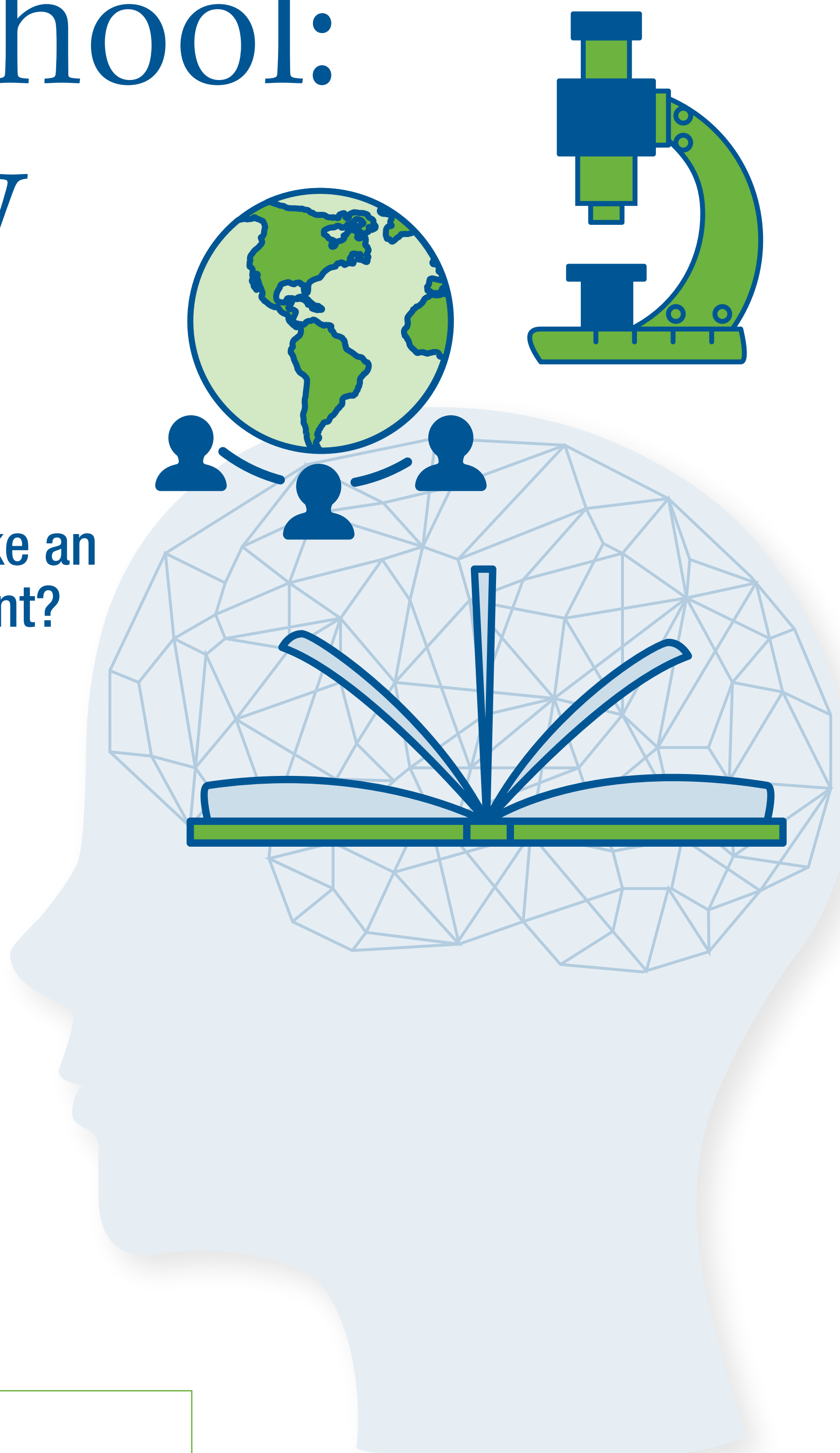
Ready for High School: Literacy

Academic Notebook

Science Unit 2

Do our actions really make an impact on the environment?

Informational Text



Name

Unit 2
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Course Overview

In this unit, you will continue to apply literacy strategies in science in order to analyze issues in environmental science. You will examine environmental problems facing our planet today and the scientific concepts underlying these issues. You will focus on the disciplinary literacy strategies critical in science, such as questioning, analyzing data, using models, analyzing cause and effect relationships, constructing explanations, and finally constructing scientific arguments. You will apply your understanding in order to propose a solution for a particular environmental problem. This is the ultimate application of scientific understanding – to apply scientific principles in order to design a solution to a problem facing humans.

Purposes of the Academic Notebook

The Academic Notebook has three roles in this course. First, the notebook provides you with a starter kit of tools aimed to prepare you for high school science courses. These tools will assist you in learning and comprehending the information from the scientific text, animations, and lectures you receive in the class.

A second role of the notebook is to provide you with a personal space to record your work. The Academic Notebook is where you will take your notes for the class on any materials you are covering. For example, if you are reading an article in class, take notes in this notebook. If you are doing a lab, make your observations and notes here. Likewise, if you are listening to a lecture, take notes here. Use the tools in the resource portion of the notebook to assist you in organizing your notes.

The third and final role of the notebook is that of an assessment tool. Your instructor may periodically collect the notebooks and review your work to ensure that you are remaining on task and to assist you with any material that is causing you difficulty. Your instructor may also assign tasks to be completed in the notebook, such as in-class writing assignments. At the end of this six-week module, your instructor will review the contents of this notebook as part of your overall grade. Thus, it is important that you work seriously, as this notebook becomes the record of your activity in this course.

Helpful Hints for Science Literacy Success

About Scientists: How do scientists think?

As you will spend much of your time in class learning this on your own, it is best to be brief. In short, scientists learn by careful observation of the world around them to discover general principles. They do this through careful experimentation that results in data. Scientists use this data to draw conclusions. You likely have heard of the scientific method. Scientists use this method as a structured way to investigate the questions they have. An important use of the scientific method is to be able to replicate previous work. Scientists strive to organize, analyze, and explain things clearly. Scientists believe that science is an attempt to build understandings of the world and that science findings are tentative and subject to revision based on new understandings.

About Scientists: What do scientists ask?

Scientists ask lots of questions about nature and the world around them. These are questions that you will hopefully come to ask upon completing this coursework, and the tools in the Resource Materials section of the Academic Notebook are intended to aid you in asking these questions.

Scientists are systematic when they ask questions. Scientific inquiry helps scientists answer questions through investigation. They begin with observations. They may start with big, broad questions: “Why? What’s going on? How is this explained?” They then may break a larger question into smaller parts to examine. They examine work that has already been done. They use the scientific method to hypothesize, test, analyze, and draw conclusions. This inquiry is often, cyclical with experience and observation leading to new hypotheses.

Lesson 1

Introduction to Environmental Issues

In this lesson you will be introduced to the gravity of environmental issues facing our planet today. You will begin by examining an ancient civilization of Easter Island in order to analyze how the overuse of environmental resources ultimately led to the demise of the civilization. You will reflect on this example from history as you begin examining environmental issues facing us today. You will reflect upon the guiding question – are we likely to repeat the past by exhausting our planetary resources? You will be introduced to the unit writing task, and to some environmental issues facing our planet today as you begin to brainstorm your research and solution proposal.

Activity

1 Easter Island Reflection

Begin by performing a close read and making annotations of this article from *Discover Magazine*. Recall from Science Unit 1 the purpose of annotation, and how this looks different in science than it might in other subject areas.

Annotating in Science

What is annotation?

- Writing brief summaries in the textbook's margin.
- Enumerating multiple ideas (i.e., causes, effects, reasons characteristics).
- Sketching pictures or charts to explain difficult processes/concepts.
- Writing possible test questions.
- Noting puzzling or confusing ideas that need clarification.
- Underlining key ideas.

Why should I annotate?

- It will improve your concentration so you will not become distracted and have to reread.
- It can provide an immediate self-check for your understanding of the textbook's key ideas.
- It will help you remember more.
- It can assist you in test preparation.
- It will negate the need of time spent in rereading the chapters.
- It will help you state ideas in your words.

What should I annotate?

- Definitions
- Lists, features, causes, effects, reasons, characteristics
- Diagrams and Processes
- Examples of good ideas

Easter's End

In just a few centuries, the people of Easter Island wiped out their forest, drove their plants and animals to extinction, and saw their complex society spiral into chaos and cannibalism. Are we about to follow their lead?

By Diamond Tuesday, August 01, 1995

Among the most riveting mysteries of human history are those posed by vanished civilizations. Everyone who has seen the abandoned buildings of the Khmer, the Maya, or the Anasazi is immediately moved to ask the same question: Why did the societies that erected those structures disappear?

Their vanishing touches us as the disappearance of other animals, even the dinosaurs, never can. No matter how exotic those lost civilizations seem, their framers were humans like us. Who is to say we won't succumb to the same fate? Perhaps someday New York's skyscrapers will stand derelict and overgrown with vegetation, like the temples at Angkor Wat and Tikal.

Among all such vanished civilizations, that of the former Polynesian society on Easter Island remains unsurpassed in mystery and isolation. The mystery stems especially from the island's gigantic stone statues and its impoverished landscape, but it is enhanced by our associations with the specific people involved: Polynesians represent for us the ultimate in exotic romance, the background for many a child's, and an adult's, vision of paradise. My own interest in Easter was kindled over 30 years ago when I read Thor Heyerdahl's fabulous accounts of his Kon-Tiki voyage.

But my interest has been revived recently by a much more exciting account, one not of heroic voyages but of painstaking research and analysis. My friend David Steadman, a paleontologist, has been working with a number of other researchers who are carrying out the first systematic excavations on Easter intended to identify the animals and plants that once lived there. Their work is contributing to a new interpretation of the island's history that makes it a tale not only of wonder but of warning as well.

Easter Island, with an area of only 64 square miles, is the world's most isolated scrap of habitable land. It lies in the Pacific Ocean more than 2,000 miles west of the nearest continent (South America), 1,400 miles from even the nearest habitable island (Pitcairn). Its subtropical location and latitude--at 27 degrees south, it is approximately as far below the equator as Houston is north of it--help give it a rather mild climate, while its volcanic origins make its soil fertile. In theory, this combination of blessings should have made Easter a miniature paradise, remote from problems that beset the rest of the world.

The island derives its name from its discovery by the Dutch explorer Jacob Roggeveen, on Easter (April 5) in 1722. Roggeveen's first impression was not of a paradise but of a wasteland: We originally, from a further distance, have considered the said Easter Island as sandy; the reason for that is this, that we counted as sand the withered grass, hay, or other scorched and burnt vegetation, because its wasted appearance could give no other impression than of a singular poverty and barrenness.

The island Roggeveen saw was a grassland without a single tree or bush over ten feet high. Modern botanists have identified only 47 species of higher plants native to Easter, most of them grasses, sedges, and ferns. The list includes just two species of small trees and two of woody shrubs. With such flora, the islanders Roggeveen encountered had no source of real firewood to warm themselves during Easter's cool, wet, windy winters. Their native animals included nothing larger than insects, not even a single species of native bat, land bird, land snail, or lizard. For domestic animals, they had only chickens.

European visitors throughout the eighteenth and early nineteenth centuries estimated Easter's human population at about 2,000, a modest number considering the island's fertility. As Captain James Cook recognized during his brief visit in 1774, the islanders were Polynesians (a Tahitian man accompanying Cook was able to converse with them). Yet despite the Polynesians' well-deserved fame as a great seafaring people, the Easter Islanders who came out to Roggeveen's and Cook's ships did so by swimming or paddling canoes that Roggeveen described as bad and frail. Their craft, he wrote, were put together with manifold small planks and light inner timbers, which they cleverly stitched together with very fine twisted threads. . . . But as they lack the knowledge and particularly the materials for caulking and making tight the great number of seams of the canoes, these are accordingly very leaky, for which reason they are compelled to spend half the time in bailing. The canoes, only ten feet long, held at most two people, and only three or four canoes were observed on the entire island.

With such flimsy craft, Polynesians could never have colonized Easter from even the nearest island, nor could they have traveled far offshore to fish. The islanders Roggeveen met were totally isolated, unaware that other people existed. Investigators in all the years since his visit have discovered no trace of the islanders' having any outside contacts: not a single Easter Island rock or product has turned up elsewhere, nor has anything been found on the island that could have been brought by anyone other than the original settlers or the Europeans. Yet the people living on Easter claimed memories of visiting the uninhabited Sala y Gomez reef 260 miles away, far beyond the range of the leaky canoes seen by Roggeveen. How did the islanders' ancestors reach that reef from Easter, or reach Easter from anywhere else?

Easter Island's most famous feature is its huge stone statues, more than 200 of which once stood on massive stone platforms lining the coast. At least 700 more, in all stages of completion, were abandoned in quarries or on ancient roads between the quarries and the coast, as if the carvers and moving crews had thrown down their tools and walked off the job. Most of the erected statues were carved in a single quarry and then somehow transported as far as six miles--despite heights as great as 33 feet and weights up to 82 tons. The abandoned statues, meanwhile, were as much as 65 feet tall and weighed up to 270 tons. The stone platforms were equally gigantic: up to 500 feet long and 10 feet high, with facing slabs weighing up to 10 tons.

Roggeveen himself quickly recognized the problem the statues posed: The stone images at first caused us to be struck with astonishment, he wrote, because we could not comprehend how it was possible that these people, who are devoid of heavy thick timber for making any machines, as well as strong ropes, nevertheless had been able to erect such images. Roggeveen might have added that the islanders had no wheels, no draft animals, and no source of power except their own muscles. How did they transport the giant statues for miles, even before erecting them? To deepen the mystery, the statues were still standing in 1770, but by 1864 all of them had been pulled down, by the islanders themselves. Why then did they carve them in the first place? And why did they stop?

The statues imply a society very different from the one Roggeveen saw in 1722. Their sheer number and size suggest a population much larger than 2,000 people. What became of everyone? Furthermore, that society must have been highly organized. Easter's resources were scattered across the island: the best stone for the statues was quarried at Rano Raraku near Easter's northeast end; red stone, used for large crowns adorning some of the statues, was quarried at Puna Pau, inland in the southwest; stone carving tools came mostly from Aroi in the northwest. Meanwhile, the best farmland lay in the south and east, and the best fishing grounds on the north and west coasts. Extracting and redistributing all those goods required complex political organization. What happened to that organization, and how could it ever have arisen in such a barren landscape?

Easter Island's mysteries have spawned volumes of speculation for more than two and a half centuries. Many Europeans were incredulous that Polynesians--commonly characterized as mere savages--could have created the statues or the beautifully constructed stone platforms. In the 1950s, Heyerdahl argued that Polynesia must have been settled by advanced societies of American Indians, who in turn must have received civilization across the Atlantic from more advanced societies of the Old World. Heyerdahl's raft voyages aimed to prove the feasibility of such prehistoric transoceanic contacts. In the 1960s the Swiss writer Erich von Däniken, an ardent believer in Earth visits by extraterrestrial astronauts, went further, claiming that Easter's statues were the work of intelligent beings who owned ultramodern tools, became stranded on Easter, and were finally rescued.

Heyerdahl and Von Däniken both brushed aside overwhelming evidence that the Easter Islanders were typical Polynesians derived from Asia rather than from the Americas and that their culture (including their statues) grew out of Polynesian culture. Their language was Polynesian, as Cook had already concluded. Specifically, they spoke an eastern Polynesian dialect related to Hawaiian and Marquesan, a dialect isolated since about A.D. 400, as estimated from slight differences in vocabulary. Their fishhooks and stone adzes resembled early Marquesan models. Last year DNA extracted from 12 Easter Island skeletons was also shown to be Polynesian. The islanders grew bananas, taro, sweet potatoes, sugarcane, and paper mulberry--typical Polynesian crops, mostly of Southeast Asian origin. Their sole domestic animal, the chicken, was also typically Polynesian and ultimately Asian, as were the rats that arrived as stowaways in the canoes of the first settlers.

What happened to those settlers? The fanciful theories of the past must give way to evidence gathered by hardworking practitioners in three fields: archeology, pollen analysis, and paleontology.

Modern archeological excavations on Easter have continued since Heyerdahl's 1955 expedition. The earliest radiocarbon dates associated with human activities are around A.D. 400 to 700, in reasonable agreement with the approximate settlement date of 400 estimated by linguists. The period of statue construction peaked around 1200 to 1500, with few if any statues erected thereafter. Densities of archeological sites suggest a large population; an estimate of 7,000 people is widely quoted by archeologists, but other estimates range up to 20,000, which does not seem implausible for an island of Easter's area and fertility.

Archeologists have also enlisted surviving islanders in experiments aimed at figuring out how the statues might have been carved and erected. Twenty people, using only stone chisels, could have carved even the largest completed statue within a year. Given enough timber and fiber for making ropes, teams of at most a few hundred people could have loaded the statues onto wooden sleds, dragged them over lubricated wooden tracks or rollers, and used logs as levers to maneuver them into a standing position. Rope could have been made from the fiber of a small native tree, related to the linden, called the hauhau. However, that tree is now extremely scarce on Easter, and hauling one statue would have required hundreds of yards of rope. Did Easter's now barren landscape once support the necessary trees?

That question can be answered by the technique of pollen analysis, which involves boring out a column of sediment from a swamp or pond, with the most recent deposits at the top and relatively more ancient deposits at the bottom. The absolute age of each layer can be dated by radiocarbon methods. Then begins the hard work: examining tens of thousands of pollen grains under a microscope, counting them, and identifying the plant species that produced each one by comparing the grains with modern pollen from known plant species. For Easter Island, the bleary-eyed scientists who performed that task were John Flenley, now at Massey University in New Zealand, and Sarah King of the University of Hull in England.

Flenley and King's heroic efforts were rewarded by the striking new picture that emerged of Easter's prehistoric landscape. For at least 30,000 years before human arrival and during the early years of Polynesian settlement, Easter was not a wasteland at all. Instead, a subtropical forest of trees and woody bushes towered over a ground layer of shrubs, herbs, ferns, and grasses. In the forest grew tree daisies, the rope- yielding hauhau tree, and the toromiro tree, which furnishes a dense, mesquite-like firewood. The most common tree in the forest was a species of palm now absent on Easter but formerly so abundant that the bottom strata of the sediment column were packed with its pollen. The Easter Island palm was closely related to the still-surviving Chilean wine palm, which grows up to 82 feet tall and 6 feet in diameter. The tall, unbranched trunks of the Easter Island palm would have been ideal for transporting and erecting statues and constructing large canoes. The palm would also have been a valuable food source, since its Chilean relative yields edible nuts as well as sap from which Chileans make sugar, syrup, honey, and wine.

What did the first settlers of Easter Island eat when they were not glutting themselves on the local equivalent of maple syrup? Recent excavations by David Steadman, of the New York State Museum at Albany, have yielded a picture of Easter's original animal world as surprising as Flenley and King's picture of its plant world. Steadman's expectations for Easter were conditioned by his experiences elsewhere in Polynesia, where fish are overwhelmingly the main food at archeological sites, typically accounting for more than 90 percent of the bones in ancient Polynesian garbage heaps. Easter, though, is too cool for the coral reefs beloved by fish, and its cliff-girded coastline permits shallow-water fishing in only a few places. Less than a quarter of the bones in its early garbage heaps (from the period 900 to 1300) belonged to fish; instead, nearly one-third of all bones came from porpoises.

Nowhere else in Polynesia do porpoises account for even 1 percent of discarded food bones. But most other Polynesian islands offered animal food in the form of birds and mammals, such as New Zealand's now extinct giant moas and Hawaii's now extinct flightless geese. Most other islanders also had domestic pigs and dogs. On Easter, porpoises would have been the largest animal available--other than humans. The porpoise species identified at Easter, the common dolphin, weighs up to 165 pounds. It generally lives out at sea, so it could not have been hunted by line fishing or spearfishing from shore. Instead, it must have been harpooned far offshore, in big seaworthy canoes built from the extinct palm tree.

In addition to porpoise meat, Steadman found, the early Polynesian settlers were feasting on seabirds. For those birds, Easter's remoteness and lack of predators made it an ideal haven as a breeding site, at least until humans arrived. Among the prodigious numbers of seabirds that bred on Easter were albatross, boobies, frigate birds, fulmars, petrels, prions, shearwaters, storm petrels, terns, and tropic birds. With at least 25 nesting species, Easter was the richest seabird breeding site in Polynesia and probably in the whole Pacific.

Land birds as well went into early Easter Island cooking pots. Steadman identified bones of at least six species, including barn owls, herons, parrots, and rail. Bird stew would have been seasoned with meat from large numbers of rats, which the Polynesian colonists inadvertently brought with them; Easter Island is the sole known Polynesian island where rat bones outnumber fish bones at archeological sites. (In case you're squeamish and consider rats inedible, I still recall recipes for creamed laboratory rat that my British biologist friends used to supplement their diet during their years of wartime food rationing.)

Porpoises, seabirds, land birds, and rats did not complete the list of meat sources formerly available on Easter. A few bones hint at the possibility of breeding seal colonies as well. All these delicacies were cooked in ovens fired by wood from the island's forests.

Such evidence lets us imagine the island onto which Easter's first Polynesian colonists stepped ashore some 1,600 years ago, after a long canoe voyage from eastern Polynesia. They found themselves in a pristine paradise. What then happened to it? The pollen grains and the bones yield a grim answer.

Pollen records show that destruction of Easter's forests was well under way by the year 800, just a few centuries after the start of human settlement. Then charcoal from wood fires came to fill the sediment cores, while pollen of palms and other trees and woody shrubs decreased or disappeared, and pollen of the grasses that replaced the forest became more abundant. Not long after 1400 the palm finally became extinct, not only as a result of being chopped down but also because the now ubiquitous rats prevented its regeneration: of the dozens of preserved palm nuts discovered in caves on Easter, all had been chewed by rats and could no longer germinate. While the hauhau tree did not become extinct in Polynesian times, its numbers declined drastically until there weren't enough left to make ropes from. By the time Heyerdahl visited Easter, only a single, nearly dead toromiro tree remained on the island, and even that lone survivor has now disappeared. (Fortunately, the toromiro still grows in botanical gardens elsewhere.)

The fifteenth century marked the end not only for Easter's palm but for the forest itself. Its doom had been approaching as people cleared land to plant gardens; as they felled trees to build canoes, to transport and erect statues, and to burn; as rats devoured seeds; and probably as the native birds died out that had pollinated the trees' flowers and dispersed their fruit. The overall picture is among the most extreme examples of forest destruction anywhere in the world: the whole forest gone, and most of its tree species extinct.

The destruction of the island's animals was as extreme as that of the forest: without exception, every species of native land bird became extinct. Even shellfish were overexploited, until people had to settle for small sea snails instead of larger cowries. Porpoise bones disappeared abruptly from garbage heaps around 1500; no one could harpoon porpoises anymore, since the trees used for constructing the big seagoing canoes no longer existed. The colonies of more than half of the seabird species breeding on Easter or on its offshore islets were wiped out.

In place of these meat supplies, the Easter Islanders intensified their production of chickens, which had been only an occasional food item. They also turned to the largest remaining meat source available: humans, whose bones became common in late Easter Island garbage heaps. Oral traditions of the islanders are rife with cannibalism; the most inflammatory taunt that could be snarled at an enemy was, "The flesh of your mother sticks between my teeth." With no wood available to cook these new goodies, the islanders resorted to sugarcane scraps, grass, and sedges to fuel their fires.

All these strands of evidence can be wound into a coherent narrative of a society's decline and fall. The first Polynesian colonists found themselves on an island with fertile soil, abundant food, bountiful building materials, ample lebensraum, and all the prerequisites for comfortable living. They prospered and multiplied.

After a few centuries, they began erecting stone statues on platforms, like the ones their Polynesian forebears had carved. With passing years, the statues and platforms became larger and larger, and the statues began sporting ten-ton red crowns--probably in an escalating spiral of one-upmanship, as rival clans tried to surpass each other with shows of wealth and power. (In the same way, successive Egyptian pharaohs built ever-larger pyramids. Today Hollywood movie moguls near my home in Los Angeles are displaying their wealth and power by building ever more ostentatious mansions. Tycoon Marvin Davis topped previous moguls with plans for a 50,000-square-foot house, so now Aaron Spelling has topped Davis with a 56,000-square-foot house. All that those buildings lack to make the message explicit are ten-ton red crowns.) On Easter, as in modern America, society was held together by a complex political system to redistribute locally available resources and to integrate the economies of different areas.

Eventually Easter's growing population was cutting the forest more rapidly than the forest was regenerating. The people used the land for gardens and the wood for fuel, canoes, and houses--and, of course, for lugging statues. As forest disappeared, the islanders ran out of timber and rope to transport and erect their statues. Life became more uncomfortable-- springs and streams dried up, and wood was no longer available for fires.

People also found it harder to fill their stomachs, as land birds, large sea snails, and many seabirds disappeared. Because timber for building seagoing canoes vanished, fish catches declined and porpoises disappeared from the table. Crop yields also declined, since deforestation allowed the soil to be eroded by rain and wind, dried by the sun, and its nutrients to be leeched from it. Intensified chicken production and cannibalism replaced only part of all those lost foods. Preserved statuettes with sunken cheeks and visible ribs suggest that people were starving.

With the disappearance of food surpluses, Easter Island could no longer feed the chiefs, bureaucrats, and priests who had kept a complex society running. Surviving islanders described to early European visitors how local chaos replaced centralized government and a warrior class took over from the hereditary chiefs. The stone points of spears and daggers, made by the warriors during their heyday in the 1600s and 1700s, still litter the ground of Easter today. By around 1700, the population began to crash toward between one-quarter and one-tenth of its former number. People took to living in caves for protection against their enemies. Around 1770 rival clans started to topple each other's statues, breaking the heads off. By 1864 the last statue had been thrown down and desecrated.

As we try to imagine the decline of Easter's civilization, we ask ourselves, Why didn't they look around, realize what they were doing, and stop before it was too late? What were they thinking when they cut down the last palm tree?

I suspect, though, that the disaster happened not with a bang but with a whimper. After all, there are those hundreds of abandoned statues to consider. The forest the islanders depended on for rollers and rope didn't simply disappear one day--it vanished slowly, over decades. Perhaps war interrupted the moving teams; perhaps by the time the carvers had finished their work, the last rope snapped. In the meantime, any islander who tried to warn about the dangers of progressive deforestation would have been overridden by vested interests of carvers, bureaucrats, and chiefs, whose jobs depended on continued deforestation. Our Pacific Northwest loggers are only the latest in a long line of loggers to cry, Jobs over trees! The changes in forest cover from year to year would have been hard to detect: yes, this year we cleared those woods over there, but trees are starting to grow back again on this abandoned garden site here. Only older people, recollecting their childhoods decades earlier, could have recognized a difference. Their children could no more have comprehended their parents' tales than my eight-year-old sons today can comprehend my wife's and my tales of what Los Angeles was like 30 years ago.

Gradually trees became fewer, smaller, and less important. By the time the last fruit-bearing adult palm tree was cut, palms had long since ceased to be of economic significance. That left only smaller and smaller palm saplings to clear each year, along with other bushes and treelets. No one would have noticed the felling of the last small palm.

By now the meaning of Easter Island for us should be chillingly obvious. Easter Island is Earth writ small. Today, again, a rising population confronts shrinking resources. We too have no emigration valve, because all human societies are linked by international transport, and we can no more escape into space than the Easter Islanders could flee into the ocean. If we continue to follow our present course, we shall have exhausted the world's major fisheries, tropical rain forests, fossil fuels, and much of our soil by the time my sons reach my current age.

Easter Island Article: Graphic Organizer

Part I: Summarize the events of the story

Read the article first, to get an overall understanding of the story of Easter Island. Complete the summary boxes below.

First

Next

Then

Last

Part II: Cause and Effect Relationships

Re-read the article, this time paying careful attention to environmental issues that led to the fall of the civilization. Look for any cause–effect relationships that may have contributed to the downfall of this society. Note the example provided as a guide.

Cause		Effect
Easter Islanders were cutting the forest faster than it was regenerating, to clear land for agriculture and to use wood for fuel, houses, canoes, and moving statues.	→	As forests ran out, Easter islanders ran out of timber and rope to transport and erect their statues
Cause	→	Effect
Cause	→	Effect
Cause	→	Effect
Cause	→	Effect

The Fall of Easter Island

Work with your small group to compile a complete list of cause and effect relationships that led to the fall of the Easter Island civilization.

Cause	Effect

The Fall of Easter Island

Create a visual to represent the events that led to the fall of this ancient civilization.

Reflection

How does the environment serve as a foundation for all civilizations, and are we doing what we can to protect that environment in order to preserve our own civilization today?

Activity

2 Problems with ‘the scientific method’

Scientists rarely follow one straightforward path to understanding the natural world

By Jennifer Cutraro
3:53pm, July 5, 2012

In Connecticut, first-graders load up toy cars with different amounts of mass, or stuff, and send them racing down ramps, rooting for their favorites to travel the farthest. In Texas, middle school students sample seawater from the Gulf of Mexico. And in Pennsylvania, kindergarten students debate what makes something a seed.

Though separated by miles, age levels and scientific fields, one thing unites these students: They are all trying to make sense of the natural world by engaging in the kinds of activities that scientists do.

You might have learned about or participated in such activities as part of something your teacher described as the “scientific method.” It’s a sequence of steps that take you from asking a question to arriving at a conclusion. But scientists rarely follow the steps of the scientific method as textbooks describe it.

“The scientific method is a myth,” asserts Gary Garber, a physics teacher at Boston University Academy.

The term “scientific method,” he explains, isn’t even something scientists themselves came up with. It was invented by historians and philosophers of science during the last century to make sense of how science works. Unfortunately, he says, the term is usually interpreted to mean there is only one, step-by-step approach to science.

That’s a big misconception, Garber argues. “There isn’t one method of ‘doing science.’”

In fact, he notes, there are many paths to finding out the answer to something. Which route a researcher chooses may depend on the field of science being studied. It might also depend on whether experimentation is possible, affordable — even ethical.

In some instances, scientists may use computers to model, or simulate, conditions. Other times, researchers will test ideas in the real world. Sometimes they begin an experiment with no idea what may happen. They might disturb some system just to see what happens, Garber says, “because they’re experimenting with the unknown.”

The practices of science

But it’s not time to forget everything we thought we knew about how scientists work, says Heidi Schweingruber. She should know. She’s the deputy director of the Board on Science Education at the National Research Council, in Washington, D.C.

In the future, she says, students and teachers will be encouraged to think not about the scientific method, but instead about “practices of science” — or the many ways in which scientists look for answers.

Schweingruber and her colleagues recently developed a new set of national guidelines that highlight the practices central to how students should learn science.

“In the past, students have largely been taught there’s one way to do science,” she says. “It’s been reduced to ‘Here are the five steps, and this is how every scientist does it.’“

But that one-size-fits-all approach doesn't reflect how scientists in different fields actually "do" science, she says.

For example, experimental physicists are scientists who study how particles such as electrons, ions and protons behave. These scientists might perform controlled experiments, starting with clearly defined initial conditions. Then they will change one variable, or factor, at a time. For instance, experimental physicists might smash protons into various types of atoms, such as helium in one experiment, carbon during a second experiment and lead in a third. Then they would compare differences in the collisions to learn more about the building blocks of atoms.

In contrast, geologists, scientists who study the history of Earth as recorded in rocks, won't necessarily do experiments, Schweingruber points out. "They're going into the field, looking at landforms, looking at clues and doing a reconstruction to figure out the past," she explains. Geologists are still collecting evidence, "but it's a different kind of evidence."

Current ways of teaching science might also give hypothesis testing more emphasis than it deserves, says Susan Singer, a biologist at Carleton College in Northfield, Minn.

A hypothesis is a testable idea or explanation for something. Starting with a hypothesis is a good way to do science, she acknowledges, "but it's not the only way."

"Often, we just start by saying, 'I wonder'" Singer says. "Maybe it gives rise to a hypothesis." Other times, she says, you may need to first gather some data and look to see if a pattern emerges.

Figuring out a species' entire genetic code, for example, generates enormous collections of data. Scientists who want to make sense of these data don't always start with a hypothesis, Singer says.

"You can go in with a question," she says. But that question might be: What environmental conditions — like temperature or pollution or moisture level — trigger certain genes to turn "on" or "off?"

The upside of mistakes

Scientists also recognize something that few students do: Mistakes and unexpected results can be blessings in disguise.

An experiment that doesn't give the results that a scientist expected does not necessarily mean a researcher did something wrong. In fact, mistakes often point to unexpected results — and sometimes more important data — than the findings that scientists initially anticipated.

"Ninety percent of the experiments I did as a scientist didn't work out," says Bill Wallace, a former biologist with the National Institutes of Health.

"The history of science is full of controversies and mistakes that were made," notes Wallace, who now teaches high school science at Georgetown Day School in Washington, D.C. "But the way we teach science is: The scientist did an experiment, got a result, it got into the textbook." There is little indication for how these discoveries came about, he says. Some might have been expected. Others might reflect what a researcher stumbled upon — either by accident (for example, a flood in the lab) or through some mistake introduced by the scientist.

Schweingruber agrees. She thinks American classrooms treat mistakes too harshly. "Sometimes, seeing where you made a mistake gives you a lot more insight for learning than when you got everything right," she says. In other words: People often learn more from mistakes than from having experiments turn out the way they expected.

Practicing science at school

One way teachers make science more authentic, or representative of how scientists work, is to have students do open-ended experiments. Such experiments are conducted simply to find out what happens when a variable is changed.

Carmen Andrews, a science specialist at Thurgood Marshall Middle School in Bridgeport, Conn., has her first-grade students record on graphs how far toy cars travel on the floor after racing down a ramp. The distance changes depending on how much stuff — or mass —the cars carry.

Andrews' 6-year-old scientists perform simple investigations, interpret their data, use mathematics and then explain their observations. Those are four of the key practices of science highlighted in the new science-teaching guidelines.

Students "quickly see that when they add more mass, their cars travel farther," Andrews explains. They get the sense that a force pulls on the heavier cars, causing them to travel farther.

Other teachers use something they call project-based learning. This is where they pose a question or identify a problem. Then they work with their students to develop a long-term class activity to investigate it.

Three times a year, Lollie Garay and her middle school students at the Redd School in Houston storm onto a southern Texas beach.

There, this science teacher and her class collect seawater samples to understand how human actions affect local water.

Garay has also partnered with a teacher in Alaska and another in Georgia whose students take similar measurements of their coastal waters. A few times each year, these teachers arrange a videoconference between their three classrooms. This allows their students to communicate their findings — yet another key practice of science.

For the students "Completing a project like this is more than 'I did my homework,'" Garay says. "They're buying into this process of doing authentic research. They're learning the process of science by doing it."

It's a point other science educators echo.

In the same way that learning a list of French words is not the same as having a conversation in French, Singer says, learning a list of scientific terms and concepts is not doing science.

"Sometimes, you do just have to learn what the words mean," Singer says. "But that's not doing science; it's just getting enough background info [so] that you can join in the conversation."

Even the youngest students can take part in the conversation, notes Deborah Smith, at Pennsylvania State University in State College. She teamed up with a kindergarten teacher to develop a unit about seeds.

Rather than reading to the children or showing them pictures in a book, Smith and the other teacher convened a "scientific conference." They broke the class into small groups and gave each group a collection of small items. These included seeds, pebbles and shells. Then the students were asked to explain why they thought each item was — or was not — a seed.

"The kids disagreed about almost every object we showed them," Smith says. Some argued that all seeds have to be black. Or hard. Or have a certain shape.

That spontaneous discussion and debate was exactly what Smith had hoped for.

"One of the things we explained early on is that scientists have all kinds of ideas and that they often disagree," Smith says. "But they also listen to what people say, look at their evidence and think about their ideas. That's what scientists do." By talking and sharing ideas — and yes, sometimes arguing — people may learn things they couldn't resolve on their own.

How scientists use the practices of science

Talking and sharing — or communicating ideas — recently played an important role in Singer's own research. She tried to figure out which gene mutation caused an unusual flower type in pea plants. She and her college students weren't having much success in the lab.

Then, they traveled to Vienna, Austria, for an international conference on plants. They went to a presentation about flower mutations in Arabidopsis, a weedy plant that serves as the equivalent to a lab rat for plant scientists. And it was at this scientific presentation that Singer had her "aha" moment.

"Just listening to the talk, suddenly, in my head, it clicked: That could be our mutant," she says. It was only when she heard another team of scientists describe their results that her own studies could move ahead, she now says. If she had not gone to that foreign meeting or if those scientists had not shared their work, Singer might not have been able to make her own breakthrough, identifying the gene mutation she was looking for.

Schweingruber says that showing students the practices of science can help them to better understand how science actually works — and bring some of the excitement of science into classrooms.

"What scientists do is really fun, exciting and really human," she says. "You interact with people a lot and have a chance to be creative. That can be your school experience, too."

Power words

Philosopher: a person who studies wisdom or enlightenment

Linear: in a straight line

Hypothesis: a testable idea

Variable: a part of a scientific experiment that is allowed to change in order to test a hypothesis

Ethical: following agreed-upon rules of conduct

Gene: a tiny part of a chromosome, made up of molecules of DNA. Genes play a role in determining traits such as the shape of a leaf or the color of an animal's fur

Mutation: a change in a gene

Control: a factor in an experiment that remains unchanged

Unit Writing Task:

Do our actions really have an impact on the environment? After researching informational texts on environmental problems, write an essay in which you identify a specific environmental problem, and propose a solution. Support your proposal with evidence from your research.

Reflection

How will the scientific practices you develop throughout this unit help you to complete this unit writing task?

Activity

3 Global Environmental Issues: Question Brainstorm

Lesson 2

Ecological Principles by Analyzing Data

In this lesson you will

1. Learn how to analyze data.
2. Use data analysis to help you understand a science simulation.
3. Learn to organize concepts as a way to review science vocabulary terms.
4. Reflect on how one change can have many unforeseen impacts.

Activity

2 The Science Simulation

Simulations are an important part of science. Simulations are used to help us see things that would be hard to reproduce in a lab setting. Today you will be simulating the predator/prey relationship between gray wolves and deer. As you work through the simulation with your group, you are going to see how the population or numbers of the wolves and deer change. You will keep up with those changes on a table, and then create a line graph of those changes in the predator/prey relationship. Remember to give your line graph a title and a label on each axis, and to include a key. Once you have completed your table and graph, you will answer the summarizing question located at the bottom of your table. You will turn in your chart and graph when you are done. Read through all of the directions before beginning.

Deer Me!

How does a population of predators affect a population of prey?

Directions:

1. Determine the size of your forest. Using your table works well but the space can be defined using masking tape, if necessary.
2. Distribute 3 deer in the forest by tossing 3 deer cards on your "forest".
3. Toss one gray wolf card, in an effort to catch a deer. At this point in the activity there is no way that the gray wolf can catch the 3 deer it needs to survive and reproduce. The gray wolf is not allowed to skid across the table and the deer should be dispersed, or spread out, in the forest.
4. Complete the data table on your worksheet for generation #1. The gray wolf will starve and there will be no surviving gray wolf or new baby wolves.
5. At the beginning of generation #2, double the deer left at the end of generation #1 by tossing three new deer cards into your forest. Because there was no predation, the deer are able to reproduce, and the population flourishes. A new gray wolf immigrates into the forest and is interacting with the deer by being tossed on the table to try to capture the dispersed deer. If the wolf card lands on a deer card, then you remove that deer card from the forest, and the wolf survives. Mark the data for that generation on your data table. As you move on to the next generation, double the remaining deer as they will reproduce from one season to the next. Continue this process from one generation to the next, noting the population of deer and wolves on your data table.
6. Eventually the deer population increases to a point that allows the wolf to catch 3 deer in a single toss (the wolf card lands on 3 deer cards, at least partially). If the wolf catches 3 deer, it not only survives but it reproduces, too. It has one baby wolf for each 3 deer that it catches. Therefore, if it catches 6 deer, it will have 2 babies. Wolves are not allowed to cheat, but they should try to be efficient.
7. As the number of wolves increases, throw each wolf card once for each wolf. Record the number of deer caught by each wolf. The simulation is more realistic if the number of new baby wolves is based on each wolf's catch rather than merely the total number of deer caught in a generation.
8. There are always at least 3 deer at the beginning of a generation. If and when the entire deer population is wiped out, then new deer immigrate into the forest.
9. Remember that the number of deer in the forest needs to be correct at all times. Remove the deer caught and add new ones as indicated by the data table.
10. Model 16 generations and predict 9 more, for a total of 25 generations. Base your predictions on the pattern observed during the first 16 generations. Each person should make their own predictions without the help of their group members.

How does a population of predators affect a population of prey?

Follow the directions on your handout to complete your data table for generations 1–16. You will use these numbers to make predictions for the rest of the generations of deer. When you are finished, graph the number of wolves and the number of deer remaining for the 25 generations to illustrate the relationship between predators and prey.

Deer Generation	# of Wolves	# of Deer Caught	# of Wolves Starved	# of Wolves Surviving	# of Deer Offspring	# of Deer Remaining
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						

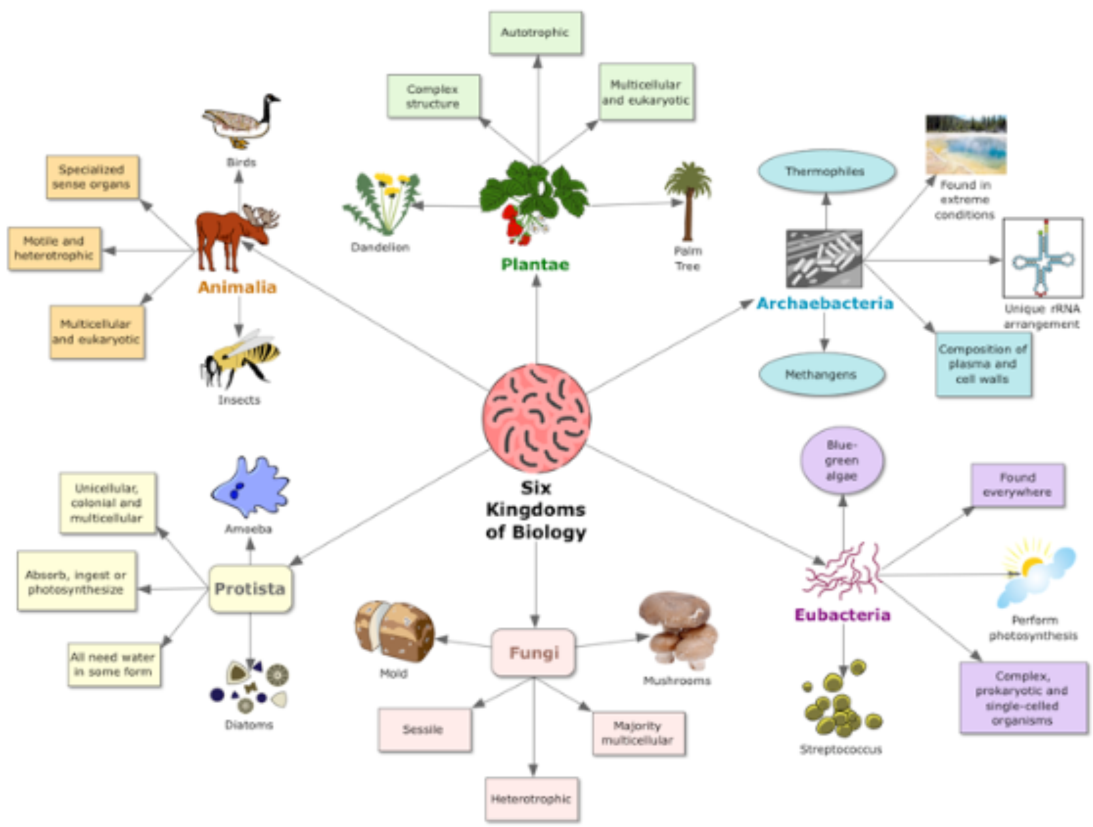
Using complete sentences, summarize the relationship between the population size of wolves and deer. You may choose to use the words “if” and “then” to show a cause and effect relationship. (If the population of deer increases, then…) Be as specific as possible in thoroughly explaining how both populations are impacted by one another.

Activity

3 Vocabulary Concept Map

Concept maps help you organize new information learned. In the center of the map is the big concept or idea. Surrounding the big concept or idea are issues related to it. Off of each of the related issues is information to support those concepts. A completed concept map can be an excellent resource to review material learned. We are going to create a concept map to help us review the vocabulary terms you have learned so far. Our supporting information for the related issues will be the vocabulary term, definition for the term, and a picture to help you visualize the term. **You will be adding to your concept map throughout the unit as you are exposed to new vocabulary terms.**

Examine the following sample concept map:



How does this help to organize learning around a central concept?

Central Idea for this Unit:

Key Ecological Principles Terminology

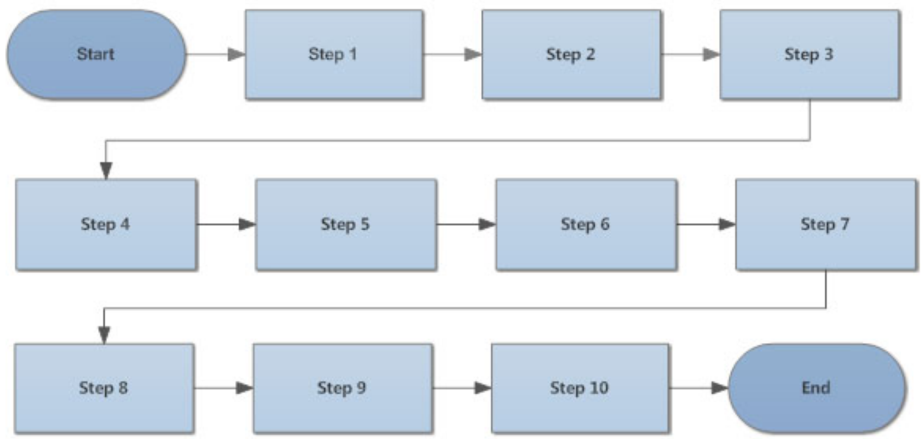
- Autotroph
- Carnivore
- Ecosystem
- Energy Conversion Efficiency
- Food Chain
- Herbivores
- Heterotroph
- Population
- Predator
- Prey
- Producer
- Pyramid of Biomass
- Pyramid of Energy

Activity

4 Vocabulary Concept Map

As you watch the video, capture the series of events by creating a simple flow chart in the space provided below. You may have to watch the video twice to make sure you included all of the events in the story.

Example Flow Chart



Video Reflection Questions

1. How does the story of Borneo illustrate the idea of ecosystems and the interaction of organisms (specifically the importance of all organisms in that ecosystem)?

2. How does the story exemplify how humans (in our attempt to fix one thing), cause unforeseeable problems in ecosystems?

3. Explain how a toxin in a food web will harm some while killing others — why did the mosquitos and cats die while other things lived?

4. Explain why you think DDT has been banned in the United States but is still in production and used in countries all over the world.

5. If DDT is still being used around the world, but not in the United States – are we still exposed to it?

6. Do you think scientists should have sprayed the island with DDT? If not, what should they have done about the Malaria issue?

Lesson 3
Population Dynamics

In this lesson you will examine trends in population growth and the factors that influence this. You will use computer simulations to explore variables and generate graphs. You will identify the challenges caused by human population growth and propose strategies that will allow for more people to be able to live on Earth.

Activity

1 Population Growth

Exponential and Logistic Growth

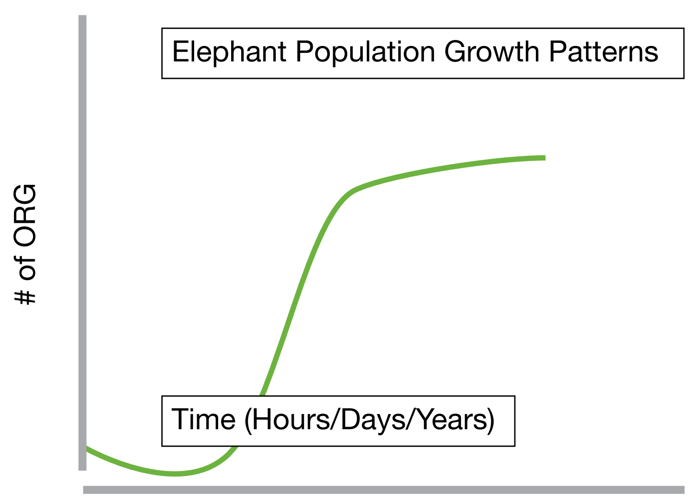
Introduction:

Populations can change due to a variety of factors: birthrate, death rate, **immigration** (moving into an area), **emigration** (moving away from an area), space and resource availability, etc. A population grows from having a higher birth rate than death rate, having more immigration than emigration, or a combination of the two. On Earth there are two different types of population growth: **Exponential Growth**, when an organism reproduces at a constant rate with a steady increase in population, and **Logistic Growth**, a more realistic growth pattern that occurs when the population levels off following a phase of **Exponential Growth** due to a finite, or limited, amount of resources. This population level that a particular environment can support is known as **Carrying Capacity**.

Activity:

With this information, it is your job to plot the data tables of population growth information given to you onto **line graphs** (one graph for each data table). You will then determine whether each graph is an example of **Exponential Growth** or **Logistic Growth**. Remember to label your graphs, including TITLE, X-AXIS, Y-AXIS.

Example:



Part I: Yeast Growth in a 10-Hour Time Period

# Bacterial Cells	2	200	600	1000	1050	1045
Time (Hours)	0	2	4	6	8	10

Part II: Rabbit Growth in a 250-Year Time Period

# Rabbits	2	200	600	1000	1050	1045
Time (Years)	0	50	100	150	200	250

Post-Activity Questions:

1. The yeast population growth data you are given is an example of which pattern of population growth: Exponential or Logistic? How do you know? Describe the curve of the line graph.

2. The rabbit population growth data you are given is an example of which pattern of population growth: Exponential or Logistic? How do you know? Describe the curve of the line graph.

3. Do you think the Exponential Growth example will continue to grow at this constant rate? Why or why not?

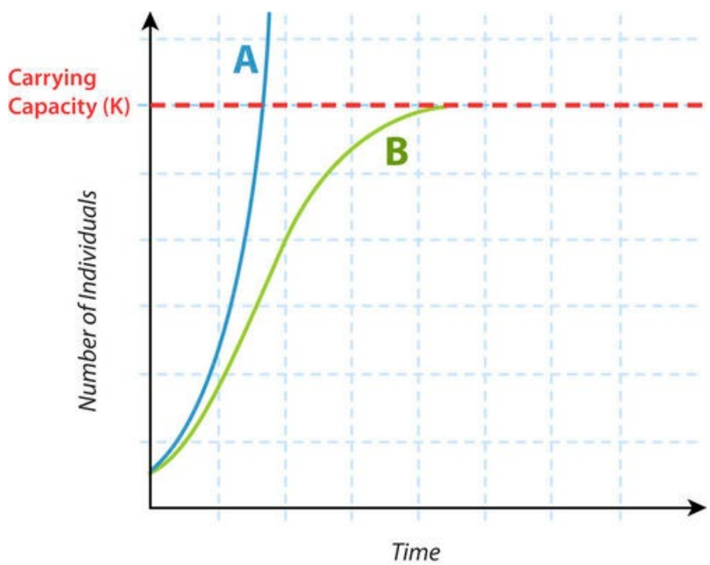
4. For the Logistic Growth example, what appears to be the Carrying Capacity (estimate)? How do you know this?

5. Describe a scenario, or situation, where Exponential Growth could happen forever. Would this be a good thing for our planet?

Limiting Factors to Population Growth

For a population to be healthy, factors such as food, nutrients, water and space, must be available. What happens when there are not resources to support the population? **Limiting factors** are resources or other factors in the environment that can lower the population growth rate. Limiting factors include a low food supply and lack of space. Limiting factors can lower birth rates, increase death rates, or lead to emigration.

When organisms face limiting factors, they show **logistic growth** (S-shaped curve, curve B). Competition for resources, like food and space, cause the growth rate to stop increasing, so the population levels off. This flat upper line on a growth curve is the carrying capacity. The **carrying capacity** (K) is the maximum population size that can be supported in a particular area without destroying the habitat. Limiting factors determine the carrying capacity of a population. Recall that when there are no limiting factors, the population grows exponentially. The growth time when no limiting factors are present is determined solely on the species' **biotic potential**, or the innate growth of a species based on reproductive rate or average number of offspring per female. In **exponential growth** (J-shaped curve, curve A), as the population size increases, the growth rate also increases.



Exponential and Logistic Growth: Curve A shows exponential growth. Curve B shows logistic growth. Notice that the carrying capacity (K) is also shown.

Food Supply as Limiting Factor

If there are 12 sandwiches at a lunch table and 24 people sit down at a lunch table, will everyone be able to eat? At first, maybe you will split sandwiches in half, but if more and more people keep coming to sit at the lunch table, you will not be able to feed everyone. This is what happens in nature. But in nature, organisms that cannot get food will die or find a new place to live. It is possible for any resource to be a limiting factor, however, a resource such as food can have dramatic consequences on a population.

In nature, when the population size is small, there is usually plenty of food and other resources for each individual. When there is plenty of food and other resources, organisms can easily reproduce, so the birth rate is high. As the population increases, the food supply, or the supply of another necessary resource, may decrease. When necessary resources such as food decrease, some individuals will die. Overall, the population cannot reproduce at the same rate, so the birth rates drop. This will cause the population growth rate to decrease.

When the population decreases to a certain level where every individual can get enough food and other resources, and the birth and death rates become stable, the population has leveled off at its carrying capacity.

Other Limiting Factors

Other limiting factors include light, **water**, nutrients or **minerals,** oxygen, the ability of an ecosystem to recycle nutrients and/or waste, disease and/or parasites, **temperature**, space, and **predation**. Can you think of some other factors that limit populations?

Weather can also be a limiting factor. Whereas most plants like rain, an individual cactus-like *Agave americana* plant actually likes to grow when it is dry. Rainfall limits reproduction of this plant which, in turn, limits growth rate. Can you think of some other factors like this?

Human activities can also limit the growth of populations. Such activities include use of pesticides such as DDT, use of herbicides, and **habitat destruction**.

Summary

- Limiting factors, or things in the environment that can lower the population growth rate, include low food supply and lack of space.
- When organisms face limiting factors, they show logistic type of growth (S-curve).

Video Clip: Populations: Biotic Potential, Environmental Resistance

Add any further annotations that would increase your understanding of this article as you watch the video clip.

Questions for discussion after viewing "Populations: Biotic Potential. Environmental Resistance"

1. What type of growth is characterized by a consistent increase in growth rate? How often is this type of growth actually seen in nature?

2. What factors keep populations from reaching their carrying capacity?

3. How do you think the length of an organism's life span will affect the species' ability to reach carrying capacity?

4. What would the growth equation look like for sessile populations (i.e., populations where individuals are fixed in space)?

Population Growth Key Vocabulary

After reading and annotating the article on logistic and exponential growth, and watching the video clip, complete the following key vocabulary comparisons. For each of the following groups of terms, write a definition in your own words of each term in its box, and then write a sentence explaining how these terms are related in the box below.

Growth Rate	**Carrying Capacity**
How the population size (number of individuals) changes with respect to time (i.e., final population size – initial population size / time). Refers to the speed at which a population increases or decreases.	*The maximum population size a particular environment can support, due to limiting factors in the environment like food or habitat.*
These terms are related because… *Carrying capacity impacts population growth rate. If the population size hasn't reached its carrying capacity, growth rate can be high. Growth rate will slow down the closer the population is to its carrying capacity. If a population over-reaches its carrying capacity, you will actually have a negative growth rate.*	
Exponential Growth	**Logistic Growth**
These terms are related because…	
Biotic Potential	**Environmental Resistance**
These terms are related because…	
Density-Dependent Limiting Factors	**Density-Independent Limiting Factors**
These terms are related because…	

Summarize what you have learned about limiting factors and population growth by answering the Review questions in your Academic Notebook.

Review

1. What is a limiting factor?

2. What are three examples of limiting factors?

3. When organisms face limiting factors, what type of growth do they show?

Activity

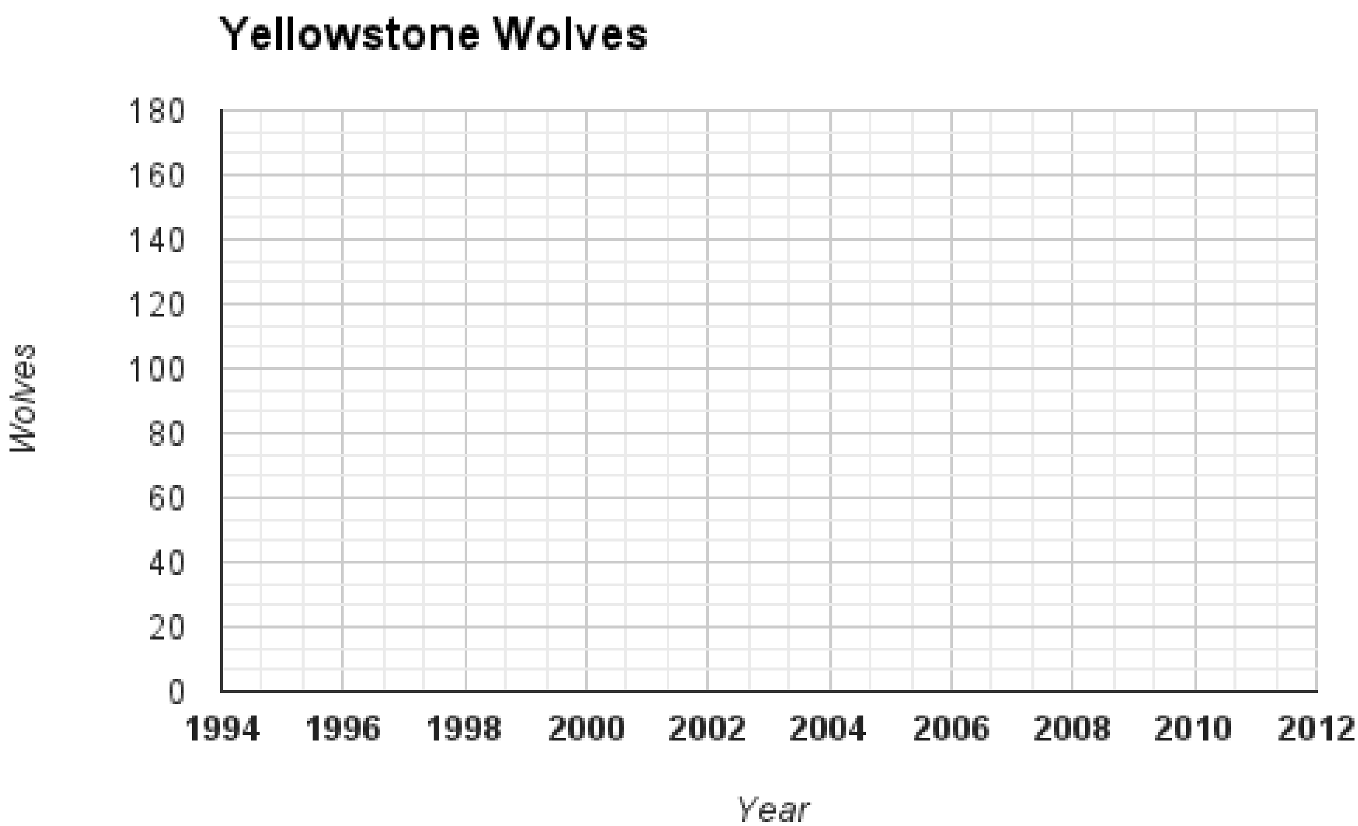
2 Modeling Population Growth

Explore Population Dynamics using the interactive tutorial at: http://smartgraphs-activities.concord.org/activities/225-african-lions-modeling-populations/student_preview

Modeling Populations Assessment

1. When Yellowstone National Park was created in the late 1800s, wolves were on the decline.

   The last wolves in Yellowstone were killed in 1926, but in the 1800s, there were between 100-160 wolves in the park. In 1995, gray wolves were reintroduced to the park. Using what you know about populations, predict the growth of the wolves on the graph below.



2. How would you describe this type of growth?

3. List three density-dependent limiting factors that could slow population growth.

a.

b.

c.

4. Populations stabilize at , number of individuals an environment can support.

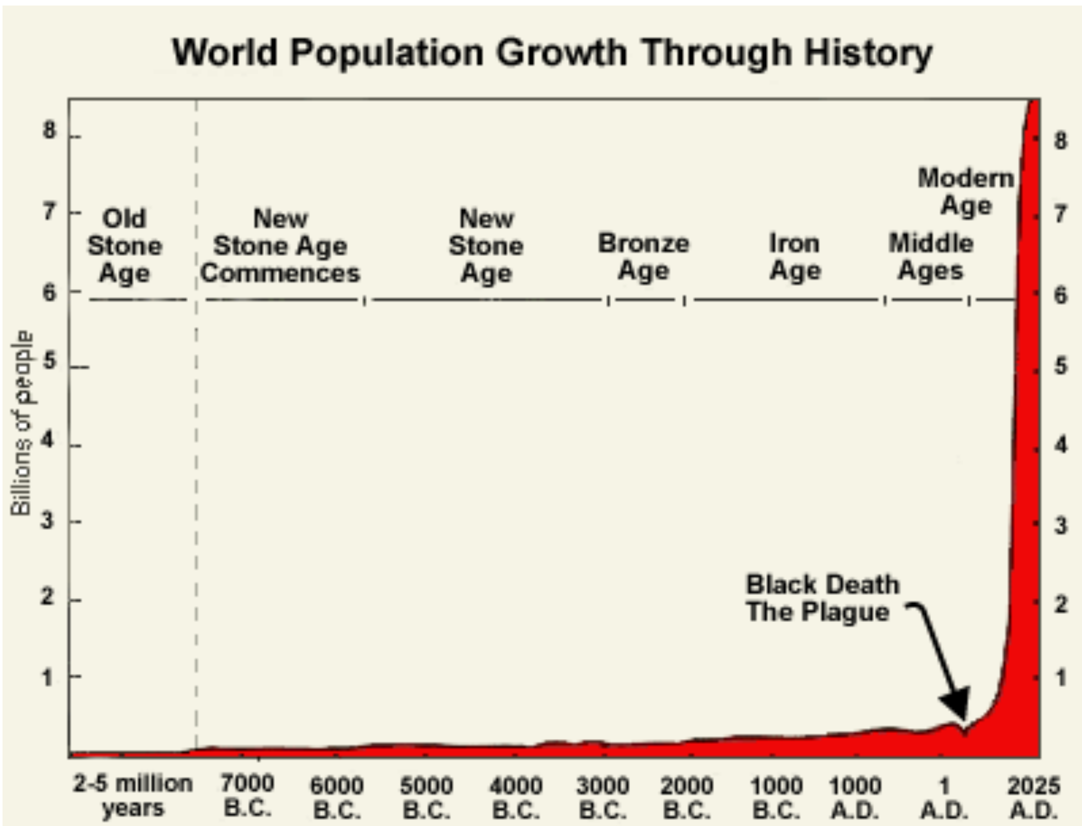
5. In logistic growth, where is competition for resources highest?

6. Are there any wild populations that undergo endless population growth? Why/why not? Are humans different?

Activity

3 Human Population Growth

Examine the graph below depicting human population growth throughout history. What type of growth (exponential or logistic) does it illustrate? What questions does this make you wonder about?



Read and annotate the following article from “How Stuff Works.” http://science.howstuffworks.com/environmental/green-science/earth-carrying-capacity.htm

Has Earth reached its carrying capacity?

By Julia Layton   Science | Green Science

http://science.howstuffworks.com/environmental/green-science/earth-carrying-capacity.htm

In 1798, an English clergyman named Thomas Malthus made a dire prediction: He said the Earth could not indefinitely support an ever-increasing human population. The planet, he said, would check population growth through famine if humans didn't check themselves.

The theory publicized by Malthus is known as the carrying capacity of Earth. Carrying capacity itself is a well-known and widely accepted concept in ecology. It's a very basic idea – sustainability requires balance. There is a certain population number above which a species starts to damage its habitat, and life as it stands at that moment cannot go on. Typically, it's starvation that kicks in to cull the herds down to a manageable number.

The idea of Earth's carrying capacity goes something like this: Humans need certain resources to survive at subsistence level -- most commonly air, food, water and usually some kind of shelter. A sustainable habitat is one in which supply of and demand for these resources are balanced. The problem, Malthus suggested, is the difference in growth patterns between the human population and food production. He said that while the human population tends to grow exponentially (by a greater amount each year – a percentage of the total), the food supply will only grow linearly (by a fixed amount each year – a number, not a percentage). In this model, humans are bound to outgrow the Earth's resources [source: Sachs].

For two centuries, scientists have pretty much dismissed Malthus' hypothesis, saying he neglected to account for one very important variable that applies exclusively to humans: technological advancement [source: Sachs]. They have argued that this human ability allows food production to grow exponentially, as well. But scholars have recently begun to rethink their dismissal of Malthus' prediction, for several reasons.

It seems Earth may have a carrying capacity after all.

So are we doomed? How many human beings can the Earth support before resources run low and nature takes over, culling the human herds in order to reestablish a sustainable balance? Or do humans' unique abilities to develop new food and energy-production methods negate the danger?

Well, it all depends.

What's the Earth's Carrying Capacity?

Carrying capacity is not a fixed number. Estimates put Earth's carrying capacity at anywhere between 2 billion and 40 billion people [source: McConeghy]. It varies with a wide range of factors, most of them fitting under the umbrella of "lifestyle." If humans were still in the hunter-gatherer mode, Earth would have reached its capacity at about 100 million people [source: ThinkQuest]. With humans producing food and living in high-rise buildings, that number increases significantly [source: ThinkQuest].

As of 2008, there were about 6.7 billion people living on this planet [source: Sachs]. A good way to understand the flexibility of Earth's carrying capacity is to look at the difference between the projected capacities of 2 billion and 40 billion. Essentially, we're working with the same level of resources with both of those numbers. So how can the estimates swing so widely?

Because people in different parts of the world are consuming different amounts of those resources. Basically, if everyone on Earth lived like a middle-class American, consuming roughly 3.3 times the subsistence level of food and about 250 times the subsistence level of clean water, the Earth could only support about 2 billion people [source: McConeghy]. On the other hand, if everyone on the planet consumed only what he or she needed, 40 billion would be a feasible number [source: McConeghy]. As it is, the people living in developed countries are consuming so much that the other approximate 75 percent of the population is left with barely what they need to get by [source: McConeghy].

To the surprise of those scientists who dismissed Malthus' prediction as fatally flawed, this limit on resources appears to stand despite the human ability to develop technologies that alter Malthus' presumed linear growth of the food supply. The issue, then, is why technology isn't saving us from the disaster of naturally mediated population control.

What are we doing wrong?

Thomas Malthus: Right After All?

If we look at the vast advances in food-production technology, known as the green revolution, we would expect to be able to feed everyone on Earth indefinitely. The more people there are, the more inventors and advances in irrigation, agriculture, genetic engineering, pest control, water purification and other methods of increasing the food and water supply beyond what our habitat would provide normally. But in fact, food prices are rising at an alarming rate. The problem, it seems, has to do with the uniquely human byproducts of technological advancement, like systematic habitat destruction. We appear to be using technology in a way that defeats the purpose.

The ideal use of technology – the use that would extend Earth's carrying capacity – is to find ways to make fewer resources stretch much farther. Take, for instance, the Earth's energy resources. Ideally, we would've switched en masse to technologies like solar power and electric cars long ago. Instead, we've used technology to simply extract and use more fossil fuels. So instead of technology allowing us to live better on less, we're living better on more.

Since oil is a limited resource, and our technologies like home heating systems and farm equipment still run primarily on oil-dependent power, when we run out of oil, we potentially freeze to death in winter and run out of food. At the same time, air and water pollution resulting from technological advancement is reducing our supply of even more necessary resources.

So, are we doomed? Not if we make lifestyle adjustments that get us back into balance with our habitat. Major worldwide shifts to sustainable energy resources like sun and wind, and a movement toward eating locally grown food, reducing carbon emissions and even taking shorter showers can help. Mining space for additional resources might also help us avoid Earth-wide shortages, although that's a far more uncertain solution to the problem [source: ThinkQuest].

Ultimately, the idea is this: If everyone on Earth can manage to do more with less, we'll be back on track to Earth's indefinite carrying capacity. Also, since economic development and education tends to lower fertility rates, spreading modern knowledge to currently under-developed parts of the world can work as a sort of natural population control, further extending the lifetime of humanity on Earth [source: The Economist].

Writing Prompt:

Have humans reached their carrying capacity on Earth? Construct a paragraph in which you present a clear and convincing claim to respond to this question.

Activity

4 Human Impacts and Sustainability

Below are three articles about human population growth and the resulting environmental impact. As you read each of these, use the graphic organizer to describe problems/challenges that arise from our growing population. Cite the sources (article) for each item listed in your graphic organizer. Complete the first two columns as you read.

Seven Billion and Counting

https://www.worldof7billion.org/wp-content/uploads/2014/08/seven-billion-and-counting.pdf

The growing human population places huge amounts of pressure on the Earth. The sheer number of people, and their behaviors, contributes to many of the environmental, social, and economic issues facing the planet. Although it may not seem as if the world is getting more crowded, growing population threatens the health of our ecosystems and the quality of life for Earth's inhabitants.

In the six seconds it takes to read this sentence, 15 more people will be living on the Earth. In fact, the world's population grows at a near-record pace, with a population equal to New York City added every month, and equal to Germany added every year. In the year 2000, there were six billion of us, and the number of people is growing every second. This growth in human numbers has been called a "population explosion."

What Ignited the Explosion?

The population explosion has been very recent in the scope of human history. People lived on Earth for about three million years before the world population reached 500 million, around the year 1600. Until then, **birth rates** and **death rates** were about the same, keeping the population stable.

People had many children, but a vast number of them died before age five. Without modern medicine, vaccines, and clean, healthy living conditions, many children did not survive common diseases.

The late 1700s and the 1800s was a time of great advancement in science and technology in Europe and North America. The Industrial Revolution produced many inventions that promoted longer life, such as improvements in farming, nutrition, medicine, and sanitation. By 1930, the world population had reached two billion.

As people moved to cities to live and work, families became smaller. It was no longer necessary to have many children to work on family farms in Europe and North America, and birth rates dropped in industrialized countries. By the mid-twentieth century, death rates throughout the rest of the world also began to drop as medical technologies spread across the globe. But, birth rates remained high in developing countries, since their economies still relied largely on farming.

Families in these places still needed many children to work the land. Although population growth slowed in developed countries, the "population explosion" continued in the less developed world.

In 1960, the global population reached three billion. Just 15 years later, in 1975, the population soared to four billion and it topped five billion in 1987. In 1999, the Earth became home to six billion people, and the population had doubled in less than 40 years. Although population growth is now slowing, the population reached seven billion in late 2011, and demographers predict that the world will grow by two to three billion more people by the year 2050.[1]

Crowding the Earth

No one knows for sure how many people the Earth can support. Every environment has a carrying capacity – the point at which there are not enough natural resources (food and fuel) to

How Many People Can Earth Support?

by Natalie Wolchover | October 11, 2011 11:58am ET

http://www.livescience.com/16493-people-planet-earth-support.html

"The power of population is so superior to the power of the Earth to produce subsistence for man, that premature death must in some shape or other visit the human race."

The late-18th century philosopher Thomas Malthus wrote these ominous words in an essay on what he saw as the dire future of humanity. Humans' unquenchable urge to reproduce, Malthus argued, would ultimately lead us to overpopulate the planet, eat up all its resources and die in a mass famine.

But what is the maximum "power of the Earth to produce subsistence," and when will our numbers push the planet to its limit? More importantly, was Malthus' vision of the future correct?

Many scientists think Earth has a maximum carrying capacity of 9 billion to 10 billion people. One such scientist, the eminent Harvard University sociobiologist, Edward O. Wilson, bases his estimate on calculations of the Earth's available resources. As Wilson pointed out in his book "The Future of Life" (Knopf, 2002), "The constraints of the biosphere are fixed."

Aside from the limited availability of freshwater, there are indeed constraints on the amount of food that Earth can produce, just as Malthus argued more than 200 years ago. Even in the case of maximum efficiency, in which all the grains grown are dedicated to feeding humans (instead of livestock, which is an inefficient way to convert plant energy into food energy), there's still a limit to how far the available quantities can stretch. "If everyone agreed to become vegetarian, leaving little or nothing for livestock, the present 1.4 billion hectares of arable land (3.5 billion acres) would support about 10 billion people," Wilson wrote.

The 3.5 billion acres would produce approximately 2 billion tons of grains annually, he explained. That's enough to feed 10 billion vegetarians, but would only feed 2.5 billion U.S. omnivores, because so much vegetation is dedicated to livestock and poultry in the United States.

So 10 billion people is the uppermost population limit where food is concerned. Because it's extremely unlikely that everyone will agree to stop eating meat, Wilson thinks the maximum carrying capacity of the Earth based on food resources will most likely fall short of 10 billion.

According to population biologist Joel Cohen of Columbia University, other environmental factors that limit the Earth's carrying capacity are the nitrogen cycle, available quantities of phosphorus, and atmospheric carbon concentrations, but there is a great amount of uncertainty in the impact of all of these factors. "In truth, no one knows when or at what level peak population will be reached," Cohen told Life's Little Mysteries.

Slowing growth

Fortunately, we may be spared from entering the end-times phase of overpopulation and starvation envisioned by Malthus. According to the United Nations Population Division, the human population will hit 7 billion on or around Oct. 31, and, if its projections are correct, we're en route to a population of 9 billion by 2050, and 10 billion by 2100. However, somewhere on the road between those milestones, scientists think we'll make a U-turn.

UN estimates of global population trends show that families are getting smaller. "Empirical data from 230 countries since 1950 shows that the great majority have fertility declines," said Gerhard Heilig, chief of population estimates and projections section at the UN.

Globally, the fertility rate is falling to the "replacement level" — 2.1 children per woman, the rate at which children replace their parents (and make up for those who die young). If the global fertility rate does indeed reach replacement level by the end of the century, then the human population will stabilize between 9 billion and 10 billion. As far as Earth's capacity is concerned, we'll have gone about as far as we can go, but no farther.

Overpopulation Is Not the Problem

(A conflicting opinion about humans over-running their carrying capacity – http://www.nytimes.com/2013/09/14/opinion/overpopulation-is-not-the-problem.html?_r=0)

By ERLE C. ELLISSEPT. 13, 2013

BALTIMORE — MANY scientists believe that by transforming the earth's natural landscapes, we are undermining the very life support systems that sustain us. Like bacteria in a petri dish, our exploding numbers are reaching the limits of a finite planet, with dire consequences. Disaster looms as humans exceed the earth's natural carrying capacity. Clearly, this could not be sustainable.

This is nonsense. Even today, I hear some of my scientific colleagues repeat these and similar claims — often unchallenged. And once, I too believed them. Yet these claims demonstrate a profound misunderstanding of the ecology of human systems. The conditions that sustain humanity are not natural and never have been. Since prehistory, human populations have used technologies and engineered ecosystems to sustain populations well beyond the capabilities of unaltered "natural" ecosystems.

The evidence from archaeology is clear. Our predecessors in the genus Homo used social hunting strategies and tools of stone and fire to extract more sustenance from landscapes than would otherwise be possible. And, of course, Homo sapiens went much further, learning over generations, once their preferred big game became rare or extinct, to make use of a far broader spectrum of species. They did this by extracting more nutrients from these species by cooking and grinding them, by propagating the most useful species and by burning woodlands to enhance hunting and foraging success.

Even before the last ice age had ended, thousands of years before agriculture, hunter-gatherer societies were well established across the earth and depended increasingly on sophisticated technological strategies to sustain growing populations in landscapes long ago transformed by their ancestors.

The planet's carrying capacity for prehistoric human hunter-gatherers was probably no more than 100 million. But without their Paleolithic technologies and ways of life, the number would be far less — perhaps a few tens of millions. The rise of agriculture enabled even greater population growth requiring ever more intensive land-use practices to gain more sustenance from the same old land. At their peak, those agricultural systems might have sustained as many as three billion people in poverty on near-vegetarian diets.

The world population is now estimated at 7.2 billion. But with current industrial technologies, the Food and Agriculture Organization of the United Nations has estimated that the more than nine billion people expected by 2050 as the population nears its peak could be supported as long as necessary investments in infrastructure and conducive trade, anti-poverty and food security policies are in place. Who knows what will be possible with the technologies of the future? The important message from these rough numbers should be clear. There really is no such thing as a human carrying capacity. We are nothing at all like bacteria in a petri dish.

Why is it that highly trained natural scientists don't understand this? My experience is likely to be illustrative. Trained as a biologist, I learned the classic mathematics of population growth — that populations must have their limits and must ultimately reach a balance with their environments. Not to think so would be to misunderstand physics: there is only one earth, of course!

It was only after years of research into the ecology of agriculture in China that I reached the point where my observations forced me to see beyond my biologists' blinders. Unable to explain how populations grew for millenniums while increasing the productivity of the same land, I discovered the agricultural economist Ester Boserup, the antidote to the demographer and economist Thomas Malthus and his theory that population growth tends to outrun the food supply. Her theories of population growth as a driver of land productivity explained the data I was gathering in ways that Malthus could never do. While remaining an ecologist, I became a fellow traveler with those who directly study long-term human-environment relationships — archaeologists, geographers, environmental historians and agricultural economists.

The science of human sustenance is inherently a social science. Neither physics nor chemistry nor even biology is adequate to understand how it has been possible for one species to reshape both its own future and the destiny of an entire planet. This is the science of the Anthropocene. The idea that humans must live within the natural environmental limits of our planet denies the realities of our entire history, and most likely the future. Humans are niche creators. We transform ecosystems to sustain ourselves. This is what we do and have always done. Our planet's human-carrying capacity emerges from the capabilities of our social systems and our technologies more than from any environmental limits.

Two hundred thousand years ago we started down this path. The planet will never be the same. It is time for all of us to wake up to the limits we really face: the social and technological systems that sustain us need improvement.

There is no environmental reason for people to go hungry now or in the future. There is no need to use any more land to sustain humanity — increasing land productivity using existing technologies can boost global supplies and even leave more land for nature — a goal that is both more popular and more possible than ever.

The only limits to creating a planet that future generations will be proud of are our imaginations and our social systems. In moving toward a better Anthropocene, the environment will be what we make it.

(Erle C. Ellis is an associate professor of geography and environmental systems at the University of Maryland, Baltimore County, and a visiting associate professor at Harvard's Graduate School of Design.)

Problems/Challenges that Arise from Human Population Growth

Problem/Challenge	Source	Possible Solution	Source

Next, review the articles again. Find suggestions for human actions that can decrease human impact. Cite sources. If a solution is for a specific problem that you identified, record it in the same row as the problem.

Using the points you have described in your graphic organizer, write a paragraph in which you summarize the impact of human population growth. Write a second paragraph in which you summarize ways in which we can act to limit the impact of human population growth.

Lesson 4
Biodiversity

In this lesson you will use simulations and modeling to develop an understanding of what biodiversity means and why it is important. You practice research strategies and apply concepts to particular examples of endangered species. You will explore human impacts on biodiversity.

Activity

1 What is Biodiversity?

Write your ideas for the meaning of biodiversity.

Biodiversity of Different Habitats

Habitat	Tally of Different Species of Animals	Tally of Each Species Found Species#: Tally	Total Number of All Animals Found	Biodiversity Index # of Species/ Total # of Animals
Example	*4 different species*	*Species 1: 3* *Species 2: 4* *Species 3: 1* *Species 4: 3*	*11*	*4/11 = 0.3636*
Tropical Rainforest	7 different species	Species 1: 2 Species 2: 1 Species 3: 1 Species 4: 1 Species 5: 1 Species 6: 1 Species 7: 1		
Coniferous Forest	3 different species	Species 1: 2 Species 2: 1 Species 3: 1		
Deciduous Forest	3 different species	Species 1: 1 Species 2: 2 Species 3: 1		
Grassland	2 different species	Species 1: 3 Species 2: 3		
Lawn	2 different species	Species 1: 100 Species 2: 5		

Write a paragraph in which you summarize your findings about biodiversity based on the simulation.

Activity

2 The Importance of Biodiversity

Answer the following questions after participating in the monoculture vs diverse culture simulations.

1. What does biological diversity mean?

2. What is a monoculture?

3. Why didn't all the different trees get the disease?

4. In which forest would you need to use more chemicals to control disease – the Loblolly Pine forest or the more varied forest? Why?

5. Which forest would have more diversity of wildlife? Why?

6. If you cut down a forest that has a variety of trees and replanted with one type of tree:

   a. What will happen to much of the wildlife that was adapted to that prior forest?

   b. Will this happen to all the wildlife? Explain.

7. Growing one plant, as is the case of growing only Loblolly Pine, is called monoculture. Where might we find monocultures?

Activity

3 Endangered Species

Use the U.S. Fish and Wildlife Service's interactive map on endangered species, http://www.fws.gov/endangered/map/index.html, to identify three different species that are endangered in (your state) and complete the first four columns of the graphic organizer. Then, search for one additional source of information on each species. Add one more piece of information on the species to the organizer and cite the source.

Endangered Species in ______________________________ (your state)

Problems/Challenges that Arise from Human Population Growth

Endangered Species	What is the habitat where this species lives?	What caused this species to become endangered?	What is being done to help this species?	Additional information and source of information

Global Invaders Readings (Project Learning Tree)

Your teacher will tell you which readings you should use.

1. California's Coastal Scrub

If you visit some parts of Marin County, California, you'll discover a unique habitat known as coastal scrub. A multitude of shrubs and low-growing plants grow there, including wax myrtle, monkey flowers, California sagebrush, California bay laurel, coyote bush, and native bunchgrasses. But you won't find many trees—just the occasional coast live oak or willow. All of those plants have adapted to the region's Mediterranean climate, where six months of wet cool weather are typically followed by six months of hot drought.

Many birds perch on and fly among the coastal scrub, including golden-crowned kinglets, white-crowned sparrows, golden-crowned sparrows, and Bewick's wrens. Rufous-crowned sparrows, vireos, kinglets, and wood warblers forage for insects in the green leaves of live oaks and wax myrtles. Bay checkerspot butterfly larvae feed on narrow-leaved plantain. Nearby streams are home to threatened coho salmon and steelhead, which support important fisheries. Rare owls nest in nearby forests. In addition, many shorebirds move up local creeks when high tide covers their favored mud flats.

NEW ARRIVAL

In the 1850s, people began planting eucalyptus trees from Australia throughout coastal and central California. The trees grew extremely fast in the United States. They were deemed the perfect source of timber and fuel, replacing the redwood forests that had been clearcut.

Eucalyptus trees survive by sending long roots down and out through the soil. In the process, though, they can clog drains and damage streamsides. In addition, the trees blow over easily in the wind, bringing down more soil in the process. Most eucalyptus trees are filled with combustible resin and have long shredding bark. They produce great quantities of litter—fallen leaves, bark, and so forth—which in their native habitat was broken down by microbes and insects. To ensure that few other plants compete with them, eucalyptus trees also produce their own herbicide that kills many young plants beneath them.

Each winter, eucalyptus trees produce flowers that attract insects and, with them, insect eating birds. But the flowers of the tree are filled with a sticky gum. In Australia, birds such as Australian honeyeaters and leaf gleaners have evolved long bills that enable them to reach into the flowers without getting the sticky gum all over their bills and faces.

2. Hawaiian Islands

If you've taken a close look at a world map, you know that the islands of Hawaii are isolated from the nearest mainland by huge distances—more than 2,500 miles. That's one of the main reasons for the tremendous number of species in Hawaii that are found there and nowhere else. Too far away to interbreed with populations on other continents, the species of Hawaii evolved over time in completely unique ways. One species of finch, possibly a Eurasian rosefinch, colonized the islands and eventually evolved into 54 separate species of Hawaiian honeycreepers!

Hawaii's birds did not evolve with any particular adaptation to predators because the islands had few. There were no snakes, no foxes, no raccoons, and no wild cats. There were only two birds of prey: the 'io (hawk) and pueo (owl). Many birds were flightless. Many birds, such as the nene goose, Hawaiian blackrumped petrels, and Newel's shearwaters, built their nests on the ground.

Hawaii's original list of native species included only two mammals: a bat and a seal. Reptiles, amphibians, insects, and other invertebrates abounded. In fact, the islands' tree snails are among the most prized native species.

NEW ARRIVAL

By the 1880s, the Hawaiian landscape had already changed considerably. Early Polynesian settlers—and later waves of Europeans—cut down native forests and introduced grazing animals and poultry. They also began cultivating sugar cane and other crops. But those crops were under attack by accidentally introduced Norway and black rats that had stowed away on ships. Because Hawaii had no predators, the rat populations threatened to grow out of control. So, settlers decided to introduce the small Indian mongoose, a weasel-like animal that is known to eat rats. The Indian mongoose is native from Iran, and traveled through India to Myanmar and the Malay Peninsula.

Mongooses are small, slender animals with brown fur and a bushy tail. They breed two or three times a year, producing litters of three young. Females can begin breeding at the age of 10 weeks. Mongooses live in burrows and can adapt to a variety of settings. They feed on a wide variety of small vertebrates, including small mammals, snakes, iguanas, birds, eggs and young of larger vertebrates (for example, sea turtle eggs), large invertebrates, and on occasion, fruits and vegetables.

3. Florida Everglades

If you've spent any time in the Florida Everglades, you've seen an exceptionally rare and rich habitat. The Florida Everglades is North America's only flooded grassland, a "river of grass" that flows from the Kissimmee River south to the Florida Bay. Along the way, the water fills deep areas called sloughs, surrounds hardwood-covered islands called hammocks, and trickles past the roots of mangrove trees clinging to the shore.

Those varied habitats provide home to a wealth of creatures, many of them found nowhere else on Earth. The United States' only population of Florida panthers—numbering only about 60—ekes out a life by hiding in remote areas and feeding on deer, raccoons, and other animals. Flocks of wading birds rely on small fish and invertebrates for their food. Large fish prey on those smaller fish. Alligators cruise the waters in search of a meal of large fish, birds, or other easy prey. Large birds called snail kites fly overhead keeping an eye out for their one and only food: Florida apple snails.

All of those species have been hard hit by habitat loss in the Everglades, by drastic alterations to the natural flow by human communities, and by pollution. Panthers, wading birds, snail kites, and many other species are threatened or endangered. But new efforts are underway to restore some of the region's water flow, which could help the rare species bounce back and could lead to cleaner water resources for wildlife and people alike.

NEW ARRIVAL

In the mid-1990s, scientists were surprised to discover a strange creature inhabiting waterways in Georgia and Florida: the Asian swamp eel. Swamp eels grow to lengths of up to three feet, and they eat crayfish, shrimp, worms, frogs, tadpoles, and other fishes.

In their native region, swamp eels are commonly caught and sold for food, but in the United States, they have no known predators. They are native to Central and South America, Africa, and Australia, and extend from India to eastern Asia, including much of China.

Asian swamp eels have many adaptations to help them survive in the United States. They can live in everything from ponds to marshes to roadside ditches. They are highly secretive, with most of their activities occurring at night. Because they are air breathers, they can even survive on and travel across land to other bodies of water. The Asian swamp eel can survive weeks without food.

Asian swamp eels have been spotted within a mile of Everglades National Park.

4. Chicago Hardwood Forests

If you walk down the streets of Chicago's city neighborhoods, you'll be impressed by the number and size of large street trees. Among the most common trees are ash, cherry, elms, maples, elms, mulberry, oak, and plum.

You may not normally equate city trees with a forest, but that's what they form: an urban forest that makes cities cleaner, more attractive, and more wild. Chicago's urban forest is a rich habitat for wildlife, providing food and shelter for migrating and resident birds, squirrels, raccoons, opossums, and a host of insect species. The trees provide shade for residents and reduce cooling costs during the summer when they block sun from houses and businesses. They absorb pollutants from automobiles, making the air much healthier to breathe. In fact, scientists recently calculated that city trees in places such as Chicago play a major role in absorbing carbon dioxide that would otherwise reach the atmosphere and contribute to global warming (see source below).

Urban trees are so important to the city of Chicago that experts have estimated their value at about half a billion dollars. And that figure does not even include the hard-to-quantify benefits such as improved appearance, resident quality of life, and long-term climate improvement.

NEW ARRIVAL

In 1998, Chicago residents discovered unusual insects living on city trees: Asian longhorned beetles from China. Just two years before, Asian longhorned beetles had been found in two New York sites. Asian longhorned beetles are about 3/4 to 1 1/2 inches long. They feed on a variety of hardwood trees, especially ash, birches, buckeyes, elms, horse chestnuts, maples, poplars, sycamores, and willows.

Their life cycle begins when a female beetle chews her way through the bark of a host tree and deposits her eggs. Eleven days later, the larvae emerge from their eggs and begin to feed on the living tissue of the tree's xylem and phloem. These are the tree's pathways for carrying water from the tree roots up the tree and taking nutrients from the leafy canopy down, respectively. Once the pathways have been disrupted, the tree will no longer be able to circulate the water and nutrients it needs to survive. After reaching lengths of approximately two inches, the larvae enter the pupal stage. When the adults emerge from the pupa, they bore their way out of the trunk, leaving round exit holes that are just a bit larger than the diameter of a pencil.

Asian longhorned beetles live about one year and usually spread by natural means—flying about 400 yards or more in their beetle stage.

Nowak, D. J. "Atmospheric Carbon Dioxide Reduction by Chicago's Urban Forest." In E. G. McPherson, D. J. Nowak, and R. A. Rowntree, (eds.). *Chicago's Urban Forest Ecosystem: Results of the Chicago Urban Forest Climate Project*.

USDA Forest Service General Technical Report NE-186. Radnor, PA: USDA, 1994, 83–94.

cufr.ucdavis.edu/products/cufr_189_gtr186b.pdf.

5. Sagebrush Shrub Steppe

When early settlers traveled the intermountain west, they traveled through mile after mile of sagebrush habitat. More than 12 species of sagebrush grow from British Columbia to Baja California, reaching their greatest concentration in the Great Basin region of Nevada, western Utah, southern Oregon and Idaho, and a small part of eastern California. The hardy plant survives where many others can't by using its deep roots to tap into water and nutrients and by accomplishing photosynthesis even under very low levels of light.

Where sagebrush grows strong, it's something like a community center, providing food, shelter, and even dance space to residents who need it. A total of about 100 bird species, 70 mammals, and 23 amphibians and reptiles depend on sagebrush to some degree, but some are extremely dependent. Pronghorn, for example, rely on sagebrush for about 90 percent of the food they eat. Sage grouse, sage sparrow, sagebrush lizard, and sagebrush vole rely on eating sagebrush and the grasses that grow around it. Sage sparrows and Brewer's sparrows build their nests in sagebrush. Mule deer hide their fawns in the brush. Sage grouse also find shelter from wind, snow, and sun in sagebrush areas. What's more, the spare ground around sagebrush bushes provides the perfect spot for male sage grouses to perform their annual mating dances.

The value of sagebrush extends beyond the species that rely directly on it. Predator species, such as raptors, are drawn to the diversity of small mammals and birds that inhabit sagebrush areas. Where it grows, sagebrush also plays an important ecological function by stabilizing soils and preventing erosion.

NEW ARRIVAL

Cheatgrass, also known as Downy Brome, is native to the Mediterranean region and was introduced in the United States in packing materials and, perhaps, as a seed contaminant, in the 1800s. This plant is hardy and grows rapidly, particularly on land that has been disturbed by cattle grazing, farming, or other uses.

The plant is unpalatable and may injure livestock because it forms sharp-edged seed clusters. Cheatgrass also is highly flammable. This plant now affects more than 100 million acres in the United States.

Sources:

Lipske, Michael. "America's Forgotten Ecosystem." National Wildlife, (October/November 2000).

Cox, George W. *Alien Species in North America and Hawaii: Impacts on Natural Ecosystems.* Washington, DC:

Island Press, 1999.

Sagebrush in Wyoming, photo by Bureau of Land Management Wyoming

6. Atlantic Coastal Estuaries

Up and down the Atlantic Coast, oysters, clams, crabs, and mussels thrive in rich marine habitats called estuaries. Estuaries form where rivers empty out into saltwater bays, creating a mixture of freshwater and saltwater. You will often find them surrounding coastal salt marshes. Wherever they occur, estuaries support a tremendous diversity of marine life— including a lot of popular seafood.

Rich in nutrients and sheltered from big waves, estuaries provide the perfect conditions for many aquatic species to begin their lives. The juvenile Atlantic stingray, summer flounder, bluefish, white perch, striped bass, and other coastal fish spend part of their lives feeding and reproducing in estuary waters. Blue crabs carry out their entire life cycle in and near estuary waters. Scallops, softshell clams, and oysters breed and feed in the brackish waters. Those species, in turn, provide food for many shorebirds including American oyster catchers, gulls, terns, herons, and more.

The Chesapeake Bay, located between Maryland, Virginia, and Delaware, is the largest estuary in the United States. The Chesapeake Bay is one of many Atlantic Coastal estuaries that supplies us with seafood. In fact, more than 60 percent of the edible seafood in the United States comes from coastal estuaries.

NEW ARRIVAL

Scientists estimate that the first European green crabs arrived on the Atlantic Coast more than 150 years ago. Those crabs, originally from Europe, probably arrived in the ballast water of ships. Ships take on ballast water in port after emptying cargo. The water helps the ships stay stable for their next journey. Unfortunately, that ballast water is full of aquatic species from the original port. When the ships discharge the ballast water in their next port, the species are discharged, too.

Young green crabs do best in coastal ponds, lagoons, and bays. They are voracious eaters, consuming mussels, clams, snails, other crabs, barnacles, aquatic worms, and green algae. They can't easily crush a hard clam shell, but they can dig out soft clams from the clams' burrows that are six inches deep. Under the right conditions, female green crabs can spawn up to 185,000 eggs at a time.

Understanding Invaders Worksheet

Answer the following based on your assigned reading.

1. Describe the original ecosystem (before the arrival of the new species).

2. Using the information provided, draw a diagram showing the web of relationships in the original ecosystem (for example, predator/prey relations, ways animals depend on plant habitat, ways people depend on wild species, etc.).

3. Are there any plants or animals in the original ecosystem that seem particularly important?

   Explain.

4. What is the nonnative species described on your handout?

5. Where did it come from, and how did it get to the ecosystem?

6. Make some predictions about how this new species might affect the ecosystem. What changes might occur? What benefits might come of those changes? What problems?

   Be sure to provide a justification for your ideas.

Lesson Summary:

Summarize what you have learned about biodiversity and its importance in 10 words (no more, no less).

Lesson 5
Environmental Issues

In this lesson you will

1. Complete a Daily Consequences lab.
2. Support an argument with facts.
3. Organize information gathered from videos using a graphic organizer.
4. Reflect on how the loss of biodiversity affects you.
5. Reflect on how land management affects not only you, but everyone around you.

Activity

1 Air Pollution

Pollutants Information Sheet

- **Carbon Monoxide:** A colorless, odorless gas formed when a compound containing carbon burns incompletely because there is not enough oxygen. It is present in the exhaust gases of automobile engines and is very poisonous.
- **Lead:** Heavy metal that can cause mental retardation and an increase in the rate of infections and cancer by blunting the body's defense mechanisms (the immune system). Lead accumulates in blood, bones, and soft tissue and may result in damage to the brain, central and peripheral nervous systems, and the kidneys. While its suggested threshold is 0.4 parts per million (ppm) for adults and 0.3 ppm for children, people can exhibit lead poisoning symptoms at 0.2 ppm. Lead intake can occur through water stored in lead pipes, food contaminated by lead in soil, lead-paint flakes, or motor exhaust that contains lead compounds as ant-knocking or performance enhancing additives in gasonline.[3]
- **NAAQS:** National Ambient Air Quality Standards. The designated level at which the presence of a criteria pollutant is deemed safe. The Clean Air Act established two types of national air quality standards. Primary standards set limits to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly. Secondary standards set limits to protect public welfare, including protection against visibility impairment and damage to animals, crops, vegetation, and buildings.[4]
- **Nitrogen Dioxide**: A poisonous brown gas, often found in smog and automobile exhaust fumes and synthesized for use as a nitrating agent, a catalyst, and an oxidizing agent.[5]
- **Ozone:** An unstable, poisonous allotrope of oxygen that is formed naturally in the ozone layer from atmospheric oxygen by electric discharge or exposure to ultraviolet radiation. It is also produced in the lower atmosphere by the photochemical reaction of certain pollutants. It is a highly reactive oxidizing agent used to deodorize air, purify water, and treat industrial wastes.[6]
- **Particulate Matter:** Material suspended in the air in the form of minute solid particles or liquid droplets, especially when considered as an atmospheric pollutant.[7]
- **Sulfur Dioxide:** A colorless, poisonous gas or liquid with a strong odor. It is formed naturally by volcanic activity, and is a waste gas produced by burning coal and oil and by many industrial processes, such as smelting. It is also a hazardous air pollutant and a major contributor to acid rain.[8]
- **US Environmental Protection Agency (EPA):** An independent agency of the U.S. government, with headquarters in Washington, D.C. It was established in 1970 to reduce and control air and water pollution, noise pollution, and radiation, and to ensure the safe handling and disposal of toxic substances. The EPA engages in the research, monitoring, setting, and enforcement of national standards. It also issues statements on the impact of operations of other federal agencies that are detrimental to environmental quality, and it supports the antipollution activities of states, municipalities, and public and private groups.[9]

[2] The American Heritage® Science Dictionary Copyright © 2005 by Houghton Mifflin Company. Published by Houghton Mifflin Company. All rights reserved. Retrieved 05 May 2011 from http://www.thefreedictionary.com/carbon+monoxide.

[3] What Is Lead (Pb)? Definition and Meaning." BusinessDictionary.com - Online Business Dictionary. Retrieved 05 May 2011 from http://www.businessdictionary.com/definition/lead-Pb.html.

[4] National Ambient Air Quality Standards (NAAQS)." Air and Radiation. EPA, 18 Apr 2011. Web. 28 Jun 2011. http://www.epa.gov/air/criteria.html.

[5] The American Heritage Dictionary of the English Language, Fourth Edition, 2000 by Houghton Mifflin Company. Updated in 2009. Published by Houghton Mifflin Company. Retrieved 05 May 2011 from http://www.thefreedictionary.com/nitrogen+dioxide.

[6] The American Heritage Dictionary of the English Language, Fourth Edition, 2000 by Houghton Mifflin Company. Updated in 2009. Published by Houghton Mifflin Company. Retrieved 05 May 2011 from http://www.thefreedictionary.com/ozone.

[7] The American Heritage Dictionary of the English Language, Fourth Edition, 2000 by Houghton Mifflin Company. Updated in 2009. Published by Houghton Mifflin Company. All rights reserved. Retrieved 05 May 2011 from http://www.thefreedictionary.com/particulate+matter.

[8] The American Heritage Science Dictionary, 2005 by Houghton Mifflin Company. Published by Houghton Mifflin Company. All rights reserved. Retrieved 05 May 2011 from http://www.thefreedictionary.com/sulfur+dioxide.

[9] The Columbia Electronic Encyclopedia, 2007. Columbia University Press. Licensed from Columbia University Press. Retrieved 05 May 2011 from http://encyclopedia2.thefreedictionary.com/Environmental+Protection+Agency.

Writing Prompt:

Write a 150-word paragraph in which you argue which pollutant you believe to be the WORST and why. Also explain ways that we could reduce the concentration of that pollutant in our air and therefore reduce the impact it may have on our overall environment.

Activity

2 Organizing Information on Biodiversity

As we continue to look at environmental issues for loss of biodiversity, we are going to view some videos. You will be using the following graphic organizer to help collect the information given in each of the videos.

Video	Problem	Effect	Actions
Preserving Bees			
World Marine			
Bio. in the Tropics			
Arctic Biodiversity			

Reflection Question: Even though you may not live in any of the areas mentioned in the videos shown, how are you being directly affected by the loss of biodiversity in each of the videos?

Activity

3 Land Management

So far we have looked at environmental issues such as air pollution and loss of biodiversity. The last activity for this lesson that you are going to take part in deals with land management. Today you will be working in groups to determine how to use your recently acquired land. Read through the instructions before you begin your work in groups.

A River Runs Through It

Activity Instructions

Bad News:

- A family member, Great Uncle Richie Rich, who owned lots of property on a nearby river, recently passed away.
- Unfortunately, Uncle Richie had no children, no friends, just a pound pup named Benjamin and 100 acres of land. (This is equal to about the size of 100 football fields.)

Good News:

- He named you as his sole heir…. You inherit the land…and the dog.

The Problem:

- Just like your parents, you will have to pay taxes to the government on the land you inherit. You just received a letter saying that you owe $12,000 in taxes on the land or you will lose it. But how are you going to raise the money? You are still in school! That afterschool job you have wouldn't even cover 10% of the cost of your taxes.
- With your group, you must come up with ways to raise money using your land. You can use the land however you like.
- You will have one hour to develop your plan. Use your dry erase markers and draw pictures on your piece of land to show the following:
  - Fresh water supply
  - Transportation (roads, streets, bike paths, marina, etc.)
  - Trash, waste water, and raw sewage storage/treatment
  - Shelter
  - Power supply
- Make sure to answer the questions that follow these instructions in your Academic Notebook.

A River Runs Through It Questions

1. Draw and label an illustration of your land below:

2. How did your group decide to get fresh water to your land?

3. What forms of transportation did you make accommodations for?

4. What impact do you think these forms of transportation will have on the land and river environments?

5. How did you plan to get rid of waste on the property?

6. What forms of shelter did you provide? Why?

7. What forms of power did you provide? Why?

8. What pollutants are produced in your development, and how might they affect the river?

9. Is your property affected by the land upstream? How?

10. Do you think your property affects the water downstream? How?

A River Runs Through It Reflection Question

People often argue that land management should uphold the rights of all, rather than the rights of the owner. After completing this activity, what do you think?

Lesson 6

Designing Solutions to Environmental Problems

In this lesson you will

1. Identify a specific environmental problem and research the underlying causes and scientific principles involved.
2. Apply your scientific understanding to develop a solution to that problem.
3. Create a mini-poster organizing your research and proposed solution.
4. Work together to develop a rubric and provide feedback to one another on the mini-poster.
5. Make final revisions to your product
6. Present your mini-posters to your peers in a symposium setting.

For your culminating assignment, you will research environmental issues we face today. As you research, you must narrow your focus to a particular environmental problem that is of interest to you, and one that you feel you could devise a solution that would resolve or at least mitigate the problem in your local community. As you research this particular environmental issue, you must practice the cause-effect relationship analysis you have developed throughout this unit to identify the root cause of the problem. This, in turn, will help you to develop solutions to that problem.

You will need to include at least five sources to use in your work. To help you read and organize the material, you will take notes on each source in your Academic Notebook. Articles can be found in many different places, including journals, magazines, newspapers, and websites. Popular journals, such as Scientific American, are aimed at the general public. The articles are written by journalists who have consulted with experts and written in a way that is accessible by the public. Peer-reviewed journals contain articles written by experts and aimed at experts. The reader is expected to know the basics on the topic covered in the article. For the final project, we are going to focus on popular journals, magazines, newspapers, and websites.

Research Notes

Complete one chart for each source used as you research your topic.

Source			
Key Ideas			
Pertinent Statistics			
Examples			
Possible Solution(s)			

Source			
Key Ideas			
Pertinent Statistics			
Examples			
Possible Solution(s)			

Source			
Key Ideas			
Pertinent Statistics			
Examples			
Possible Solution(s)			

Source			
Key Ideas			
Pertinent Statistics			
Examples			
Possible Solution(s)			

Source			
Key Ideas			
Pertinent Statistics			
Examples			
Possible Solution(s)			

You must complete the project proposal below and have it approved before you may continue in your work on this project.

Remember that the audience for your presentation is a group of investors, so you will want to convince them that your environmental issue is of utmost importance, and your proposed solution will do the most good in helping to improve our environment.

Project Proposal

Name

Environmental Problem

Background Information:

Root Cause Analysis:

Effects of this Environmental Problem:

Rationale for choosing this focus:

Possible Solution(s):

Activity

2 Drafting the Proposal

You will use your research to draft your proposal. You will present your proposal in a scientific poster symposium. You must use the following poster template to organize your work.

Title

Author

Abstract

Introduction/
Background Information

Cause and Effect Analysis

Must include evidence to support your claims.

Solution Proposal

Must include the basic cost/ benefit analysis and reasoning to support why the proposed solution will solve/mitigate the environmental problem.

Conclusion

Essay Scoring Rubric							
Scoring Elements	**Emerging**		**Approaches Expectations**		**Meets Expectations**		**Advanced**
	1	1.5	2	2.5	3	3.5	4
Controlling Idea	Addresses prompt. Presents a general or unclear controlling idea.		Addresses prompt appropriately. Presents a clear controlling idea with an uneven focus.		Addresses all aspects of prompt appropriately. Presents a clear, specific controlling idea that takes into account the complexity of the topic.		Addresses all aspects of prompt appropriately. Presents a clear, specific controlling idea that takes into account the complexity of the topic and acknowledges gaps in evidence or information.
Development/ Use of Sources	Includes minimal details from sources, with irrelevant, incomplete, or inaccurate elements.		Includes relevant details, examples, and/or quotations from sources to support the controlling idea, with incomplete reasoning or explanations.		Accurately explains relevant details, examples, and/ or quotations from sources to support and develop the controlling idea.		Thoroughly and accurately explains most relevant details, examples, and/ or quotations from sources to effectively support and develop the controlling idea.
Organization	Lacks an evident structure. Makes unclear connections among ideas, concepts, and information.		Uses an evident organizational structure and transitional phrases to develop the controlling idea, with minor lapses in coherence or organization.		Maintains an appropriate organizational structure that creates cohesion. Uses transitional phrases to clarify the relationships among complex ideas, concepts, and information.		Maintains a cohesive organizational structure including a logical sequence that builds on preceding ideas to create a unified whole. Uses varied syntax and transitional phrases that clarify the precise relationships among complex ideas, concepts, and information.
Conventions	Lacks control of grammar, usage, and mechanics. Uses inappropriate language or tone. Rarely or never cites sources.		Demonstrates an uneven command of standard English conventions. Uses language and tone with some inaccurate, inappropriate, or uneven features. Inconsistently cites sources.		Demonstrates a command of standard English conventions, with few errors. Uses language and tone appropriate to the audience and purpose. Cites sources using an appropriate format with only minor errors.		Demonstrates and maintains a well-developed command of standard English conventions, with few errors. Consistently uses language and tone appropriate to the audience and purpose. Consistently cites sources using an appropriate format.